

Conclusions of the Agricultural Expert Panel

Recommendations to the State Water Resources Control Board pertaining to the Irrigated Lands Regulatory Program

in fulfillment of SBX 2 1 of the California Legislature

September 2, 2014 draft v3



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Editing and organization by: Irrigation Training & Research Center (ITRC)
September 2014

EXECUTIVE SUMMARY

The Agricultural Expert Panel (Panel) was convened to address thirteen questions posed by the State Water Resources Control Board (State Water Board). The questions were primarily technical in nature, and are abbreviated below. The full text of the questions is included in *Section 2: Questions for the Panel*.

Questions Posed to the Expert Panel

1. How can risk to or vulnerability of groundwater best be determined in the context of a regulatory program such as the Irrigated Lands Regulatory Program (ILRP)?
2. Evaluate and develop recommendations for the current approaches taken to assessing risk to or vulnerability of groundwater.
3. How can risk to or vulnerability of surface water best be determined in the context of a regulatory program such as the ILRP?
4. Evaluate and develop recommendations for the current approaches taken to assessing risk to or vulnerability of surface water.
5. What management practices are expected to be implemented and under what circumstances for the control of nitrogen?
6. What management practices are recommended for consideration by growers when they are selecting practices to put in place for the control of nitrogen?
7. Evaluate and make recommendations regarding the usage of various nitrogen management and accounting practices.
8. Evaluate and make recommendations regarding the most effective methods for ensuring growers have the knowledge required for effectively implementing recommended management practices.
9. What measurements can be used to verify that the implementations of management practices for nitrogen are as effective as possible?
10. Evaluate and make recommendations regarding the usage of various verification measurements of nitrogen control.
11. Evaluate the relative merits, and make recommendations regarding the usage of, surface water measurement systems derived from either receiving water or a discharge monitoring approach to identify problem discharges.
12. Evaluate and make recommendations on how best to integrate the results of the Nitrogen Tracking and Reporting System Task Force with any above recommendation regarding management practices and verification measures.
13. Evaluate and make recommendations on the reporting requirements to report budgeting and recording of nitrogen application on a management block basis versus reporting aggregated numbers on a nitrate loading risk unit level.

General Understanding by the Panel

The Panel reviewed a large volume of material from various coalitions, regional boards, agricultural groups, environmental groups, and other organizations. The Panel also received valuable input throughout the process in the form of both written and verbal testimony and critique. The Panel recognizes the tremendous efforts that have been made historically in attempts to understand and begin to regulate groundwater nitrate problems – which were the major focus of this Panel’s efforts.

Having benefited from the ability to view the regulatory process in hindsight, and without being burdened by the weight and bruises of historical battles on the subject, this Panel believes that the State Water Board has reached an opportune moment to optimize efforts by shifting the emphasis of regulatory efforts and energy.

The Panel recognizes and agrees with the need for regulatory actions to protect drinking water quality. The Panel also believes that the primary future source of nitrate additions to the groundwater will be via agricultural fields. [Q1] The fundamental reason for the emphasis shift lies in the word “future”.

It appears to the Panel that many of the proposed regulatory efforts and investments are related to better understanding the regulatory value itself – which is high nitrates in groundwater. The Panel observes that proposed regulatory monitoring and research puts a large emphasis on understanding the characteristics of how the nitrate moves into first-encountered groundwater, how the groundwater moves, and how nitrate levels in the groundwater might be tied to surface discharges. [Q3]

The Panel sees that emphasis on groundwater studies as being reactive, rather than being proactive. The facts are: [Q9]

1. What is seen in the groundwater today is, by nature, the result of history. It does not necessarily indicate the impacts of current farming practices.
2. The nitrate levels in groundwater, while providing a regulatory trigger, will be merely symptoms of surface (e.g., farming) practices.
3. Attempts to completely understand the groundwater and vadose zone characteristics and movement, plus the associated nitrate movement, are extremely expensive, inexact, and do little to solve the problem.

The Panel therefore proposes a comprehensive regulatory program that is proactive. [Q9] It focuses on efforts to minimize the loads of nitrates to the groundwater, without trying to understand all the details of the groundwater itself. [Q10] There are several over-riding principles that have guided this Panel’s development of a recommended program:

1. This is a non-point-source pollution problem, which requires a significantly different approach than historical State and Regional Water Board programs that have focused on point-source problems. This is discussed in more detail in the body of this report
2. Good nitrate management is essential across the board for agriculture, and should not just be restricted to areas that presently have high levels of detected nitrate in groundwater. [Q5]

3. Nitrate does not move below the crop root zone unless water deep percolates. The mechanism of nitrate transport requires water. Therefore, good irrigation management is an essential part of the solution. [Q6][Q10f]
4. The whole process of nitrate leaching by irrigation and rain water is extremely complicated, has a variety of poorly or uncontrolled aspects (such as timing and amounts of rainfall), and will require active participation by, and innovation from, the agricultural community. There is a definite social aspect to this regulatory program. [Q6]
5. If more nitrogen is applied to a field than is removed, over the long term, most of the excess nitrogen applications will be leached to groundwater. It is that simple. We do not need models to tell us this. [Q6]
6. As a corollary, there have been decades of demonstrations, research, and practical implementation of practices that reduce deep percolation of irrigation water. [Q10f] The fact that many people (regulatory, academic, and the farming community) are unaware of this historical research and active implementation by progressive farmers does not justify repeating the research to prove that there a link between surface practices and groundwater contamination.
7. The Panel recommends a relatively simple metric to identify progress for this particular regulatory issue. [Q7a][Q9] The reasons for recommending this metric, as opposed to other proxy values or metrics, are discussed in detail in the report.

The metric, to be measured and reported by farmers is the “A/R ratio”, where:

$$A/R = \frac{\text{Nitrogen Applied}}{(\text{Nitrogen removed via harvest}) + (\text{Nitrogen sequestered in the permanent wood of perennial crops})}$$

Where “Nitrogen Applied” includes nitrogen from any source. Example sources are organic amendments, synthetic fertilizer, and irrigation water. [Q4b]

8. Advances can be made immediately. However, it will take many years to develop and implement a complete program. Education and knowledge transfer must be on-going. [Q8] There must be a strong appreciation by the regulating agencies of such facts as:
 - a. Historical university and consultant recommendations for nitrogen applications have focused on maximizing yield, rather than simultaneously minimizing nitrate leaching.
 - b. We do not know the appropriate A/R values to expect under different climate, crop, and other conditions.
 - c. Information of existing A/R ratios is minimal.
 - d. We have not yet even determined how to best measure the nitrogen removed via harvest, for proper reporting of the A/R ratios for a wide assortment of crops.
9. Annual reported values of the A/R ratio have minimal value in evaluating the effectiveness of nitrogen