Kern River Watershed Coalition Authority

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May 14, 2014

Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1101 I Street, 24th Floor
Sacramento, CA 95814
Sent via email to: commentletters@waterboards.ca.gov

Re: Agricultural Expert Panel Comments

Dear Members of the Agricultural Expert Panel:

The Kern River Watershed Coalition Authority (KRWCA) is a joint powers authority serving the coalition of landowners in the Kern River watershed. In addition to facilitating regulatory compliance for coalition members and representing growers in water quality issues, our goal is to develop and implement effective, economical, and scientifically valid water quality monitoring programs for surface and groundwater in the region. Therefore, the matters of the Agricultural Expert Panel are of great importance to us and our members.

We support and appreciate the efforts of the State Water Resources Control Board (SWRCB) and the California Department of Food and Agriculture (CDFA) to convene and facilitate the Nitrogen Tracking and Reporting Task Force and the Agricultural Expert Panel. Our comments as included below, refer to the Nitrogen Tracking and Reporting Task Force Final Report (Final Report), as well as, additional comments for the Expert Panel to consider. We have based our comments on our understanding of the Expert Panel's charge, and the extensive work we have done through the KRWCA for the last three years, which has identified the unique nature of this area.

Comments

Though the Final Task Force Report acknowledged the limitations of its recommended nitrogen (N) tracking and reporting system, the impact and weight of these limitations were not clearly described, considered, or attempted to be quantified. Specifically, the report states:

> *"The benefits of the recommended nitrogen tracking and reporting system are intended, but not proven. Limitations can also be anticipated. Primary among these is the fact that the scientific knowledge currently available for understanding nitrogen's movement beyond the root zone for the many crops growing in California is limited and in some cases non-existent,*

particularly in terms of calculating exact amounts of nitrogen lost to air and groundwater. Additionally, it is recognized that the timing and amount of water applied can be critical to water/nitrogen moving below the root zone and is not tracked as part of these recommendations."

The comments that follow address some of the limitations that we think were not adequately acknowledged in the Final Task Force Report, as well as other comments that we think are pertinent to your assigned questions and your charge:

1. The quantitative approach of tracking and reporting N using a N budget approach depends on the measurement of numerous components of the N cycle, and/or making assumptions about other components that are impossible or very difficult to measure because of their spatial and temporal variability. In a practical sense, partial N budgeting cannot accurately capture the variability of N dynamics in California agriculture at the field scale across the wide range of geography, climate and cultural practices throughout the state in a timely manner that will be useful for the regulatory purpose of the Irrigated Lands Regulatory Program (ILRP). More importantly, N budgeting can neither provide information on what is contributing to, or causing high or low nitrates in groundwater in any given scenario, because the assumption that applied N fertilizer alone correlates to groundwater nitrate concentration is only valid under certain circumstances, specifically those with shallow groundwater conditions.

2. Because the (ILRP) is intended to be a management practice based program rather than a treatment based one (as stated by Joe Karkoski, Central Valley Regional Water Quality Control Board, ILRP Program Manager on March 4, 2014, during the State Water Resources Control Board Public Meeting on Draft Vulnerability Maps), any data collection and interpretation system designed to minimize groundwater pollution from agricultural nitrate must include management practices as a **key** factor, not a secondary one, for the dual purpose of interpreting groundwater quality data and reducing groundwater pollution risk.

3. Because the charge of the Nitrogen Tracking and Reporting System Task Force was to identify an appropriate N tracking and reporting system, alternatives and/or complements to the N mass balance approach should have been considered more carefully than the Final Report indicates. Though the Nitrate Groundwater Pollution Hazard Index (NHI) was developed and vetted by a panel of experts, similar to this Agricultural Expert Panel, specifically for California agriculture and subsequently adopted by the State Water Resources Control Board in 1994 as a scientifically valid and practical regulatory tool to voluntarily minimize nitrate risk to groundwater; and though it has potential to mitigate the shortcomings of the N balance approach to "track and report" N, it was given little consideration in the Final Report as a viable option.

4. The NHI has three potential functions; 1) a groundwater vulnerability assessment tool; 2) an interpretive tool to better understand how N management practices influence N dynamics; and 3) as an incentive for growers to meet water quality objectives by improving their NHI score with BMPs that they know work best on their own farms. As acknowledged by Dr. Ken Baerenklau during his testimony to the Expert Panel on May 5, 2014, there must be a balance between voluntary BMPs that are inexpensive to implement but often less effective, and polluter-pays approaches that are more effective but put the entire burden of regulation on individual farms and leave little flexibility. A ranking method to document and track BMP choices would achieve this balance. The potential incentivizing function of the NHI should not be overlooked.

5. Two common themes in testimony to the Expert Panel have been: 1) the need for flexibility between and within regions and the avoidance of a "one size fits all" approach, and 2) the meaning and use of data is known before it is collected, and the avoidance of collecting data for data's sake. The NHI addresses both of these concerns, by using readily available data at its most basic application, and only requiring other very specific data for specific reasons. Other specific data would be required if factors were added to the NHI, such as indicators of N use efficiency that are documented and proven in scientific literature, such as split applications and fertilization with other macro and micro nutrients when needed. Both of these practices are proven to improve N use efficiency, and can be used in the NHI without having to know accurately and precisely what the absolute value of N use efficiency is in any given situation.

6. Problems with using the NHI in areas such as the Central Coast point to its incorrect application and need for refinement and completion, not to the fundamental concept that underpins it. For example, requirements by the Central Coast Board to use the highest risk practice (short-lived sprinkler irrigation on transplants vs. drip irrigation, for example) instead of the most used practice, is a misguided application of the NHI and causes it to produce inaccurate results. The problem of incomplete hazard values for soils is easily solvable. In fact, the NHI will always need updating at some level because agricultural practices have and will always evolve – particularly to more efficient practices.

We have also attached documentation to this correspondence that fully explains this technical perspective and other supporting information in much greater detail. It provides evidence from: peer reviewed scientific literature that illuminates the importance of scientific validity in approaching the matters of the Agricultural Expert Panel (Attachment 1); provides original, adopted, documentation of the NHI approach (Attachment 2); provides a link to documentation of the use of the NHI in the UC Davis Report to the SWRCB, as an approach to assess and mitigate groundwater pollution risk (Attachment 3). These reports are summarized as follows:

1. Additional written comments to the Agricultural Expert Panel as supplement to this cover letter (May, 2014).
2. Nutrient Technical Advisory Committee Report to the State Water Resources Control Board (1994).
3. Addressing Nitrate in California's Drinking Water, Technical Report 3: Nitrogen Source Reduction to Protect Groundwater Quality, Report for the State Water Resources Control Board Report to the Legislature, California Nitrate Project, Implementation of Senate Bill X2 1, Center for Watershed Sciences University of California, Davis (2012). http://groundwaternitrate.ucdavis.edu/files/139103.pdf

We thank you in advance for your thoughtful consideration of our comments and this supporting information.

Respectfully,

Nicole M. Bell

Nicole Bell
Manager
Kern River Watershed Coalition Authority

Attachment 1
Agricultural Expert Panel Comments

Agricultural Expert Panel Comments

May 14, 2014

Kern River Watershed Coalition Authority

CONTENTS

1 INTRODUCTION AND PURPOSE

The Nitrogen Tracking & Reporting System Task Force (Task Force) was convened by the California Department of Food and Agriculture (CDFA) as a requirement of the State Legislature to implement Recommendation 11 of the Recommendations Addressing Nitrate in Groundwater (SWRCB, 2013). The Task Force was charged with identifying an appropriate nitrogen (N) tracking and reporting system. The objective of the Task Force was to provide meaningful and high quality data to help CDFA, the State Water Resources Control Board (SWQCB) and the Regional Water Quality Control Boards (RWQCB) address groundwater quality in nitrate high-risk areas in California.

The Final Report of the Task Force ([Final Report] December, 2013) included recommendations for certain data to be tracked and reported by growers and third parties (aggregators). These data include information related to crop type and characteristics, N fertilizer use and consumption by crop, and irrigation system. The Task Force did not specify how each of these data types would be used for the purpose of protecting groundwater; however, the data types were selected in response to the recommendation from the State Water Board Report to the Legislature (January 2013) that a N mass balance approach be pursued as a starting point. The Final Report of the Task Force acknowledged limitations of this approach as follows:

> *"The benefits of the recommended nitrogen tracking and reporting system are intended, but not proven. Limitations can also be anticipated. Primary among these is the fact that the scientific knowledge currently available for understanding nitrogen's movement beyond the root zone for the many crops growing in California is limited and in some cases non-existent, particularly in terms of calculating exact amounts of nitrogen lost to air and groundwater. Additionally, it is recognized that the timing and amount of water applied can be critical to water/nitrogen moving below the root zone and is not tracked as part of these recommendations."*

The impact and weight of these limitations were not clearly described. This document is submitted in response to the request by the State Water Resources Control Board to submit written comments to the Agricultural Expert Panel. These comments seek to describe and clarify the impact if these limitations, and illuminate why an N mass balance approach, while appropriate for large-scale modeling applications, will have limited effectiveness in achieving the ultimate purpose of the Irrigated Lands Regulatory Program (ILRP), and how its limitations can be addressed.

Because some of the conclusions of the Task Force were unable to be fully defined during the limited time-frame allowed, some of the more technical components were referred to the Agricultural Expert Panel, as established by the SWRCB and as required by the State Legislature (Recommendation 14). During the community forums, CDFA stated that the Final Report is considered one component of a broader analysis that includes work done by the SWRCB and the Agricultural Expert Panel specifically and therefore may be modified.

2 SUMMARY

A quantitative approach of tracking and reporting N depends on the measurement of numerous components of the N cycle, and/or making assumptions about other components that are impossible or very difficult to measure because of their spatial and temporal variability. The N cycle has been studied for decades in agricultural systems, is very complex and dynamic, and N in any form can transform and change within the N cycle according to a variety of environmental and human-induced factors transient. Therefore, the mass of N in an agricultural system can only be "balanced" with great expense, time and effort to determine all the components of a complete N balance. Such mass balance requires rigorous monitoring that is impractical over large landscapes. Nitrogen "balances", as described in the Final Report, are actually partial N balances and are inherently incomplete. Though an incomplete N balance might represent what is potentially available for leaching, it does not does not truly represent and account for the variable, unmeasured pools of agricultural N that influence the amount of N available for actual leaching.

In a practical sense, partial N balances (or N budgeting) cannot accurately capture the variability of N dynamics in California agriculture at the field scale across the wide range of geography, climate and cultural practices throughout the state in a timely manner that will be useful for the regulatory purpose of the ILRP. More importantly, N budgeting can neither provide information on what is contributing to, or causing high or low nitrates in groundwater in any given scenario, because the assumption that applied N fertilizer alone correlates to groundwater nitrate concentration is only valid under certain circumstances. The key factor that links nitrate concentration in groundwater to N in soil (not only N applied) is water volume passing through the root zone, which can be measured, but has great spatial and temporal variability. Therefore, no amount of tracking, reporting and/or "balancing" N can account for or encapsulate the influence of this key factor and in turn, provide meaningful information that can be used to decrease N leaching to groundwater in agricultural systems.

Because of the great complexity and variability of the N cycle in the highly diverse agricultural systems in California, the results of N budgeting will be uncertain (as proven by numerous examples from scientific literature, described in this report), as with any attempt to quantify a natural, biologically mediated system. In addition, these results will have little use without a means to interpret their underlying cause.

This means of interpretation can be provided by using other factors known to influence N leaching, such as irrigation system type, to improve N management and immediately decrease N migration. Management factors, specifically irrigation, crop, and soil types should be documented and used in the Nitrogen Groundwater Pollution Hazard Index (NHI) or a modified version of the NHI, which might include other factors related to leaching such as effective precipitation or irrigation distribution uniformity, and those identified by the Task Force. The NHI was developed and validated specifically for California agriculture to track both management factors and crop type changes. This tool and its supporting documentation, rationale, and scientific underpinnings were developed by a team of experts in the mid-90s, convened by the SWRCB to determine the best way to assess and address nitrate leaching potential on agricultural land. The main conclusion of this expert team was that a qualitative (not quantitative) approach was the most effective and immediate way to address agricultural nitrate contamination identification, characterization, and minimization. In other words, the NHI can be used to identify: 1) where nitrate contamination is likely; 2) what is likely causing it; and 3) how to minimize it.

Though the shortcomings of an N budgeting approach cannot be entirely mitigated by using NHI, their impact can certainly be reduced. The NHI can use the same information that the Task Force identified as important, but in a more informed and educational way. Growers have no control over intrinsic site factors (e.g. soil type) that influence N leaching, but they do have control over specific vulnerability, which refers to the specific management factors such as fertilizer N and irrigation management that impact N leaching. Therefore, strategies intended to reduce nitrate in groundwater that do not consider specific vulnerability (management factors) in combination with intrinsic variables are likely to be unsuccessful.

At best, the N tracking and reporting approach should be modified with a system that addresses what growers can control and improve – N management, irrigation management, specifically irrigation uniformity – through BMPs, improvements in crop production (to allow for more uptake) and improved N application management. An inaccurate partial N balance will serve as a poor approximation of N status in agricultural systems, potentially erroneous regulatory requirements, and thus, inappropriate management decisions. At the least, the quantitative approach to N tracking should be supplemented with a methodical system that focuses on collecting information that can be used to make decisions that will successfully manage agricultural N to protect groundwater statewide.

3 Overview of Nitrogen Mass Balance Applications

Approaches proposed in the ILRP have been made in the context of guiding documents, specifically:

1. The UC Davis Report for the SWRCB SBX2 1 Report to the Legislature (Harter and Lund, 2012); and
2. Recommendations based on the UC Davis report from the SWRCB to the legislature, Recommendations Addressing Nitrate in Groundwater (SWRCB, 2013).

The purpose of the former document was to provide insight into the extent and status of nitrate contamination in groundwater, and identify ways to address it. The purpose of the latter document was to make specific recommendations, based on the former, on how to address nitrate contamination through specific regulatory processes.

The Harter and Lund (2012) report determined groundwater nitrate loading from agriculture using the cropland inputs and outputs in the context of a N mass balance, where the sum total of all inputs (one of many being synthetic fertilizer) equals the sum total of all outputs (one of many being leaching of N below the root zone). This approach was also used in the California Nitrogen Assessment (CNA), an effort to compile data and analyze trends for the purpose of informing policy and agricultural practice (http://nitrogen.ucdavis.edu). This approach is useful in developing a gross inventory of relative N pools in a particular agricultural system to gain understanding of how N flows between components, and the relative proportion of each component. The N mass balance is also a convenient and easily understandable way to portray the N cycle as it relates to a particular activity, in this case farming. It is depicted in Harter and Lund (2012) as an orderly, logical, mathematical set of relationships that can be determined with a combination of data and assumptions. Although simplified relative to a more detailed N mass balance approach, this method of determining and portraying groundwater nitrate in relation to other pools of N at a gross scale was an appropriate use of the N balance approach for these purposes.

The SWRCB (2013) report then recommended the N mass balance approach as a framework and methodology to track and report N in farming systems, for the ultimate purpose of decreasing groundwater nitrate contamination and preventing further degradation. This step in the process, from identifying and characterizing the problem to recommending how to solve the problem, is where the detailed field-scale N dynamics were overlooked.

In actuality, the N cycle is not a neat, orderly, set of mathematical relationships; it is a highly variable, transient cycle of ever-changing interactive relationships that are exceedingly difficult to quantify. An N balance is a model that is only as accurate as the data that informs it. Conducting an N balance requires large amounts of frequently measured data, for which accurate sources are not necessarily available, and the variability many times unpredictable. To achieve true balance, assumptions must be made about certain elements which are highly variable. For this reason, conducting N balances to determine farm- or regional-scale agricultural N pools over the large and diverse agricultural area in California has high potential for error.

In addition, conducting an N balance alone, even with good data, does not provide information on what management change is needed to alter the N cycle in a way that decreases N leaching. In fact, the N balance approach promotes the idea that decreasing N inputs of a certain variety will necessarily decrease N outputs of a certain variety (e.g. decreasing N fertilizer inputs will decrease N leaching). This assumption is only valid under certain circumstances, largely because of the interaction of N with water via irrigation, as well as differences in plant vigor and subsequent plant uptake mechanisms. Therefore, interpreting the results of an N balance, for the purposes of managing (not describing) N requires the methodical collection and application of other information such as cropping systems, management and irrigation practices, N management, and soil physical, chemical and biological attributes that have a major influence on N leaching.

For these reasons, the N balance approach, though appropriate for other purposes, namely a more gross understanding of the pools of N in a larger system (e.g. agriculture in general), is not an effective tool for achieving the goals of the ILRP which is to regulate at a much more refined level. This document includes:

- a general summary of the findings of numerous scientific studies that support this rationale,
- a detailed review of these findings,
- and an alternative method for further understanding, supplementing, modifying and/or selectively using the N balance approach.

4 DESCRIPTION AND EVALUATION OF THE N BALANCE APPROACH IN REGULATING AGRICULTURAL SYSTEMS

The quantitative approach of tracking, reporting and budgeting N for the purpose of developing an N balance depends on the measurement of one or more components of the N cycle. The result of this type of assessment, such as nitrate concentration in groundwater, which is what is generally used to determine the status of leached N, is a measurement that is assumed to be an accurate indicator of the N status of a particular scenario. This value is then categorized as being over or under a threshold, and is also used as a benchmark to compare future measurements and determine whether N leaching potential has decreased after steps are taken to reduce N leaching potential. Evaluating this approach requires an understanding of the N cycle in the context of agricultural systems.

COMPONENTS OF A NITROGEN MASS BALANCE

Nitrogen in the soil is found in several forms, including:

1. Organic N in soil humus;

2. Inorganic N, such as ammonium, nitrite and nitrate; and,

3. Gaseous forms (such as ammonia and NO_x forms).

Mineralization is a combination of two biological process that convert organic N to ammonium (ammonification), which can then be converted to nitrate by another biological process called nitrification. Plants use both nitrate and ammonium. The rate at which these transformations occur depends on many factors, including moisture, temperature and biological activity, which are interdependent of soil type and management as well as environmental conditions. All fertilizer N, whether it is organic or inorganic, can be transformed into nitrate, which is the form of N that is mobile in water. **The only way that N reaches groundwater is by water through leaching.**

Nitrogen is otherwise lost from the soil-plant system through volatilization and denitrification, processes that convert N to gaseous forms, which are also biologically mediated and highly variable between sites, seasons, and years. Nitrate is leached when water moves beyond the root zone and transports the nitrate in the soil solution at that time. The N cycle in agricultural systems is illustrated in Figure 1.

One concept that has been used as an indicator of N management is N use efficiency (NUE). Though it has several definitions, it is generally understood as the ratio of N consumed and exported by the crop to the amount of N applied. NUE greater than 100% is not ever sustainable over an extended period of time because one must account for N losses described previously. NUE can be greater than 100% for one or more years if the amount of mineralized organic N is substantial as compared to the amount of N applied. Because NUE is a ratio of N taken up by the crop to the amount applied, the numerical value is also affected by yield that controls the amount of uptake. Applying low amounts of N that causes a low yield frequently causes an increase in the NUE number. Indeed, some yield commonly can be achieved without applying any N for a year or two. This results in a NUE value of infinity. So every value from much less than 100% to infinity are possible making it an imperfect indicator of the effectiveness of N management.

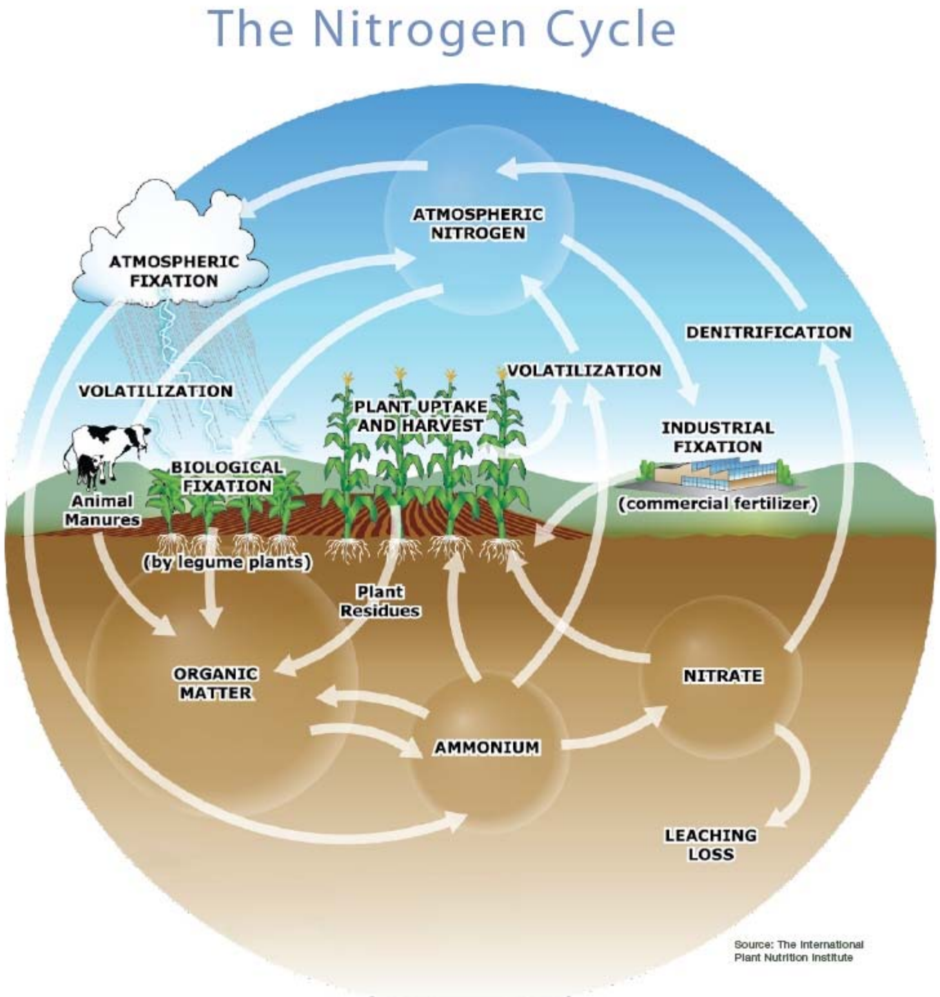

Figure 1. The N cycle in an agricultural system

LIMITATIONS OF THE N BUDGET APPROACH

It would appear in Figure 1 that the N cycle in agricultural systems is similar to a bank account; if all the credits (or N inputs) and debits (or N outputs) could be quantified then we could know with certainty how much N resides in the system and where. Unfortunately, that is not a valid comparison due to the dynamic nature with the "account" itself and the many variables that affect it. It could also be assumed that N must reach equilibrium or "balance" at some point. However, N in agricultural systems is unique because its behavior is affected by both natural biological interactions and imposed management. Therefore, N in agricultural systems:

- Exists in several pools, many of which are poorly understood (such as organic N);
- Is biologically mediated, and is therefore affected by environmental factors as well as management;
- Is extremely variable; and,

- Is constantly involved in transformations (additions and losses) and always seeking equilibrium but not achieving it.

In other words, the N cycle in an agricultural system is very complex and dynamic, and N in any form is transient. Therefore, the mass of N in an agricultural system can never truly be "balanced" without assuming the size of N pools, and the rate and nature of how these pools transform. An N budget, which estimates how much N is in each form and where it is in the system, can be used to estimate certain components of the N cycle. However, it cannot be used to describe the entire N cycle in any system at any given point in time, make assumptions about other parts of the N cycle that are not measured, or, in the case of the ILRP, be used in an attempt to make inputs and outputs of N equal each other in this type of system.

The N cycle as illustrated in Figure 1 contains many N pools with connecting arrows. A very complex network is portrayed. However, the cycle is even more complex than shown. The following provides examples of the extreme complexity of the actual N cycle.

Organic matter is listed in one pool. However, there are several different organic chemicals and each should have their designated pool. There is an arrow directed from the organic pool to ammonium that may be extended to nitrate. The arrows merely depict the directions of flow and not the rate of flow. The rate of conversion of organic N to inorganic N decreases exponentially with time. Each pool has its unique rate of conversion. Also the conversion is very temperature dependent and soil temperatures vary with time of year. A complete depiction of mineralization of organic N would contain several pools, each with different rates of mineralization.

There are arrows from ammonium and nitrate to plants. The rate of flow depends on plant uptake which varies greatly with time as well as the growing conditions of the crop. If the N supply at any time is not adequate to supply the full crop demand, yield is reduced. Any factor that affects plant growth such as weather, disease, pest damage, drought etc. will modify the crop demand at any time and can vary widely.

An arrow is from the nitrate pool labeled as leaching loss. Water flow through the soil is the transporting medium and thus, the controlling factor in leaching nitrate. One could illustrate a water cycle on an agricultural field in a manner that the nitrogen cycle is depicted in Figure 1. Computing the leaching loss would require interconnecting the water cycle with the nitrogen cycle. The water cycle contains components that are rate dependent and interactive with plant growth. A true depiction of leaching loss would entail the overlay of the water and nitrogen cycles and results even more complexity.

Nitrogen is a "moving target"; for this reason, it is difficult, if not impossible to quantify N in any given form. For this reason, N balances are widely used in scientific studies to isolate, quantify, or predict specific N pools and acquire relative understanding of the N cycle; however, they are seldom successful in quantifying or characterizing a complete agricultural N system on which to base management decisions or institute regulatory restrictions or requirements.

The limitations of a quantitative N balance approach outweigh the potential advantages, which include the following:

1. Absolute values provide benchmarks that in time, can provide useful comparisons in helping to understand the fate of N in agricultural systems;

2. Measurements provide valuable information about status of N groundwater contamination; and,

3. The relative proportions of N pools can be portrayed at a gross scale to improve general understanding of N in the environment.

The first advantage is thwarted by the lack of data requirements proposed in the Task Force Report to achieve an accurate N balance; absolute values are only useful if they are accurate and reflect the true status of N but are not useful if they are "precisely wrong." The second and third advantages can only be realized at much larger scales, as have been evidenced by statewide efforts such as the CNA and Harter and Lund (2012).

5 RESULTS OF N BALANCE STUDIES

Because of the complexities of the N cycle in agricultural systems, many studies have attempted to quantify the many pathways, pools and forms of N in agricultural systems. The results of these studies have two important commonalities:

1. The results are extremely variable from year to year, from site to site, and within seasons; and,
2. They do not provide any information, from a management perspective, about *why* particular N parameters (such as groundwater nitrate) are what they are and therefore cannot be used to make management decisions.

A detailed review of these studies is provided in the literature review at the end of this document. Because N is and has always been the most studied agricultural nutrient, experiments focused on N research number far too many to include here. The studies included in this review were selected because of their focus on one or both of the following research objectives:

- Using an N balance approach to describe N flows; and,
- Measuring specific inputs and/or outputs of N in specific agricultural systems

The high variability exhibited in N studies means that there is great potential for error when assumptions from one scenario are applied to others, which must be done when N is tracked and reported on a statewide scale. Considering that N needs to be tracked and reported on approximately 10+ million acres across a wide range of soils, climates, and practice regimes, the amount of data required to apply an N budget approach is unreasonable and would likely produce erroneous results. Conclusions from the literature review are summarized below.

SUMMARY OF CONCLUSIONS

1. Nitrogen *cannot* be budgeted so that N fertilizer input is equivalent to crop consumption.
2. Cropping systems necessarily accumulate residual N at the end of the growing season because of the nature of plant physiology and optimizing resource efficiency.
3. Residual N and/or N fertilizer applied is *not* necessarily related to amount of N leached.
4. Reducing N fertilizer application rates does *not* necessarily minimize N leaching.
5. No individual factor on its own (soils, crop types, irrigation methods, climatic conditions or N management) can account for the potential of a site to leach nitrate.
6. Of farm management practices, the amount of nitrogen leached *primarily* depends on the amount of water percolating through the root zone and the nitrate concentration in the soil profile.
7. Irrigation system management, maintenance, and uniformity are key factors, not accounted for in N balance approaches, in minimizing leaching.
8. Quantification by assumption of certain N cycle processes (i.e. mineralization, denitrification, etc.) is not a valid approach to completing N balances at the field scale.
9. The N balance approach is *not* an adequate tool for minimizing N leaching at the field scale.

ASSUMPTIONS AND SCIENTIFIC FINDINGS RELATED TO N BALANCE APPROACHES

The N balance approach implies numerous assumptions that are largely associated with the use of N concentration in soil water and/or groundwater as an indicator of how N is managed on the surface of an agricultural field, and how surface applied N should be managed to reduce N leaching risk. Many of these assumptions are not scientifically valid because they have been disproven by agricultural studies in California and elsewhere. Although the Task Force Report states the Recommendation is not intended to provide scientific analysis, as stated above, SWRCB, 2013 Recommendation 11 directs the Task Force to, "…identify appropriate nitrogen tracking and reporting systems, and potential alternatives, that would provide meaningful and high quality data to help better protect groundwater quality."

The scientific limitations of the recommendation to provide "high quality data" should be covered in the limitations section of the Task Force Report. The assumptions and the scientific findings that disprove them are listed and described as follows:

1. **Assumption:** The concentration of N in soil water and/or groundwater is correlated with the amount of N fertilizer applied, and can be used with an N mass balance to manage N fertilizer applied.

   Scientific Finding: The amount of N leached to groundwater does not correlate well with the amount of N applied alone, though it does correlate well with the drainage volume, and with drainage volume *and* N applied as co-factors.

   Typically, the concentration of nitrate in groundwater or soil water is measured without measuring the rate of water flow. The reason the rate of water flow is not measured is because it is impossible to measure it accurately at any given time because of its spatial and temporal variability (Letey and Vaughan, 2013; Broadbent and Rauschkolb, 1977). Therefore, the discharge load is difficult, if not impossible, to determine. The measure of N concentration has little meaning by itself, because N concentration in groundwater is not directly related to N fertilizer applications. Studies show unequivocally that the best correlation with leached N is a combination of drainage volume and amount of N fertilizer applied, indicating that both of these causal factors are important in assessing and improving N leaching risk (Letey and Vaughan, 2013; Wang et al, 2013; De Vos et al., 2000;)

   For example, very efficient systems result in high N concentrations in soil water, but these high concentrations may never reach the aquifer because of low downward movement of water. Conversely, inefficient irrigation systems or high water duties result in low N concentrations in soil water; however, over time high drainage volume would result in a high amount of N being leached to the aquifer. In this case, N concentrations by themselves would lead to incorrect conclusions about N leaching risk potential, and in turn, changes in management that would not serve to reduce N leaching risk.

   Additional studies that support this finding are reviewed in the Literature Review and include: Feaga et al. (2004); Randall and Iragavarapu (1995); Gaines and Gaines (1994); and Tindall et al. (1995); Wang et al. (2013); Burrow et al. (1998).

2. **Assumption:** Reducing N fertilizer application reduces N leaching.

   Scientific Finding: Reducing N applied does not necessarily result in a corresponding reduction in N leached, and may lead to *increased* leaching. Nitrogen leaching is only reduced if the N applied is over what is needed for maximum yield, and then is reduced to equal or below what is needed for maximum yield. Except for conditions of maximum yield, a reduction in the amount of N applied does not induce an equal reduction in the amount of N leached

(Rosenstock, 2013; Letey and Vaughan, 2013; Broadbent and Rauschkolb, 1977). This results from the relationship between N uptake and crop vigor. As more and more fertilizer N is applied, the rate of increase in yield decreases and reaches a point where further N application does not result in additional yield. This reduction in N uptake leaves more N available for N leaching. Conversely, reducing N fertilizer applications below a rate needed for maximum yield in hopes of reducing N leaching can lead to reduced crop vigor, poor N uptake, poor yield, and resulting reduction in evapotranspiration, which results in greater probability of over-irrigation increased deep percolation, and hence, more leaching. Therefore, reducing N fertilizer applications can sometimes result in *more* N leaching because of adverse impacts on plant vigor and N uptake.

Additional studies that support this finding are reviewed in the Literature Review and include: Pang et al. (1997); Altman et al. (1995); Fix and Piekielek (1983).

3. **Assumption:** The concentration of N in groundwater and soil water represents current N status on the surface of the overlying field and correspondingly, current management practices.

   Scientific Finding: There are temporal and spatial components that must be considered. The transport time between nitrate leaving the root zone and reaching first-encountered groundwater can be anywhere from days to decades, depending not only on depth to groundwater, but soil heterogeneity in the root zone, vadose zone, deep vadose zone; and also on irrigation management practices (Harter and Lund, 2012; Pratt et al. 1972; Fogg et al., 1995). Also, groundwater contamination is not a one-dimensional phenomenon and is influenced by vertical and horizontal water movement. Therefore, assessing the N status of an agricultural system using an indicator such as groundwater does not represent the current N status of the fields directly above or the many factors that influence it that are currently in use in many cases. In addition, studies show soils may retain more fertilizer N over the long term (up to 15 percent) than previously assumed (Sebilo et al., 2013).

4. **Assumption:** Irrigation management is less important than N fertilizer management in reducing N leaching risk.

   Scientific Finding: In California, irrigation is one of two key factors that determine how much N leaches to groundwater – 1) residual nitrate in the soil profile, and 2) volume of water that passes through the root zone. If nitrate can only reach groundwater through the movement of water, then it is reasonable that the amount of water that leaches through the root zone is not just a contributing factor to N leaching risk, but is an *essential* factor. Growers have applied what might be considered “excessive” irrigation water for numerous reasons (salinity management, lack of irrigation uniformity, poor irrigation management, etc.), all of which are significant management concerns in agricultural production and cannot be ignored in addressing N leaching risk factors.

   In addition, excessive drainage resulting from excessive irrigation has been found to be the cause of N fertilizer over-application, not the other way around. In other words, growers have been found to over-apply N because excessive/inefficient irrigation causes greater losses of N, and this reduces crop yield (Letey and Vaughan, 2013). This finding underscores the importance of irrigation management, because it can be used to minimize leaching losses, and in turn minimize over-application of fertilizer N.

   Studies that support the finding that irrigation factors (specifically, uniformity) is equally important as applied or residual N in soil include Waskom (1994); Feaga et al. (2004); Barragan et al. (2010); Pang et al. (1997), Allaire-Leung et al. (2001); Wang et al. (2013); Letey et al. (1979).

5. **Assumption:** The N balance approach is an adequate tool for characterizing agricultural N losses to leaching at the field scale, and ultimately minimizing N leaching at the field scale.

   Scientific Finding: The uncertainties associated with the N balance approach result in a broad range of "results" which are not ultimately useful in minimizing N leaching to groundwater in agricultural systems. The great variability in N leaching and the processes that influence it not only between cropping systems but within them, have been documented numerous times in scientific literature (including but not limited to Randall and Iragavarapu, 1995; Altman et al., 1995; Aschmann et al.,1992; Denton et al., 2004). N balance approaches have been rejected by numerous initiatives intended to effect change at the field scale (Waskom, 1994, Feaga et al. 2004, Gross et al., 2010). Attempts at using the N balance approach to quantify leaching are generally limited to simulation modeling, and are not always successful when their results are compared to field data. Uncertainties include the temporal and spatial variability of N losses such as volatilization and denitrification, and long term soil retention of applied N (Sebilo, 2013).

   One example of the limited success of using an N balance approach to predict nitrate in groundwater is that of **Botros et al. (2011)**. These authors used various approaches in conjunction with standard hydrologic modeling techniques to estimate groundwater nitrate at the UC Kearney agricultural experimentation site. They concluded that the simple root zone mass balance model was limited in its ability to predict the low total nitrate mass measured in the deep vadose zone or the large variability of nitrate observed in the deep vadose zone at the field site. They further concluded that the results of their study raised questions about our understanding of the fate of nitrate in the vadose zone. Additionally, they suggest that not all vadose zone water can be modeled with current techniques, yet needs to be considered for "*simulating nitrate transport under conditions of cyclical infiltration with gravity dominated convective flux*". In other words, downward movement of irrigation water cannot be described accurately. If downward movement of irrigation water is key in determining the amount of N that leaches to groundwater, but we have no means to describe it, then it is unlikely that attempts to balance N in this complicated system will yield meaningful results.

   Additional studies that support this finding are reviewed in the Literature Review and include Burrow et al. (1998); Delgado (2008); and Nolan 2001.

The main reason why these assumptions do not hold true for many agricultural systems is because they do not consider the complex interactions between plant response to yield, plant response to water, plant response to N, and interactions of N with water, which are not inherent in the N budget approach.

CONCLUSIONS

The current approach commonly used in hydrogeological studies to minimizing the impact of agricultural N on groundwater quality, as described by Denton et al. (2004), is to evaluate nitrate leaching by monitoring root zone nitrate levels up to a 6-foot depth. Nitrogen balance models are then used to estimate the impact of N fertilizer on groundwater quality. The same authors state, "*The common assumption is that nitrate losses to below approximately six feet represent the amount of nitrate leached into ground water. This assumption is justified for many areas in the US, where ground water is found at depths <u>of less than 10 to 20 feet</u>*". In conclusion, the authors state, "*Our current understanding of the spatial variability of hydraulic properties and their impact on nitrate fate and transport below the root zone is therefore limited and based on greatly simplified models.*"

The National Research Council (1993) determined that groundwater vulnerability depends on both *intrinsic vulnerability* and *specific vulnerability*. Intrinsic vulnerability is the result of soil and hydrogeologic factors that cannot be controlled by a grower. Specific vulnerability consists of the vulnerability that results from crop type, irrigation system, and other management factors. Growers have no control over intrinsic vulnerability, but they do have control over specific vulnerability. Therefore, strategies intended to reduce nitrate in groundwater that do not consider specific vulnerability (management factors) *at the field scale* are likely to be unsuccessful. This is largely because groundwater/soil water N concentration measurements taken out of context of management practices can easily lead to erroneous conclusions, reflected in the assumptions listed above.

If the ILRP is underpinned by these assumptions, it will not necessarily be successful at protecting groundwater and will likely waste financial, human and natural resources. The N tracking and reporting approach should employ a system that addresses what growers can control, such as N fertilizer management (form, placement, and timing) and irrigation management (time and amount of application). At a minimum, the quantitative approach to N tracking should be supplemented with a methodical system that can track management practices and use them as interpretive tools to make decisions that will successfully manage agricultural N to protect groundwater statewide.

6 AN ALTERNATIVE/COMPLEMENT TO THE N BALANCE APPROACH

Because numerous studies have shown that there is little correlation between groundwater nitrate concentration and N fertilizer applied alone, the values of N cycle components derived from N balance approaches have little meaning if they are not coupled with information about what intrinsic factors (such as soil type and depth to groundwater) and/or how management factors contribute to the cause of the level of nitrate contamination. And since management is the only thing that growers can control, *modifying management practices and choices at the field scale is the only way growers can decrease groundwater nitrate contamination overall.*

Therefore, it is imperative that the N tracking and reporting protocol, which will be used state-wide for the purposes of protecting and preventing further degradation of groundwater for beneficial uses, incorporate a method for compensating for the two main shortcomings of the N budgeting approach, namely:

1. **N budgeting alone cannot accurately capture the variability of N dynamics in California agriculture** across the wide range of geography, climate and cultural practices throughout the state in a timely manner that will be useful for the purpose of the ILRP.
2. **N budgeting cannot necessarily provide information on what is contributing to or causing high or low nitrates in groundwater** in any given scenario, because the assumption that N fertilizer applied correlates to groundwater nitrate concentration has been shown to be invalid in many cases.

In other words, tracking and reporting N for the purpose of conducting an N balance alone will not completely protect groundwater from degradation because it does not account for or include the impacts of management practices, which are key factors in nitrate leaching. The influence of management factors on leaching has been documented in numerous studies, specifically in California (see Literature Review at the end of this document). Management factors must also be tracked and reported to determine the source of nitrate, and used to provide context for quantitative, inherently uncertain N budgeting. Management factors must also be tracked and reported to determine if strategies to better manage N and reduce leaching are successful.

The Nitrogen Tracking and Reporting Task Force included several components of agricultural systems in their recommendations on what to monitor for purposes of implementing the ILRP. Clearly, the intent of including components such as N fertilizer applied, N in irrigation water, and N removed in crop yield is to use them in a partial N balance. However, the data needs specified in the Final Report in no way provide the necessary data for a complete N balance. Because of the great complexity and variability of the N cycle in the highly diverse agricultural systems in California, the results of an N balance approach will be uncertain, as with any attempt to quantify a natural, biologically mediated system, especially with poor and/or incomplete input data**.** A farm-gate N mass balance that only measures N fertilizer going in and estimates crop consumption N going out does not account for the N cycle within, the dynamics of which significantly influence leaching. **In addition, these results will have little meaning without a means to interpret their underlying cause.**

This means of interpretation can be provided by tracking other factors known to influence N leaching, such as irrigation system type. Though it has not been specified how these factors will be used in the tracking and reporting system in the Final Report, they would serve as meaningful data if they were used in a scientifically valid methodology to identify the localized, underlying causes of groundwater nitrate concentrations. If they are not used this way, but merely reported as part of a comprehensive tracking strategy without defined purpose or analysis approach in mind, they will result in wasted time, effort and resources.

Management factors, specifically irrigation practices and type, should be documented along with crop type and soil type (at a minimum) and used in the NHI, which was developed (University of California Agriculture and Natural Resources) and validated (Wu et al., 2005) specifically for California agriculture, to track both management factors and crop type changes. The NHI tool was developed as a first step in a Best Management Practice (BMP) approach. The NHI provides a field-scale rating of the potential for nitrate leaching, but it also identifies the major factor that is contributing to this potential. It can be used in its simplest form with basic on-farm information, or can be refined for regions with common irrigation systems, soil types, etc. Paired with GIS resources and landscape information, it is a powerful tool for assessing groundwater pollution vulnerability specifically for N and for guiding BMPs. Using the NHI as a way to track, assess, and modify management factors would serve two purposes:

1. **The NHI could be used to provide insight into the causative factors of N budget results.** Without such an interpretive tool, there is no way to determine what is causing N concentrations that are either measured or determined through an N budget. For example, crop type has a major influence on N budgeting because different crops have different rooting depths and uptake patterns. A change in irrigation system type from surface flood to micro-irrigation would dramatically change the potential for nitrate leaching. This may not be observed immediately in groundwater monitoring results and reflected in an N budget if groundwater is at great depth; however, an NHI assessment would capture the change in nitrate leaching risk beneath the root zone. The NHI serves as a built-in education tool that provides meaningful and practical information to growers, who will ultimately effect positive change towards decreasing groundwater nitrate contamination.
2. **The NHI would serve as a means of validating, verifying, and providing context for N budgeting results,** which are likely to be highly uncertain (and potentially inaccurate) given the high variability and unknown dynamics of N cycles in wide-ranging California agricultural systems. For example, if the N budget and NHI approaches yield dissimilar results for a particular site, this would indicate that more investigation into site-specific factors must be considered. In this way, the NHI can be used to verify the results of the N balance, given the latter's expected variability in accuracy.

The SWRCB accepted this approach when this work was developed (Plant Nutrient Management TAC Report, http://www.waterboards.ca.gov/water_issues/programs/nps/tacrpts.shtml), as part of the SWRCB Initiatives in Nonpoint Source Management program, but it could not be implemented at the time because the indexing information for the factors that determine N leaching potential (soils, crop types, and irrigation system types) was not completely available. However, this information is now available and this constraint no longer exists.

Though the shortcomings of an N budgeting approach cannot be entirely mitigated by using NHI, the impacts can certainly be reduced. Specifically, one of the factors that directly determines amount of N leached below the root zone is volume of water that passes through the root zone. This factor is excluded from N budget approaches because it is not part of the N cycle per se. Most importantly though, it cannot be measured on a large scale. Therefore, no amount of tracking, reporting and/or budgeting N can account for or encapsulate the influence of this key factor. However, a methodical system of tracking and relating management factors to groundwater nitrate can provide irrigation management information that would serve as a useful proxy for this important determinant of N leaching.

7 Summary of Advantages and Disadvantages of N Tracking and Budgeting for Use in the N Balance Approach

In summary, the advantages and disadvantages of using a quantitative N balance approach to assess and decrease N leaching are summarized below:

Advantages

- Measurements of N in any part of the N cycle provide benchmarks that in time, can provide useful comparisons in helping to understand the fate of N in agricultural systems.
- Measurements of N can provide valuable information about status of N groundwater contamination as it currently exists, regardless of how or when it achieved that status.
- The relative proportions of N pools can be portrayed at a gross scale to improve general understanding of N in the environment.

Disadvantages

- When N measurements are not evaluated in context of management practices for the purpose of managing N, erroneous conclusions can result.
- Absolute values of some N status indicators, such as groundwater, do not reflect current N leaching; rather, because of long transport times, they frequently reflect legacy N contamination.
- The N balance approach that usually results from N cycle component tracking is extremely complex and difficult to accomplish, resource intensive and requires major assumptions that call the accuracy of the balance into question.
- Absolute values of N cycle components only provide information about that particular component, and do not necessarily provide information about other components of the N cycle.
- Absolute values of N indicators do not provide any information about the causal factors of that component's status. Further analysis is necessary to make the value useful.
- N tracking and budgeting approaches are data-rich; they require the collection of large amounts of detailed data that is not available at the farm gate.
- These approaches are generally inefficient and do not yield quick results, largely because of the large amounts of data required and the nature and variation of N cycling.
- Scientific uncertainty and potential for erroneous conclusions does not support the Recommendation's use in a regulatory program such as ILRP.

8 LITERATURE REVIEW

The following conclusions represent what is generally known about N leaching in crop systems based on findings in published, scientific literature. This literature represents only a small fraction of the peer-reviewed scientific resources published on N fate in agricultural systems; it has been selected and included because it is particularly relevant to the objective of determining what factors influence N leaching, and how those factors can be measured and controlled to protect groundwater resources in California.

CONCLUSIONS

1. <u>Nitrogen cannot be budgeted so that N fertilizer input is equivalent to crop consumption.</u>

"One fact emerges when one considers the mechanism of N transport to plant roots. It is impossible to extract all the soluble mineral N from soil solution without suffering decreased plant growth. The consequence of this fact is that there will always be some soluble N that can be leached beyond the root zone when "excess" water is applied. The amount and concentration of N leached depends on several dynamic and temporal factors…." **University of Arizona et al. (undated).**

This conclusion is recognized widely in the scientific literature on agricultural N. Biological efficiencies are always less than 100%, largely because of the constant fluctuation in growing conditions that influences a plant's ability to take up nutrients. In other words, optimum growing conditions are never constant. A general rule of thumb is that N fertilizer uptake efficiency is 50 percent, on average, for agricultural crops (**Meyer, 2008**). However, typical fertilizer N uptake efficiencies of major agronomic crops range from less than 30 to greater than 70% because of several factors. First, it is not possible for a plant to deplete the entire inorganic N from the soil solution. As the nitrate and ammonium concentrations decrease in solution, the rate of N uptake also decreases, in a relationship similar to substrate-enzyme reactions.

Harter and Lund (2013) also acknowledged this important conclusion and determined that "*Due to unavoidable N losses, complete crop recovery of all applied inputs is impossible to sustain. Our approach in this report is to identify and describe practices and technologies that are potentially available to growers for achieving high crop N use efficiencies, and for reducing, but not eliminating, nitrate leaching to the groundwater from cropped land.*"

2. <u>Cropping systems necessarily accumulate residual N at the end of the growing season because of the nature of plant physiology and optimizing resource efficiency.</u>

Minimal N concentrations in the soil are required to result in N influx into crop roots. In addition, some N losses (volatilization or leaching) from the root zone are inevitable during the season. As a result, not all of the N supplied will be available for plant uptake. Finally, and perhaps most importantly that to achieve maximum or near maximum yields, N must be supplied at high levels. According to Mitscherlich's Law, as N supply increases, there is a decrease in the incremental yield increase per unit of N input.

As a result, N use efficiency invariably decreases at high levels of N input that are required to achieve maximum yield. On the other hand, if minimal N is supplied so that the soil N is depleted to near zero to minimize nitrate leaching potential, there is an insufficient concentration of soil N to drive maximal rates of N uptake (**Broadbent and Rauchkolb, 1977)**, and crop yield will be limited. For this reason, the presence of residual soil N at the end of a growing season is inevitable in intensively managed cropping systems that are achieving near maximum or maximum economic yields (**Hermanson, et al., Undated**).

3. Residual N and/or N fertilizer applied is not necessarily related to amount of N leached.

The findings of **Broadbent and Rauschkolb (1977)** demonstrate that N application rates alone are not always enough to predict N leaching. **Olson (1982)**, after working on the fate of N applied in the fall using labeled-N and agronomic rates in winter wheat, found that from all the leaching produced during the winter time, only about 10% of it came from the fertilizer nitrogen. **Burrow et al. (1998)** found that nitrate in domestic wells could not be correlated with N fertilizer applications on adjacent farmland. These results are consistent with the results of **Broadbent and Rauschkolb (1977)**, who suggested that the dilution effect of applying more irrigation, which may lower the concentration of nitrate, may also result in more N leached over the long term.

Researchers investigating other forms of N loss, such as nitrous oxide (N_2O) have reported similar results. **Hoben et al. (2011), Linquist et al. (2012),** and **Van Groenigen et al. (2010)** all showed that these losses are not necessarily related to N applied.

Some authors have suggested that N leaching can be better predicted by the amount of residual or surplus N remaining after crop uptake, which is largely a function of N use efficiency. **Rosenstock et al. (2013)** cite the N_2O studies listed above to support their suggestion that "*the best indicator of potential nitrogen loss into the environment is the "surplus" N, which is the difference between the N applied as fertilizer and the N taken up by the crop*." However, the relationship between N applied, residual N, yield and N_2O emissions may not necessarily apply to leachable nitrate. **Hart et al. (1993)**, working with labeled-N in winter wheat, indicated that most of the labeled-N was presumably mineralized during the fall and winter when the losses are high and crop demand is low. They concluded that leaching of NO_3-N from cereals comes predominantly from mineralization of organic N, not from residual unused N. These results call the assumed direct relationship between residual or surplus N and leached N into question.

4. Reducing N fertilizer application rates does not necessarily minimize N leaching.

The findings of a major National Science Foundation Research Applied to National Needs (RANN) Program study conducted on the relationship of N fertilization to water pollution potential in California are summarized in **Broadbent and Rauschkolb (1977)**. This multi-year study demonstrated that addition of N fertilizer beyond that needed for maximum crop yield increases the amount of N that can potentially be leaching. However, at rates of N required for maximum yield, the amount of N remaining in the soil is small, representing little that is available for leaching. Therefore, little can be achieved by reducing N fertilizer applications to below the amount needed for maximum yield; yield is sacrificed and leaching potential is not affected.

Rosenstock et al. (2013) state that applying a greater amount of N fertilizer in and of itself is not necessarily harmful, but the fraction of excess applied is what is harmful. **Pang et al. (1997)** support these findings; in irrigation quantity and uniformity study, concluding that N leaching was very low when the N application was close to crop N uptake and slightly higher when the uniformity coefficient of the irrigation was 90%. When N application exceeded N uptake, N leaching increased dramatically for all uniformity levels. **Rosenstock et al. (2013)** further state that for almost every one of 33 crops evaluated in their study, yields and N uptake increased with greater N supply. They suggested that their findings indicate that growers of the 33 commodities evaluated have become more agronomically N-efficient over the last 40 years and that for most crops, less N is applied per unit of product.

These findings would indicate that optimizing fertilizer application to meet total N crop demand would minimize N leaching. However, **Altman et al. (1995)** reported NO_3-N losses from crops amounting to 24 to 55% of the N applied at economic optimum rates (typically providing for near maximum crop yields). **Jego et al. (2008)** demonstrated that on a high N-uptake crop such as sugar beet, N application rate did not influence the amount of N leached. In Pennsylvania, the apparent recovery of N fertilizer (ammonium nitrate) applied at the economic optimum N rate in 42 experiments averaged 55% (**Fix and Piekielek, 1983**). Therefore, even when using optimum fertilization rates, a potential exists for fertilizer N to accumulate in the soil with subsequent risk of loss through leaching. The missing link that was not addressed in these studies is the amount and timing of water passing through the soil profile and when.

5. **No individual factor on its own (soils, crop types, or irrigation methods) can account for nitrate leaching; leaching potential of a site depends on soil properties, management, irrigation, crop type, and climatic factors.**

This concept provides the foundation for numerous strategies of addressing groundwater N contamination, including that of the **National Research Council Groundwater Vulnerability Assessment (1993)**. Reducing the assessment and management of agricultural N to the result of an N balance is inappropriate in approach, even in consideration of management factors. Management factors must be assessed and given equal weight to N leaching potential in order to determine the true causes, and provide the ability to address those causes.
"While soil, climatic, and geologic characteristics of the site strongly influence leaching potential, management practices finally determine the amount and extent of N leaching. Conscientious management of irrigation water is critical to proper N management." (**Waskom, 2013**)

Increasing irrigation efficiency and uniformity reduces the amount of water drained through the soil, and decreases the amount of NO_3 and other contaminants leached. Proper N rates and good irrigation management are the most critical components of N management. Attempting to minimize leaching by budgeting N fertilizer applications alone will not necessarily ensure the lowest possible leaching if irrigation uniformity and management are not addressed.

6. **The amount of nitrogen leached depends primarily on the amount of water percolating through the root zone and the nitrate concentration in the soil profile, for which there is great spatial and temporal variability.**

"Nitrate-N concentration in groundwater is a function of the quantity of water recharging the aquifer and the rate of N loss from the surface." (**Feaga et al. 2004**)

Concentration data collected over the 5-year study were averaged with respect to flow. Flow-weighted averaging is an appropriate method to represent the average concentration over multiple sampling events, or when more than one sampler is measuring an event. To find a flow-weighted average for a 5-year period, for example, the total mass of nitrate collected divided by the total volume of water collected would be the 5-year flow-weighted average. Flow-weighted averages are better than simply averaging monthly NO_3-N concentrations because the method can prevent misleading data caused when sampling events that collect small volumes have very high concentrations. (**Feaga et al. 2004**)

This nitrate concentration is strongly influenced by N application rates, methods and management. Cropping systems may be a major factor in regulating nitrate movement below the root zone and toward the water table. Rooting depth, water requirement, water-use rate, N-uptake rate, and time of water and N uptake are all factors involved in nitrate leaching that can be affected by choice of cropping system and associated management. For nitrate leaching to occur, appreciable concentrations of nitrates must be present in the root zone at the time that water is percolating.

Perhaps the greatest uncertainty when measuring or predicting deep water percolation and associated nitrate leaching in soil deals with the heterogeneous pore distribution in the root zone where microbial N cycling can greatly alter N availability for leaching. Large pores created by shrinking and swelling of clays, decomposition of roots, and faunal activity can accelerate water movement (two to five times higher for soils without obvious macropores, and as much as twenty times for soils with cracks). This increased water movement will have different effects on nitrate leaching depending on N concentration of those areas of the soil "bypassed" by infiltrating water, the rate of water application, the N concentration of infiltrating water, and other factors. The net result, however, is generally one of increased N amounts being transported beyond the reach of crop roots. **Aschmann et al. (1992)** detected flushes of nitrate and other ions and attributed them to preferential flow through the profile.

Randall and Iragavarapu (1995) also showed that the amount of N leaching is related to the amount of percolating water. They conducted a study on a poorly drained clay loam soil in Minnesota with continuous corn and N fertilization rates of 200 kg N/ha for several years (fertilizer N was applied as one dose in the spring before planting). They found that annual losses of NO_3-N in the tile water ranged from 1.4 to 139 kg/ha. In dry years, losses generally were equivalent to less than 3% of the fertilizer N applied, whereas in the wet years, losses ranged from 25 to 70% of that applied.

Gaines and Gaines (1994) indicated that soil texture affects NO_3-N leaching. In coarser soils, NO_3-N will leach faster than from finer ones. The addition of peat in sandy soils helps in reducing the velocity of N leaching. However, **Tindall et al (1995),** in a laboratory analysis, indicated that leaching of NO_3-N was significant in both clay and sandy soils. They concluded that in clay soils leaching occurred less rapidly than in sandy soils. Nevertheless, after enough time, 60% of the NO_3-N was leached from the clay soils.

These studies highlight the challenge identified by **Broadbent and Rauschkolb (1977)** in assuming that nitrate concentration in the soil profile is related to the nitrate concentration that will reach the aquifer. In the NSF study that evaluated the interaction of N fertilizer treatments and irrigation treatments, they found that higher N concentrations were associated with less irrigation, while lower N concentrations were associated with higher irrigation treatments, because of the dilution effect. The important measure, however, is how much total N mass is transported to groundwater, which clearly cannot be determined from N concentration measurements alone.

La Folie (2000) concluded that it is difficult under non-uniform irrigation to manage either water or N application to achieve high yields without N leaching or water and nitrogen stress, as a consequence of the spatial variability in water and nitrogen fluxes. The authors recognize that farmers commonly apply excess N as insurance against deficiency, or in response to excess deep percolation (**Letey et al,2013)**, but they also state that "*in agricultural practice, irrigation is probably less uniform than under experimental conditions, and more N fertilizer may have to be applied to attain the same yield. Consequently, it remains essential to optimize both mean irrigation depth, and the amount and timing of fertilization*".

7. **Irrigation system management and maintenance ensuring high uniformity, not necessarily efficiency, is a key factor in minimizing leaching.**

Feaga et al. (2004) describe the influence of irrigation uniformity on nitrate leaching thusly:

> *The effects of an improperly maintained irrigation system on nitrate leaching potential are similar to over-irrigation. An improperly maintained irrigation system will not distribute water evenly throughout the field. Uneven irrigation can set off a chain of events that effectively cause the grower to require additional fertilizer applications. Consider an irrigation system that applies water excessively to certain parts of the field and deficiently in others. Portions of the field receiving the bulk of this water will have higher NO_3- leaching rates. Other parts of the field will be under-watered. In response, the grower will increase the irrigation*

amount to ensure that the drier areas are receiving enough water. Now the leaching potential in the wetter areas will further increase. Nitrogen-deficient plants in the over-irrigated areas will require additional fertilizer, assuming that the grower is able to realize the problem in time to counteract the deficiency. Crops in the drier areas of the field will have a N surplus.

Barragan et al. (2010) also suggested that water distribution uniformity in micro-irrigation systems, in addition to irrigation efficiency and other management strategies was influential in achieving environmental quality. Their work did not involve field experiments. **Pang et al. (1997),** as mentioned above, also demonstrated that irrigation system uniformity in sprinkler systems impacted nitrate leaching; specifically, leaching increased as uniformity decreased from 100 to 75 percent. They used a CERES model. **Allaire-Leung et al. (2001)** concluded that irrigation uniformity did not have a significant effect on nitrate leached; however, the irrigation uniformities used in their field study on carrots grown on coarse-textured soil were all above 80 percent. Therefore, their results were not inconsistent with those of Wang et al. (2013). **Wang et al. (2013)** noticed by reviewing the literature that simulation models might tend to over-estimate the significance of irrigation uniformity on nitrate leaching, compared to results from field studies. So they conducted a field experiment on spring corn (in semi-humid conditions) to test the influence of nitrate applied, soil nitrate residual, and irrigation uniformity on nitrate leaching. They reported that all three of these factors contributed to nitrate leaching and recommended that irrigation uniformity remain above 60% to minimize nitrate leaching.

Therefore, the scientific literature to date supports the conclusion that irrigation uniformity, amongst other strategies, is key in minimizing nitrate leaching.

8. Quantification by assumption of certain N cycle processes is not a valid approach at the field scale.

Volatilization is a biologically mediated N loss pathway that is highly variable and cannot be assumed to be constant across sites, seasons, or years. Volatilization can occur whenever free ammonia is present near the surface of the soil. The ammonia concentrations in the soil solution will increase by applying ammonia-based fertilizers or decomposable organic materials to neutral or alkaline soils. The amounts of ammonia volatilized are small when N materials are incorporated into the soil, and ammonia losses are also low (≤15% of applied N) when ammonia-based fertilizers are applied in the surface of acidic or neutral soils.

Ammonia volatilization is a complex process involving chemical and biological reactions within the soil, and physical transport of N out of the soil. The method of N application, N source, soil pH, soil cation exchange capacity (CEC), and weather conditions influence ammonia emissions from applied N. Conditions favoring volatilization are surface applications, N sources containing urea, soil pH above 7, low CEC soils, and weather conditions favoring drying. Precise estimates of ammonia emissions are only possible with direct local measurements. Depending on application conditions, general ranges would be 2 to 50% emissions for soil pH > 7 and 0 to 25% emissions for soil pH < 7. If the N source is mixed into an acid soil, the emissions are usually greatly reduced (0 to 4% lost) (**Meisinger and Randall, 1991**).

Similarly, denitrification can represent significant N loss in agricultural systems, and cannot be assumed to be a constant value. Compared to volatilization, denitrification emissions in agricultural systems are generally lower, however can be significant in some high water table/reduced soil environments. Emissions of N_2O were found to be lower than 5 to 7 % of the applied N, even at high application rates of 680 kg N/ha/year (**Ryden and Lund, 1980**). Similarly, **Mosier et al. (1986)** reported that, on well-drained clay-loam soil sown with corn in 1982, 2.5% of the 200 kg N/ha applied as $(NH_4)_2SO_4$ was lost as N_2O or N_2. The following year, only a loss of 1% could be measured from the same soil sown with barley.

Conversely, considering possible inputs to the N cycle aside from inorganic N fertilizer applications, mineralization is another biologically mediated process where the decomposition of organic matter can contribute up to 50% or more of the plant required N (**Gardner et al., 2009)**. Determining the N contribution from this process is very difficult as climatic and other biological factors can have a significant bearing on the rate of release of N in a plant available form.

9. The N balance approach is an inadequate tool for minimizing N leaching at the field scale.

"If N efficiencies can be estimated, why can't a cookbook approach be used to ensure that crops are being fertilized at a rate to maximize efficiency and minimize N available to leaching? In reality, natural processes and seasonal variation make exact N balances difficult to achieve." (Feaga et al. 2004).

Nitrate leaching is exceedingly difficult to quantify with an N balance and correlate with agricultural fields spatially. **Stenger et al. (2002)** used geospatial statistics to try to characterize NO_3–N at a small plot scale, and found that nitrate and water contents showed a low proportion of structural variance and their distribution patterns were not stable with time. **Delgado (2008)** also stated that "*Agricultural-related nitrogen (N) losses are negatively impacting groundwater, air, and surface water quality. The complexities of the N cycle have made estimating these losses extremely difficult*."

This fact is implicit and acknowledged in large-scale N balance efforts. For example, the CNA study information states:

> *A mass balance is an efficient and scientifically rigorous method to track the flows of N in a system. The underlying premise of a mass balance is that all of the reactive N entering (i.e., inputs) the study area must be exactly balanced by N leaving (i.e., outputs) and N retained in the study area (i.e., change in storage). A mass balance approach is very useful to compare the size of N flows and also to identify gaps in understanding the size and directions of these flows.* ***Some flows are difficult to quantify -- they are highly variable in time and/or space, or there are simply no methodologies to easily measure or predict the flows.*** *Nevertheless, knowledge of the relative magnitude of the flows is needed to make informed management and policy decisions for targeting N reductions.*

Describing the mass balance approach as "efficient and scientifically rigorous" may be appropriate for large-scale assessments, but is questionable for the purposes of managing field-scale N, and applying regulatory requirements with the aim to modify agriculture to decrease groundwater leaching. Though numerous scientific studies have used N balance approaches to gain understanding of the N cycle, all of these studies identify uncertainties with this approach and acknowledge the use of major assumptions to achieve "balance." Though the high variability of N flux is recognized by the CNA effort, there is no indication of how these uncertainties are addressed. Information from this initiative further states:

> *The range…places nitrate (NO_3) storage in groundwater as one of the major nitrogen sinks in the state, but highlights the uncertainty around some chemical processes, particularly in difficult-to-monitor locations such as aquifers.*

This statement is important because the foundation of the ILRP is to monitor groundwater nitrate concentration *in aquifers* and use it as an indicator of N leaching. Regardless of the accuracy or inaccuracy of N mass balances, their results ultimately do not identify specific causes of nitrate leaching and how to change management practices at the farm scale to address them. Therefore, the N balance approach might be useful for determining gross estimates of N pools and flows, but it is not useful for addressing specific farm management to effect change in real-time or potential N leaching across a wide and varied landscape.

One example of the unsuccessful use of the N balance approach to predict nitrate in groundwater is that of **Botros et al. (2011)**. These authors used various approaches in conjunction with standard hydrologic modeling techniques to estimate groundwater nitrate at the UC Kearney agricultural experimentation site. They concluded that the simple root zone mass balance model was limited in its ability to predict the low total nitrate mass measured in the deep vadose zone or the large variability of nitrate observed in the deep vadose zone at the field site. They further concluded that the results of their study raised questions about our understanding of the fate of nitrate in the vadose zone. Additionally, they suggest that not all vadose zone water can be modeled with current techniques, yet needs to be considered for "*simulating nitrate transport under conditions of cyclical infiltration with gravity dominated convective flux*". In other words, downward movement of irrigation water cannot be described accurately. If downward movement of irrigation water is key in determining the amount of N that leaches to groundwater, but we have no means to describe it, then it is unlikely that attempts to balance N in this complicated system will yield meaningful results.

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Attachment 2
Nutrient Technical Advisory Committee Report
to the State Water Resources Control Board (1994)

NUTRIENT TAC REPORT

EXECUTIVE SUMMARY

The surface and ground waters of California can be impaired by nutrient leaching and runoff from agricultural and other sources. For the past eight months, Nutrient Technical Advisory Committee (TAC) members have worked hard and carefully to develop recommendations for nutrient management in California which meet the varied interests of those who have a stake in the quality of California's waters.

The TAC recommends that all growers participate in a mandatory self assessment program to determine their potential risks of contributing to nutrient-related nonpoint source pollution, and to develop a management plan to minimize their potential contribution to water quality degradation in California.

The completion of hazard index determines whether a grower must prepare a written nutrient management plan incorporating management practices proposed by the TAC. Hazard index scores can range from two to nine, with a score of six or greater triggering the requirement for a written nutrient management plan. Hazard index scores of less than six exempt the grower from having to prepare a written nutrient management plan, but the completion of a risk assessment matrix and a year-end evaluation is still required.

Section I of this report describes the TAC's purpose, goal and problem statement. A summary of the interest-based approach used to arrive at the TAC's recommendations is also provided. The recommendations of the TAC and descriptions of the proposed management practices appear in Section II. Section III outlines how the recommendations should be implemented and enforced, and describes the institutional changes and educational outreach efforts critically needed for successful implementation of the recommended management strategy. Section IV describes the TAC's required evaluation of the management measures contained in the Coastal Zone Act Reauthorization Amendments guidance document prepared by the Environmental Protection Agency and the National Oceanic and Atmospheric Administration.

Finally, the members of TAC wish to express their gratitude to the State Water Resources Control Board (Board) and its staff who bravely embarked upon an interest-based approach to arrive at fair and equitable solutions to California's nonpoint source pollution problems. The members of the TAC believe firmly that the solutions derived from this approach are far more likely to be accepted by the agricultural community and Board alike, an important first step in improving the quality of California's waters to the benefit of all citizens. The TAC looks forward to seeing its recommendations included in California's nonpoint source management program.

SECTION I

INTRODUCTION

The Coastal Zone Act Reauthorization Amendments (CZARA, 1990) require states to develop and implement plans for reducing nonpoint source runoff from specific source and land use categories. As part of this mandate, US EPA and NOAA jointly prepared a guidance document specifying management measures that would fulfill CZARA requirements. The California Water Resources Control Board (SWRCB) and the California Costal Commission (CCC) share responsibility for implementing CZARA requirements. In response to this mandate, the SWRCB conducted a comprehensive review of its existing Nonpoint Source Management Program and incorporated a step into the process that would verify usefulness of the US EPA/NOAA management measures for California conditions. Where necessary, alternatives to the CZARA requirements are proposed.

For review of the NPS Program, the SWRCB/CCC used committees for technical and policy guidance. They solicited Technical Advisory Committee (TAC) membership from a broad base of interests related to nutrient application activities in agricultural operations. Fifteen people (Appendix I) contributed to the Nutrient TAC, attending eight full day meetings and developing the recommendations presented in this report.

GOAL

Nutrient TAC members agreed to follow the process advocated by the SWRCB in order to meet an agreed goal for identifying statewide water quality problems due to nutrient runoff, and to seek creative solutions to these problems.

PROCESS SUMMARY

The SWRCB/CCC recommended that the TAC use an interest-based process to evaluate the NPS Program while providing the regulated community early opportunity to respond and recommend potentially viable solutions to pollution problems. The process requested that members identify NPS nutrient runoff or leaching problems due to crop production, identify all stakeholders and their interests, propose solutions, compare proposed solutions to stakeholder interests, and then compare solutions with CZARA requirements. The Nutrient TAC followed this process. A comprehensive list of stakeholders and their interests is presented in Appendix II, and a final stakeholders list is provided in Appendix III.

PROBLEM STATEMENT

Initially the group attempted to describe the nature of problematic nutrient runoff. TAC members considered the SWRCB's Program/Problem Statement, SWRCB 1994 Water Quality Assessment (WQA) Report of impairment of beneficial uses of state surface and ground waters, and findings from the 1988 nitrate Working Group report *Nitrate in Drinking Water, 1988, SWRCB* (referenced in Appendix III). The group then brainstormed nutrient sources, arriving at the primary concern over nitrogen. TAC members then discussed priority of affected waters, and decided to consider impacts to both surface and ground water equally. The group further redefined terms and formulated the following problem statement:

The state's surface and ground waters can be impaired due to nutrient runoff and leaching from agricultural and other sources. The focus of the TAC will be on nutrient management associated with agricultural activities.

BACKGROUND INFORMATION

BMP's are the current means of controlling nonpoint source pollution in the area of nutrient management. The options available to the SWRCB for implementation of BMPs under current nonpoint source pollution plans include voluntary, regulatory based encouragement, and waste discharge requirements. Generally, the Porter Cologne Water Quality Act (13360) does not allow the State and Regional Water Boards to specify the manner of compliance when issuing waste discharge requirements. In other words, waste discharge requirements must be structured in terms of the result to be obtained (e.g. characteristics of the discharge or condition of the disposal area for receiving water). This regulatory mechanism lends itself to regulating discharges where compliance with the discharge restrictions can be verified. Such is the case with point sources and some nonpoint discharges where the discharge occurs through a pipe, or ditch. However, most nonpoint discharges are diffuse in nature and there are many sources within an area (i.e. sediment runoff to streams from grazing operations or various types of nonpoint source pollution to groundwater from farming operations) including natural sources. Thus, discharges from an individual source can not be readily measured and relative contributions to a water body from an individual source can not be determined. Additionally, the effectiveness of the BMPs are not completely observable. It may take many years before water quality improvements are noticed. Therefore, in situations where voluntary or regulatory based encouragement have not been successful in implementing BMPs, there are no additional regulatory tools available to enforce implementation.

In addition to the above options, the Regional Water Boards may also adopt discharge prohibitions or waive waste discharge requirements in exchange for implementation of BMPs. Discharge prohibitions would be difficult to adopt for the type of nonpoint pollution previously described because the discharge cannot be monitored and individual contributions assessed. Under this type of release, a regional board cannot prove that a discharge that threatened water quality occurred. Again, if an individual is not willing to implement BMPs in lieu of waste discharge requirements, there are no additional regulatory remedies available.

The regional boards may also enter into Management Agency Agreements with other agencies which have management control of land use (e.g., Bureau of Land Management, Department of Forestry), or who have authority to specify BMPs. Such is the case with control of pesticide runoff into the Sacramento River from pesticide use in rice production. While some of these agreements have been successful, other agencies do not have a mission which provides for the protection of water quality, or they may not have the resources or initiative to enforce such activities. Initially, not all land uses and potential sources of nonpoint source pollution are under the jurisdiction of agency (e.g., some farming activities such as application of fertilizers or organic wastes), such that management agency agreement can be drafted to control nonpoint source pollution.

Monitoring water discharge below the root zone which migrates to groundwater is extremely expensive and almost technically impossible. In some cases, water tables approach the surface resulting in the farmer installation of subsurface drainage systems which brings the water to the surface. Monitoring drainage outlets is feasible, so there is an inducement to place waste discharge requirements on drainage effluents. Imposing discharge requirements on drainage effluents is an anti-strategy, particularly if the criterion is concentration based. A low concentration of nitrate or other chemical can be achieved by the farmer applying large quantities of water resulting in high leaching, thus diluting the chemical.

The University of California conducted an extensive research program on nitrates in the 1970s. Part of that research included monitoring nitrate movement below the root zone in free drainage system without a high water table, and also collecting tile drainage effluents for monitoring. The results of this research were reported in various articles, but one reference is: Letey, Pratt, and Rible, "Combining water and fertilizer management for high productivity, low water degradation". A major conclusion was that there was very poor correlation between the concentration of nitrate-nitrogen in the drainage water and either applied fertilizer or amount of water leached. On other words, the nitrate-nitrogen concentration in drainage water did not accurately reflect management practices. Good management practices cannot be differentiated from bad management practices by merely using the nitrate concentration in the water leached beyond the root zone. Controlling nonpoint source pollution can more effectively be accomplished by monitoring management practices than by monitoring water quality.

Agricultural operations in California are very diverse. Almost every crop is grown on a variety of soils and under various climatic conditions. Under these conditions, it is very difficult to prescribe management plans which are appropriate for every condition. Furthermore, some agricultural operations and settings create a much higher potential for water degradation than others. It would be unreasonable to impose management practices which may be necessary to protect groundwater under the most hazardous conditions to farmlands in which the hazard is minimal. Thus, the prescribed management should be specific for given crops, soils, and potential groundwater hazards. The recommendations of the Nutrient Management TAC were adopted after considering all of these factors.

SECTION II

RECOMMENDATIONS

The committee recommends a self-assessment for growers to determine what their risks in contributing to nonpoint source pollution and to develop management plan to minimize their contribution to water degradation. All growers will participate in a two-part assessment program, but the extensiveness of the management plan depends on the pollution risk of their operation

Part 1 is a hazard index that will determine if a written management plan is necessary. Part II is a Management/Risk Assessment Worksheet that will help growers assess and evaluate their current management practices. All growers scoring 5 or less on the Hazard Index will complete the Management/Risk Assessment Worksheet, but are exempt from having to write nutrient management plans. Growers who score a 6 or higher on the Hazard Index must complete the Management/Risk Assessment Worksheet and develop written strategies for reducing the probability of water degradation by adopting management practices recommended in this report or otherwise available to that grower.

The SWRCB will be the administrating agency and will be responsible for the distribution of the Hazard Index and Management/Risk Assessment Worksheets. All Hazard Index forms, Management/Risk Assessment Worksheets, and written nutrient management reports will be kept on site by growers. Growers will be responsible to have these forms available for immediate review upon request from the SWRCB or its designee.

HAZARD INDEX AND MANAGEMENT WORKSHEET

Nitrogen is a major plant nutrient required for all plant growth. Degradation of groundwater by nitrate is a potential hazard associated with growing crops because (1) nitrogen is commonly applied in crop production; (2) all forms of nitrogen application can be eventually converted to nitrate; and (3) nitrate is soluble and readily transported by water percolating through the soil. The magnitude of the potential hazard for groundwater degradation by nitrate is highly variable and dependent on the crop, soil, and irrigation system. The extent to which nitrogen management practices must be imposed to protect groundwater from nitrate degradation is dependent upon the potential hazard associated with the crop, soil, and irrigation systems.

The first step to developing a management plan is to determine the value of a hazard index (HI) based upon soil, crop, and irrigation system. The following describes the procedure for developing the hazard index.

Soils

The soil is assigned a hazard value of 1, 2, or 3. Soils classified as 1 are those which have textural of profile characteristics which inhibit the flow of water or create an environment conducive to denitrification. Both denitrification and restricted water flow decrease the migration of nitrate to groundwater. Conversely, those soils classified as 3 are most sensitive to groundwater degradation by nitrate because of high water infiltration rates, high transmission rates through their profile, and low denitrification potential.

Soil profiles can be rated into categories of leaching and denitrification potentials. In general, soils with high leaching and low denitrification potential are usually coarse textured soils of low organic matter content with no layers in the profile to restrict water movement. Clayey soils or soils that have clay layers or textural discontinuities in the profile typically have slow water movement, allow low drainage volume, and develop anoxic conditions. These soils have low leaching and high denitrification potential. However, sandy soils with high silt content and low structural stability can have some of the same low water and air transmissives as clayey soils, and well aggregated clay silts can have some features common with sandy soils if they are sufficiently aggregated to create relatively large volumes of macro pores.

Note: It is beyond the expertise or time commitment of the TAC to index the soils of the state. This task must be completed and made available to farmers in a manner that they can determine how to properly index their soils. Different fields on the same farm may have different index values.

Crops

Crops differ in their degree of potential for nitrate leaching. Those with the highest potential for nitrate leaching which have a hazard index of 3 are those with the following characteristics: (1) the nitrogen uptake in the crop is a small fraction of the total nitrogen applied to the crop; (2) the crop requires high nitrogen input and frequent irrigation to insure rapid vegetative growth; (3) the value of the crop is such that there is a tendency to add excess nitrogen to ensure no nitrogen deficiencies; (4) the crop is not adversely affected when more than adequate amounts of nitrogen are applied; and (5) the crop has a shallow root system where a small amount of nitrogen movement would move it beyond the root system thus negating plant uptake.

Crops with the opposite characteristics of those listed above would have a low potential for nitrate leaching and have a hazard index of 1. Crops with intermediate characteristics would be classified with a hazard index of 2. Examples of crops with a hazard index of 1 would include alfalfa, which requires no nitrogen fertilizer input, and efficiently uses the available nitrogen in the soil. Grapes typically require low nitrogen inputs. The mineral nitrogen in soil profiles of irrigated lands planted to grapes have been shown to contain low levels of nitrate. Some crops such as sugar beet have the sugar yield reduced from excess available nitrogen during the latter stages of growth.

Note: It is beyond the expertise and time of this TAC to classify all crops into hazard index of 1, 2, or 3. This should be done and this information provided to the farmers so that they can accurately evaluate their hazard index.

Irrigation System

Nitrate predominately reaches the groundwater if it is transported by water percolating through the soil. The amount of water percolating through the soil is dependent upon irrigation and precipitation. Whereas the farmer has no control over rainfall, he/she does have control over irrigation. Irrigation systems which apply water uniformly across the field and allow precise control on the amount applied are those which have the greatest opportunity for minimum nitrate transport. Pressurized systems such as micro-irrigation or sprinkler allow precise control over the amount of water applied because it is controlled by a valve under the farmers control. Surface irrigation systems do not allow precise control over the amount of water applied because it is dependent upon such factors as soil infiltration rate, length of furrow, time of run, etc.

Irrigation systems can be classified as to their potential for groundwater degradation by nitrate and have a different hazard index.

The irrigation system is classified into hazard index of 0, 1, 2, or 3. A "0" hazard index is a micro-irrigation system accompanied by fertigation. Small amounts of water and nutrients are frequently applied in quantities to match the crop need. A micro-irrigation system without fertigation is assigned a hazard index of 1. Sprinklers used throughout the irrigation season or for preirrigations for crop establishment is assigned a hazard index of 2. Entire surface irrigation systems such as furrow are assigned a hazard index of 3.

It is emphasized that in assigning these hazard indexes that management of each system will be done to its maximum potential. In other words, a micro-irrigation system which is very poorly designed, maintained, and managed may not be significantly better than other irrigation systems. For each system there is opportunity for variable management. Even furrow systems can be managed differently to alter the nitrate leaching hazard.

HAZARD INDEX AND MANAGEMENT/RISK ASSESSMENT WORKSHEETS

The overall nitrate leaching hazard index is achieved by adding the individual indexes for soil, crop, and irrigation. The total Hazard Index (HI) can have a range between 2 and 9. The higher the number, the higher the Hazard Index.

The Hazard Index is designed to allow growers to determine on their own the potential for nutrient leaching of their operation. By rating the controllable factors (i.e. irrigation) and the noncontrollable factors (i.e. soil type) of their operation, growers will be able to: 1) alert themselves to high risk operations or practices, and 2) possibly adjust practices to minimize potential leaching, thereby allowing a rating that will not require a written management plan now, or prevent them from moving into a higher ratings field in the future. A very high HI (6 or greater) require a carefully designed and implemented nutrient management program to prevent potential groundwater degradation.

Again, completed worksheets should be kept on file at the farming operation. The form will reference Board personnel as to whether that operation requires written nutrient management plans.

FARM HAZARD INDEX WORKSHEET

(To be completed for each cropping unit) A cropping unit is defined as areas with similar soil, crop, and irrigation characteristics.

Determine the hazard index (HI)

Soil 1, 2, or 3	
Crop 1, 2 , or 3	
Irrigation System 0, 1, 2, or 3	
Total (HI)	

Step 1: Use accompanying material to determine whether the soil has a hazard index of 1, 2, or 3. Insert that number in the box. If the field has soils with differing HI, use the highest HI in the table.

Step 2: Use accompanying material to determine whether the crop has an HI of 1, 2, or 3 and insert this number in the table.

Step 3: Insert the HI for the irrigation system in the table using the following classification:

0: micro-irrigation with fertigation
1: Micro-irrigation without fertigation
2: Sprinkler for all irrigation or sprinkler for preirrigation and surface irrigation during rest of season
3: surface irrigation throughout the year

Step 4: Total the HI values for soil, crop, and irrigation systems. This value identifies the degree of hazard for groundwater degradation for your cropping system. Although good nutrient management should be practiced under all conditions, the importance increases with increasing numerical value of the HI.

The Management/Risk Assessment Worksheet was developed as a supplemental guide to the Hazard Index Worksheet to help growers self-assess their operations for BMPs already undertaken, and to identify areas where management practices can be improved through the utilization of BMPs. All growers will complete the Management/Risk Assessment Worksheet identifying current ongoing practices. Growers who scored 6 or above on the Hazard Index Worksheet and need to provide written nutrient plans for practices that result in a high HI rating should use the Management/Risk Assessment Worksheet as a guideline to identify those management or operational practice areas on which the growers need to focus when developing their written management plan. Growers who score 5 or lower should complete the Management/Risk Assessment Worksheet, but as their operations do not pose a real risk in negatively impacting nonpoint source pollution, do not have to provide written nutrient plans. Growers should review the following BMPs, and then complete the attached Management/Risk Assessment Worksheet.

BEST MANAGEMENT PRACTICES

Storage

In order to ensure that fertilizer is being handled in a manner that is as safe as possible, all storage facilities should be adequately maintained and protected from the weather. Secondary containment as well as impervious pads should be utilized for the storage of liquid fertilizers. Additionally, impervious pads and burms should be used whenever possible, for the storage of both dry fertilizers and organics to contain leaching and runoff. The maintenance of these storage facilities should meet both government and California Fertilizer Association standards. In the event of a spill, the spilled material should be isolated, contained, and cleaned up as soon as possible. Other good housekeeping measures that should be implemented to ensure economically and environmentally sound practices of storage would be to maintain proper calibration of fertilizer application equipment, and ongoing education and awareness programs to all levels of fertilizer handlers and users.

Selection of Fertilizers

It is a commonly known fact that the application of fertilizer can enhance production. The most effective management strategy is one that recognizes the crop demand for fertilizers and the release characteristics of all nutrient sources in the system. Nutrients should be selected that provide adequate but not excessive levels of soil nutrients provided throughout the growing season.

The efficient integration of commercial fertilizers and other nutrient sources such as manure or other green materials reduces fertilizer costs by taking full advantage of other nutrient sources. However, extra care must be taken in estimating the release times for the nutrients in these sources, so that the period of maximum plant uptake will coincide with the release time and rates for application of alternative sources of plant nutrient.

Fertilizer Rates

The applications of nutrients should be limited to that amount necessary to meet projected crop needs at the time when the crop needs it most. Potentially, nutrient leaching and runoff could increase rapidly when the amount applied exceeds that required to attain maximum or near maximum yield. When nitrogen or other nitrogen based amendments are applied repeatedly at excessive levels to the same field, it is possible for nitrogen levels to build-up to excessive amounts. In such cases there needs to be ongoing soil testing and plant tissue analysis programs to make sure that the crops total nitrogen requirement is not exceeded. It is recommended that each crop's nutrient needs be managed separately, and that when possible, soil analysis be conducted on at least an annual basis. Growers should be aware of the nutrients already available in the soil before deciding how much to add.

The nitrogen content in irrigation water should also be taken into consideration when fertilizer decisions are being made. By analyzing well water and determining its nitrogen content, a grower can conserve on the amount of nitrogen that is added to their fields, thereby increasing the efficiency of their fertilizer applications.

Timing of Application

Multiple small doses of nutrient are often superior to one or two large applications because larger applications can result in greater nutrient susceptibility to leaching and runoff. Plant growth curves and weekly uptake estimates can be used to determine what portion of a crop's nutrient requirement should be supplied during each different growth stage. The amount of nutrient that a plant takes up is relative to the size of the plants. Therefore, when possible small amounts of fertilizer concentrated around the root zone should be applied for the early growth stages. Decisions on late season fertilizer application can be aided by plant tissue testing.

When a crop is grown during the rainy season, or when making irrigation decisions, a major portion of the plants nutrient needs should not be applied within 24 hours of when a large rainstorm is expected, or before a large irrigation. The reasoning behind this is to not wash recently applied fertilizer out of the root zone.

Soils are susceptible to nitrogen leaching during non-cropped periods. Many vegetable crop fields are left fallow for a period during the fall and winter, which is when the majority of our rainfall occurs. Any nitrogen remaining in the soil during that period is subject to leaching. Where appropriate and economically practical, cover crops are recommended for use on non-cropped or fallowed lands during these periods.

Method of Application

Proper placement of fertilizers will help to ensure that more nutrients are available to a crop during periods of maximum growth. Therefore, the application of fertilizers should be by a method designed to deliver it to the area of maximum crop plant uptake. The idea is to position and concentrate the fertilizer near the majority of the crop roots, instead of leaving it spread out over 100 percent of the field. This practice would include either placing fertilizer on the seed row and watering it in, knifing fertilizer near the seed row, or broadcasting fertilizer and then listing it up into the bed.

When applying fertilizers, applicators should take special care to be sure that application valves are shut off during turns and that equipment be properly calibrated to insure even applications at proper agronomic rates. Growers should be sure to maintain ongoing safety and environmental education training programs. All wells connected to an irrigation system equipped for fertigation need to be protected against fertilizer flowing back into the well. Vacuum relief valves, low pressure drains, air gaps, interlocking circuits between the irrigation pump and the injection pump, and check valves installed between the pump discharge pipe and injection point can all be used in some combination to prevent backflow.

Irrigation

Deep percolation and nutrient losses can be minimized by monitoring crop and soil conditions to determine when to irrigate, and replacing the water that has been depleted since the last irrigation. Operating irrigation systems accurately can provide adequate water for maximum crop production without removing plant nutrients from the root zone. Therefore, the application of irrigation water should be timed to minimize water and nitrogen loss by leaching and runoff. However, providing adequate irrigation water for the evaporation and transpiration losses must be integrated with other requirements, such as leaching of excess salts.

Growers must be able to accurately determine crop water use through plant and soil water measurements or by estimations based on weather data. Any irrigation scheduling technique must recognize crop-specific soil moisture requirements.

Organic Materials

Numerous types of organic materials may be incorporated into the soil. These include incorporating crop residues, cover crops, various types of manures, sewage sludge or compost. Incorporation of organic matter can improve soil physical conditions and stimulate beneficial microbial activity. Organic materials also contain organic forms of nitrogen which can be mineralized into ammonium and eventually nitrate, both of which can serve as plant nutrients for succeeding crops. When organic materials are added to soil, consideration must be given to the amount of nitrogen applied as well as the release times. The rate of release can be highly variable, depending on types of organic material. Normally the release of inorganic N is relatively slow so that high mineral N concentrations in the soil does not occur.

Application of some forms of organic matter may also pose hazards. Sewage sludge may contain significant concentrations of undesirable trace elements, depending on the source of the sludge. Animal manures tend to have fairly high concentrations of salts. Composted green waste from urban areas may contain pesticide residues or weed seeds, depending on the source of origin or composting procedures. Disposal of urban organic wastes on agricultural lands is a rather recent phenomenon and comprehensive evaluation of this practice is in the developmental stages. Growers should be aware of current EPA standards in the use of wastes and should maintain appropriate records of amounts of wastes used and ongoing testing, in case of future problems.

MANAGEMENT/RISK ASSESSMENT WORKSHEET

Complete the following Nutrient Management Worksheet and Good Nutrient Management Checklist.

<u>Nutrient Management Worksheet</u>

A. Soil and/or plant tissue analysis. If you do not use soil or plant tissue analysis, insert "0". If either soil or plant tissue analysis is used to guide N application, insert "1". If both soil and plant tissue analysis are used insert "2". __________

B. Frequency of fertilization application. If total crop requirement is made on one application, insert "0". If N is split into two applications, insert "1". If N is split into more than two applications, insert "2". __________

C. Fertilizer placement (Row Crops). If fertilizer is broadcast on land, insert "0". If fertilizer is broadcast and then listed into bed, insert "1". If N is banded or knifed into row crop bed, insert "2". __________

D. Foliar N application. If your crop is conducive to foliar N application and some is applied in that manner, insert "1". __________

E. Cover crops. If your field will be fallow for a few months during the rainy season and you do not utilize cover crops, insert "0". If your field will remain fallow during the rainy season and you do plant a cover crop, insert "1". __________

F. If you apply much of the nitrogen in the fall before the rainy season, insert a "minus 1" (-1). __________

G. If considerable organic crop residue is left on the field or you apply organic matter and the N in the organic matter is accounted for in assessing the need for fertilizer application, insert "1".

____

H. If you use CIMIS or other irrigation scheduling guidelines, insert "1". _________

Total the numbers for the above 8 items. A high number indicates a high level of nutrient management to minimize leaching to groundwater.

Any irrigation or nutrient management practice you institute to reduce nitrate leaching should be accompanied by a reduction in total N application. In other words, you now only need to supply the crop need - not the crop need plus that which was previously leached below the root zone.

<u>Good Nutrient Management Checklist</u>

The following are practices which should be instituted where applicable. Insert "N/A" if it is not applicable to your situation. Remember to explain in your written management plan why that practice does not apply to your operation. Place a check for items you are doing. Place a "0" if you are not following the practice and work toward replacing "0" by a check mark. You should note in your written management plan how you are working towards implementing a recommended practice.

A. Handling Fertilizer Materials

1. When transporting fertilizer, do not overfill trailers or tanks and cover or cap loads properly. _________

2. Avoid spills when off-loading fertilizer into on-farm storage or into fertilizer applicator. _________

3. All storage facilities are properly maintained and protect from weather. _________

4. Clean up fertilizer spills promptly. _________

5. Shut off fertilizer applicators during turns and utilize check valve. _________

6. Maintain proper calibration of fertilizer application equipment. _________

7. Distribute rinse water from fertilizer application equipment evenly through the field. _________

B. Use of manure and other Organic Materials

1. Consider nitrogen applied with the organic material in your overall N application requirement. __________

2. Consider mineralization rates of your organic material to determine time of nitrogen availability. __________

3. Incorporate organic material into soil. If added avoid excessive erosion of the material. __________

C. Nitrate in Irrigation Water

1. If your irrigation water has significant concentrations of nitrogen, consider that it is providing some of the crop need. __________

If the total Hazard Index value is 6 or greater, there is a high potencial for groundwater degradation by nitrates from your operation. This situation requires implementation of management practices to minimize the hazard. using the Nutrient Management Worksheet, the Good Nutrient Management Checklist, and other information you may acquire as reference, write a detailed management plan that you will follow to protect groundwaters from nitrate degradation. The managment plan should include record keeping of all activities such as amount and time of fertilizer application, results of soil or plant analysis, etc.

<u>**SECTION III**</u>

IMPLEMENTATION

Each farm must complete a Hazard Index and Management/Risk Assessment Worksheet for each cropping unit. The Hazard Index will determine which classification (or tier) the farm site will fall under. Within each tier, the following items will be required of the grower:

Tier #1: Low Risk

Requirements:

- Complete a Hazard Index Form.
- Complete a Management/Risk Assessment Worksheet and Good Nutrient Management Checklist.
- Keep worksheets on site.
- Complete an annual program review.

Tier #2: High Risk

Requirements:

- Complete a Hazard Index Form.
- Complete a Management/Risk Assessment Worksheet and Good Nutrient Management Checklist.
- Complete a written plan with an explanation of strategies for improvements in nutrient management.
- Maintain a written copy of this plan on site for review by the SWRCB
- Complete an annual program review.

Problem Areas (where a recognized water body has been declared impaired)

Requirements:

- Complete a Hazard Index Form.
- Complete a Management/Risk Assessment Worksheet and Good Nutrient Management Checklist.
- Write a plan of BMPs used.
- Document corrective measures to be implemented towards improving current practices to be kept on site.
- Written records of education programs.
- Monitor program throughout year.
- Complete an annual program review.

The implementation of this program can be completed by a proactive cooperative effort between agriculture and the regulatory community. However, institutional changes should be addressed and implemented to create a system that can address the problem of nonpoint source pollution in a cost effective manner.

INSTITUTIONAL CHANGES

Nutrient management is a simple concept when seated in front of a computer with values for each nutrient source (soil, water, liquid and solid nutrient amendments). However, the usefulness of the computer exercise depends on the precision of the data used. There are no existing agencies (regulatory, technical or educational) that can fully provide such services or even educate those in allied industry who will provide the services.

Requirements for nutrient management plans generates two questions:

1) Who will write the plans? and

2) Who will review the plans?

The answers to these questions will suggest needed institutional changes.

Currently, certified professionals who provide services to growers may write these nutrient plans. Growers can certainly do their own plans, but can also opt to have a consultant provide the plans.

It is not in the scope of responsibility for the staff of the Natural Resource Conservation Service (NRCS) or the University of California Cooperative Extension Service (UCCE) to provide such services. However, these individuals should be actively involved in the education process and where they have the resources to provide growers with management recommendations do so.

Details needed for a nutrient management plan must be accessible. At this time, there is information in parts of the state related to specific crop nutrient needs that can be useful in other parts of the state. UCCE Farm Advisors, growers, and seed companies have accomplished tremendous amounts of research over the years. Unfortunately, there is no central clearinghouse where individuals can go to get specific information. This information is especially important for specialty crops. Research needs to be summarized (if completed) or designed to answer questions related to nutrient uptake, availability and potential leaching under different conditions in California. Previously accomplished research may behold answers to nutrient use efficiency.

The committee does not recommend any major change in institutions but recommends a change in focus. The SWRCB is responsible for the nonpoint source pollution control. Inasmuch as nonpoint source pollution can only be reduced through land management, the SWRCB should focus on monitoring management practices. We propose that the SWRCB be responsible for preparing and distributing all materials relevant to the preparation of the mandatory hazard index and management/risk worksheets. Furthermore, RWQCB should monitor and evaluate the completion of the management plans. If adequate authority for requiring the completion of a hazard index, management/risk assessment worksheet, or management plan does not exist, then the SWRCB/ should obtain that authority. It is recognized that the Board does not have authority to enforce the implementation of any given management plan. Nevertheless, they have the opportunity to encourage effective management by reviewing the proposed management plans. If effective management is not voluntarily adopted by the agricultural community, it may become necessary in the future to seek broader-ranging enforcement authority through the appropriate legislative procedures. The Committee, however, with the exception of one member (see Attachment I), does not recommend broader regulatory authority at this time.

EDUCATION

The Committee is unanimous in agreeing that the education of all players (growers, allied industry, technical and financial assistance personnel, etc.) is the key to the success of nutrient management plans. There needs to be a commitment from individuals, grower organizations and other agencies for this to work effectively.

Increasing the farmers' awareness of the importance of BMP-based nutrient management plans is essential to making changes in current fertilization practices. "Grower friendly" educational program that farmers can attend and benefit from should be designed and implemented. Aside from the regulatory compliance requirements that BMPs fulfill, BMPs are a very viable cost saving tool that growers should utilize. As growers become more aware through proactive efforts, they will be more fully utilized by growers.

The Committee recommends that the State Water Board advocate greater nutrient management education programs. Farming organizations such as the Farm Bureau, California Alliance of Family

Farmers, U.C. Cooperative Extension, Fertilizer Research & Education Program, Agricultural Commissioners, Soil Conservation Service as well as Grower Shipper Association, California Fertilizer Association and other industry based entities should participate in the planning and implementation of educational programs.

The Committee recognizes that the preparation of the hazard index and management/risk assessment worksheets, and if necessary development of a detailed nutrient management plan are educational activities. Each farmer becomes aware of potential for nitrate pollution from his/her agricultural operation, along with guidelines for mitigating the pollution. The necessity to complete these forms will provide an inducement for farmers to seek additional information. Thus, educational activities presently in place may be more actively sought out by farmers. For example, UC Cooperative Extension farm advisors can develop workshops to comply with farmer demands. Many farmers may seek professional consultants, so there will be an incentive for the development of a professionally competent consulting profession. Indeed, the profession may pose standards for competency in their profession.

Additional comments regarding educational activities are included in an attached minority report (Attachment II).

ENFORCEMENT

The committee recommends that the current status of the program using voluntary implementation by growers be maintained at least until the state has developed and made available to all growers, Best Management Practices sensitive to the diversified nature of California's agriculture.

As stated earlier, this committee believes that as the agronomic, economic as well as environmental benefits of improving management practices become better known and understood by growers, they will be utilized extensively. The committee believes that the state would be better served to increase the education available to growers to address this problem thereby eliciting a positive action by growers to correct problems, than it will by using negative incentives to force growers to take minimum actions to meet agency mandates. As a result, the committee recommends that no new negative incentives be implemented in the development of this program. The Committee strongly recommends, with the exception of one member (see Attachment I), the State Water Board to adopt a positive incentive based program to implement its nonpoint source pollution program, and not move towards the traditional negative fees and penalties type programs of the past that result in antagonistic rather than cooperative relationships between the regulatory community and the private sector it's supposed to work with. Other agencies like the State Air Resources Control Board have adopted this strategy of a strictly positive incentive based program, without any fees or penalties, to implement the U.S. EPAs Federal Implementation Plan for the reduction of air pollutants. We believe that the State Water Resources Control Board should adopt the same type of proactive cooperative program.

SECTION IV

CZARA EVALUATION

In developing management measures (general goal statements) for reducing nonpoint source pollution from nutrient sources, the committee considered the management measures listed in the CZARA guidance along with others developed in the western region. These included those listed in the Arizona Environmental Quality Act of 1986 and the recommendations of the Nitrate Working Group to the California Department of Food and Agriculture. The management measures from the three sources are similar in that they all consider refinement of fertilizer application to meet crop needs in quantity, timing, and placement. The California report was deemed to be most appropriate because it evaluated nitrate pollution in groundwater in California and offered solutions specific to the conditions of California. The committee adopted the six management measures recommended in the California report an included two additional measures. These additional measures deal with irrigation management and use of nonsynthetic fertilizers (green wastes, manures, etc.).

The management measures selected by the committee are in conformity with the (g) guidance because it includes all of the elements of the guidance and goes beyond by including other control measures. The additional control measures include storage management, irrigation management, and management of non-synthetic fertilizers.

APPENDIX III
FINAL LIST OF STAKEHOLDER/INTEREST GROUPS

The TAC initially listed nearly 35 stakeholders. During the process of identifying interests, the list was reduced to 17 stakeholders. All stakeholders listed in the brainstorming process may be found in Appendix II. The interests which were ascribed to identified stakeholders are listed below:

1. **FARMERS -** Survival, productivity, independence, image-taboos, maximize profit, healthy environment, competitiveness, stewardship, minimize red tape, global, optimize benefits, fairness, sensibility, sustainable ag., control own business, education, ag systems integration, technical assistance, management decisions, PR outreach.
2. **WATER DRINKERS** -Health, taste, cost, availability, quality.
3. **SUPPLIERS (NUTRIENTS)** - Profit, livelihood, customer satisfaction, education, control product quality, QA/QC, independence, OSHA, stewardship of the environment, minimize red tape, image competitive, local economy, job security, management decisions, liability.
4. **CROP ADVISORS** - Education, information, liability, competitiveness, land sustainability.
5. **LAND OWNERS** - Property rights, value (land), liability, stewardship, profit, neighbors, minimize red tape, independence.
6. **REGULATORS** - Economic feasibility, enforceable standards, regulations and measures, protect beneficial uses, worker health/safety, maintain water quality, right of enter/monitor/inspect, PR, education, outreach, funding sources, valid data, fairness, equity, fish & wildlife, air quality, sustainability, water quality, habitat, environment, recreation.
7. **TRANSPORTATION INDUSTRY -** Profit, regulatory compliance, good roads, liability.
8. **EDUCATORS -** Objectivity, convey facts, quality info, research grants, receptive audience.
9. **GENERAL PUBLIC -** Water quantity/quality, health, safety, recreation, food (affordable), air quality.
10. **MUNICIPALITIES** - Regulations, marketplace, profit, public acceptance (good PR), avoid liability, minimize red tape.
11. **FARM LABOR -** Local economy, job availability, health/safety, quality of life, water quality/quantity.
12. **ENVIRONMENTAL ADVOCATES -** Sustainability, land use control, protect natural resources, air quality, ecosystem management, water quality/quantity, watershed management, biodiversity, habitat, population growth control, increased/tougher regulations, enforceable standards, accountability, citizen involvement, funding, economic considerations, education.
13. **EQUIPMENT MANUFACTURERS -** Economic feasibility, R & D, market

research, profit, regulatory compliance, worker safety/training.

14. **BANKERS** - Environmental compliance, security interests, regulatory compliance, liability, compliance monitoring, profit, image, clear/objective regulations.
15. **WATER PURVEYORS** - Liability, regulatory compliance, standards, funding monitoring, water quality/quantity, customer satisfaction, bn\eneficial uses.
16. **MANUFACTURERS** - Regulations, disposal, by-product utilization, profit, liability, R & D, market availibility, minimize red tape, local and gobal pressure, economic distribution.
17. **POLITICIANS** - Re-election, funding, represent constituency, positive change.

APPENDIX IV
BEST MANAGEMENT PRACTICES RESOURCE CITING

Arizona Environmental Quality Act, Arizona Department of Environmental Quality, 1986

Best Management Practices For Cool Season Vegetable Production in Coastal Regions of California, Stuart Pettygrove-Project Lead, University of California, Davis, 1994

Combining Water and Fertilizer Management for High Productivity, Low Water Degradation, Letey, Pratt, and Rible, California Agriculture, 1979

Guidelines for Protection of Water Quality at Retail Fertilizer Facilities, California Fertilizer Association, 1988

Nitrate and Agriculture in California, California Department of Food & Agriculture, 1989

Nitrate in Drinking Water, State Water Resources Control Board, 1988

Our Priceless Water, California Farmer, 1994

Western Fertilizer Handbook - 8th Edition, California Fertilizer Association, 1994

ATTACHMENT A

Minority Report of Al Vargas

For the most part, I am in agreement with the technical aspects of the nutrient technical advisory committee (TAC) report. However, I feel that the report is deficient with respect to institutional reforms necessary to bring about changes in nutrient management and the desired result of improvement of water quality. I do not believe that the committee' s recommendation will succeed at bringing about change in nutrient management as it relies primarily on voluntary implementation and does not propose an enforceable mechanism to ensure implementation. The problem statement and enforceable mechanisms and the policy recommendations which arise are the subject of this minority report.

Problem Statement

Ground and surface water of the state have been impaired by nutrients from irrigated agriculture through leaching and runoff. The actual extent of the impairment may be much greater than currently assessed. The problem has developed to its current state because of lack of an adequate regulatory program and lack of economic consequences from irresponsible nutrient management.

The actual extent of impairment of the water of the state may be much greater than currently defined. Information regarding the extent of impairment is based primarily on monitoring of municipal groundwater drinking supplies. Municipal groundwater wells are generally deeper and less susceptible to contamination by nitrates than private drinking water wells, which are generally shallow and located in rural areas, primarily agricultural. Private wells are, however, generally not monitored as they are not subject to state monitoring requirements. Consequently, the extent of groundwater contamination may be greatly underestimated.

In California nutrients play a lesser role in the impairment of surface water than they do nationwide. This, however, may be due to how impairment is evaluated in California rather than to actual less impairment. Currently, the only guideline for evaluating nitrate contamination in California is the 45 mg/L MCL. This standard is based upon human health concerns. Nitrates may impact surface water long before this limit is reached. The most obvious of these impacts is the growth of aquatic vegetation which may interfere with navigation, recreation, and water pumping operations. Not as readily recognized as an impairment is increased algal production due to elevated nitrate levels. Increased algal production may be detrimental to aquatic systems because they may depress dissolved oxygen, increase turbidity, and restrict light penetration. This will have a negative effect on the aquatic ecology, although it may not be a nuisance to man. Consequently, recognizing other impacts of nutrients to surface water, other than those that pose health hazard to humans or which are a nuisance may result in additional surface water being classified as impacted.

In the 1991 Water Quality Assessment Report, sewage treatment plants, industrial, urban runoff, and land disposal accounted for approximately 15% of the impairment to streams and rivers. Nonpoint sources of pollution accounted for the remaining sources. Agriculture alone accounted for 50%. With respect to groundwater, nutrients accounted for more than twice the impaired ground water than non-pesticide organics. Despite the contribution of nonpoint sources to impairment of streams and rivers, regulatory programs and resources are focused primarily on point sources of pollution. Additionally, the existing regulatory framework is designed for controlling point sources and does not deal adequately with nonpoint sources.

The committee explored, to a limited extent the use of positive incentives, such as pollution credit trading as a means to manage nutrient water pollution. However, no situations were identified where this mechanism could be used. A tier tax was proposed for nitrogen fertilizers to discourage excessive nitrogen application (in excess of that required for optimum crop yield), however this suggestion was rejected by the TAC. Currently, the only deterrence to excessive nitrogen application is dictated by the crop. For a small number of crops (e.g., grapes and sugar beets) excessive nitrogen application results in decreased yields and thus an economic incentive exists for responsible nutrient management.

For the majority of crops, however, excessive nitrogen application does not result in reduced yields. In fact the cost of additional fertilizer (in excess of what is required for optimum yields) is so low in comparison to the cash value of the crop that growers are likely to over apply in order to ensure maximum yields. Therefore, an economic incentive is necessary as a means to encourage responsible fertilizer use.

Agriculture is unique from all other industries in that it is not held accountable for most of the pollution it causes and thus, there is no economic consequence. For example, agriculture does not remediate or pay for the ground or surface water it contaminates with pesticides or nitrate. Currently those that bear the consequences of ground water pollution by agriculture are the citizens of the state primarily those in rural communities as they loose a source of drinking water or must pay higher rates to treat. Accountability for the pollution and linking an economic consequence with irresponsible nutrient management would probably result in a change in practices. As a start an exchange program of water supplies should be instituted. This was adopted by the TAC but deleted from the final report.

Enforceable Mechanisms

The TAC felt that the obligation to complete the risk assessment (Hazard Index and Nutrient Management Worksheet) and the nutrient management plan (where appropriate) constituted the enforceable mechanism. I felt this did not go far enough because it did not ensure the implementation of the "Best Management Practices"

(BMP) outlined in the nutrient management plan without implementing the BMPs would result in no improvement with respect to mitigating nutrient pollution. Therefore, the enforcement must be directed at enforcing adoption of BMPs. The strategy would still call for a self directed program the allowed the grower flexibility with respect to selection of BMPs that are most suited for his operation. Enforcement would only be used in situations of non-compliance. Under current state law the State Water Resources Control Board and the California Regional Water Quality Control Boards can not enforce implementation of BMPs (Porter-Cologne Water Quality Control Act Section 13360). Therefore, legislative initiative would be required to provide the regulatory agencies with this power.

Policy Recommendations

There are a number of policy recommendations that arise from the above discussion. These are enumerated as follows:

1. Define extent of groundwater impairment by focusing on shallow, rural water supply wells which are the most susceptible to be impacted by nitrates.

2. Develop criteria for nitrates in surface water. Such criteria would go beyond human health hazards and nuisance to man and would recognize detriments to the aquatic system from elevated nitrate levels.

3. Re-evaluate resource allocation for water quality regulation. The allocation should be in relation to areas that would have the most impact in improving the water quality of the water of the state. These would be nonpoint sources and agriculture in particular.

4. Institute a tier tax on fertilizers. This tax would apply only to units of nitrogen fertilizer greater than those required for optimum yields. Thus only growers which apply nitrogen fertilizer of excess of what is needed would be subject to the tax and would have no negative economic impacts on growers who are responsible nutrient managers.

5. Institute exchanges of water supplies between irrigation districts with good quality surface water supplies and communities with contaminated groundwater. This exchange would be mutually beneficial. Agriculture would benefit because growers would apply less nitrogen fertilizer and thereby increase profit margins. One-acre foot of water containing 10 mg/L nitrogen as nitrate would supply 27 pounds of nitrogen per acre.

6. Seek legislative authority to enforce BMP implementation. Current law does not allow for specifying the manner of compliance with the exception of land disposal facilities and deep well injection. In the case of nonpoint source pollution, BMP enforcement would be appropriate since this is the only method by which the results can be achieved.

7. Develop a nonpoint source control strategy apart from the point source strategy. As was noted in the "Background" section of the TAC report, the current nonpoint source strategy was adopted from a regulatory framework developed for regulating point discharges. This system does not lend itself to many nonpoint sources, since discharges can not be monitored. Therefore, a new framework is needed for dealing with the primary source (nonpoint source) of impairment of the state's water. This framework should include authority to enforce BMPs.

ATTACHMENT B

November 21, 1994

TO: Plant Nutrient TAC Members
FR: Jill Klein, Community Alliance with Family Farmers Foundation
RE: Minority Nutrient TAC Report

Because my point of view is not reflected in the October 6 Draft Nutrient TAC Report, I am submitting this minority report to provide another perspective on how to reduce nitrates in groundwater.

The Nutrient TAC Report does not approach farming as an integrated, biologically based system, but rather reduces farming into separate components. Though looking at these components (soil, nutrients, water, plants) is useful for purposes of analysis, they need to be treated as a whole when developing management plans to improve nutrient cycling in complex farming systems.

Healthy soil is at the heart of a biologically managed farming system. Soil is host to a broad variety of micro flora and fauna in addition to the micro and macro nutrients which immediately feed the plant. Carbon-based soil fertilizers and amendments feed soil biota which are important to the turnover and longterm availability of nutrients. Cover crops play a variety of important roles in this system, from fixing atmospheric nitrogen (if legumes) to adding organic matter to the soil to providing food and habitat for beneficial insects. Proper management of cover crops is important to realizing their full benefit while minimizing potential negative impacts such as nitrate leaching. Composted manure, if properly made, provides a stable form of nitrogen and enhances overall soil health. Thus, soil should be viewed as more than a medium for holding a plant which can be spoon fed with water and synthetic nitrogen through drip irrigation and fertigation. What farmers really need is a menu of options that can fit into a whole systems approach to reducing overall chemical fertilizer and pestcideuse.

If the value of looking at the whole farming system were better appreciated, then TAC members might share my frustration that the Nutrient TAC has not been integrated with the Pesticide TAC Report; something we had agreed to do in one of the first meetings. Additionally, for implementation of whole systems approach to be successful at the farm level, the report must include a technical support program for growers to assist them in adopting proven alternatives to their farm. This is critical if any of the practices recommended by the Nutrient TAC are to be implemented broadly. Following is a discussion of where the current Report falls short, evidence for why an alternative approach is called for, and a description of a successful chemical fertilizer and pesticide reduction program.

Shortcomings of the Nutrient TAC Report

In one of our original meetings, we decided to work closely with the Pesticide TAC, particularly in the final stages of developing the report. I am dismayed that this consensus decision was never acted upon. Research has demonstrated direct correlations between high levels of applied nitrogen and an increased incidence of pests and disease (e.g. Ieafhoppers in grapes and brown rot and hull rot in stone fruits, respectively). By looking at the whole farming system and how fertility management can influence other elements we can develop more appropriate solutions.

Many in efficiencies occur in the use of synthetic fertilizers and pesticides; changing these practices can be achieved with sticks in the form of tighter regulations or carrots in the form of carefully developed incentives programs. The Nutrient TAC Report takes a third approach, creating additional paper work for growers without either the carrot or stick to insure action. Thus, without any provisions for enforcement or technical support in the Nutrient TAC Report, there is little reason to believe that growers will take the time to fill out more paper work, much less actually change their practices.

Furthermore, the current Report lacks a strong education component, leaving growers with little or no information or incentive to experiment with alternatives. For example, in Recommendations, it is stated that growers will need to "develop a management plan to minimize their contribution to water degradation." Growers who score a 6 or higher on the Hazard Index must develop written strategies to further control the problem. A strong education component is key to these recommendations actually being implemented. It has been my experience that focusing education and resources on technical advice which provides viable options gives growers an incentive to change their practices. It is not enough of an incentive to know that Best Management Practice's (BMP's) are cost saving tools, as stated in the document. Nitrogen fertilizer is relatively cheap, and more carefully timed applications may even be more expensive. In fact, if BMP's are so cost effective, then why aren't more growers already implementing them?

Management options which have multiple benefits, even if they cost a little more, are better than those which provide a singular solution to a problem. As an example, I will describe a recent field day I helped to organize in the Salinas Valley. More than 110 farmers and others in ag-related business were in attendance to tour an on-farm composting operation. One reason the farmer whose operation we visited gave for using compost on his 700 acre vegetable farm is its nitrogen contribution. His compost contains 1.6% total nitrogen; when applied at 5 tons/acre, it yields 160 Ibs N/acre. During this discussion, the local farm advisor reported that his findings revealed that only 5% (8 Ibs) of the nitrogen is in a leachable form (nitrate), the rest is in a slow release form. The compost also contains 5.4% calcium, which is comparable to the amounts applied as lime or gypsum when used as a soil amendment to improve soil structure and water infiltration. In addition to the benefits of slow release nitrogen (there was sufficient N for a crop of peppers 4 months after application) and calcium, the compost also supplies other macro and micro nutrients, beneficial soil microorganisms, and organic matter. Since switching to compost as his primary fertilizer, this grower reports that he no longer has problems with soil borne pathogens and that his crop is healthier and less susceptible to insect damage. Consequently, he has sharply reduced nitrate leaching and pesticide use.

Evidence for an Alternative Approach

There is emerging evidence that organic sources of nitrogen such as leguminous cover crops can act as a slow release nitrogen, although this issue was disputed by members of the committee. Research conducted at the University of California - Davis, has shown that leguminous cover crops can fix up to 200 Ibs of nitrogen/acre/year (Miller, et al., 1989). After the first few years of using a cover crop, it seems that the soil comes to a new equilibrium where organic forms of nitrogen are less likely to leach. Additional research which compared conventional, low input, and organic farming systems corroborates this theory (Temple, et al., 1993). The organic system included the annual incorporation of a leguminous cover crop over a five year period. After the fifth year of the experiment, researchers reported that:

> In the organic system, N03 levels were very low early in the season and steadily increased to 8-10 ppm by mid-May. Both N03 and NH4 levels were considerably lower in organic soils. . . This changing pattern in the organic soils may reflect long-term changes in soil microbiology and N dynamics that have occurred during the transition from fertilized to organic management. . . Fertility, microbial and nematode soil data suggest that significant differences exist between organic and conventional systems in microbial ecology, resulting in different available nitrogen levels. Higher microbial activity and biomass linked to lower available nitrogen in the organic system suggests that there was more efficient N use and possibly less potential for N03 percolation loss from the surface soil. Although the petiole data showed much lower petiole N03 in the organic plants, this did not translate to reduced yields, suggesting that the petiole test cannot be used to assess plant fertility status on organic systems when based on sufficiency/deficiency criteria established for fertilized systems. The results also indicate that currently recommended tissue nitrogen levels may exceed actual plant nitrogen requirements in conventional systems.

Building in a Technical Assistance Program

Based on these alternative options for sources of nitrogen which are not leachable, propose an expanded education component for the Nutrient TAC Report. This proposal is compatible with a modified evaluation of the growers current practices in the form of a Hazard Index and Risk Management Form. The following plan is based on a program, which I cocoordinate, that has succeeded in recruiting farmers to voluntarily reduce both pesticide and nitrogen fertilizer applications while maintaining the same economic bottom line. This project, known as Biologically Integrated Orchard Systems, or BIOS, is designed as a three-year information and technology transfer pollution prevention program for reducing synthetic nitrogen fertilizers and pesticides used in California crop production, thereby reducing contamination of surface and ground waters.

The project establishes on-farm demonstrations of University research and farmer-developed production systems, allowing growers to adapt new methods which reduce their reliance on farm chemicals. The broader farm community is made aware of these practices through field days, frequent update mailings, and the publication of document describing the practices being demonstrated. Continuation of the project's goals will be assured through active involvement of commodity boards, U.C. Cooperative Extension, USDA - ASCS and SCS and local Resource Conservation Districts.

Specific components of the program include: 1) training farmers and their agricultural consultants to use techniques including the use of cover crops, targeted release of beneficial insects, and careful monitoring of pest and beneficial insects; 2) developing a customized management and monitoring plan for each parcel enrolled in the program; 3) conducting facilitated monthly meetings in which beginning and experienced practitioners collaboratively solve problems; 4) organizing on-farm demonstrations of techniques and methods; 5) monitoring, organizing and interpreting field data; 6) publicizing the methods used by BIOS growers to the greater grower community. BIOS also recruits local representatives from key government agencies, as well as from the commodity boards, to serve as an ongoing source of information and support for farmers not enrolled in the program who are a BIOS-style farming approach.

The BIOS management team oversees all elements of the program, including creation of farm management plans and monitoring protocols, providing technical support to farmers in the program, and making presentations at BIOS field days. The management team includes representatives from the University of California extension service and researchers, farmers, professional PCAs and program coordinating staff. Currently, CAFF Foundation provides overall administration and coordination for BIOS.

BIOS creates opportunities for cooperation between various state and federal agencies whose mission includes concern over the use of farm chemicals. This program is designed to support institutionalization of the biologically integrated approach to achieving source reduction in agriculture. In order to further extend the impact of the program, BIOS is forming a local advisory committee, including participation from the local farm extension, county agriculture commissioners, ASCS, Resource Conservation Districts (RCD), SCS and representatives from appropriate commodity boards, to serve as an ongoing source of information and support for farmers wishing to reduce their use of leachable nitrogen and pesticides by adopting BIOS style techniques. Working with commodity boards will provide an opportunity to reach out beyond the circle of "innovative" farmers interested in finding new ways to farm, and into the larger mass of conventional growers. The advisory committee can continue this technical support network at the conclusion of the three-year pilot program.

Resources for coordinating this kind of program could come from the fertilizer industry and commodity boards who share in the interest of improving water quality in the state. The State Water Board could help with many aspects of the project's coordination.

It may be that some of the information provided here does not sit well with the representatives of the fertilizer industry and others who sit on the TAC, but it is important in recognizing the direction this TAC should be going. I think it is more realistic that the TAC look at whole systems instead of components; that growers have many options instead of few; that we encourage naturally occurring biologically based systems of fertilization and pest management instead of synthetic sources; and that we encourage an incentives-based technology transfer approach. I believe that if the report does not include these recommendations we will not be living up to our commitment to provide farmers with viable solutions to the problems we identified at the outset .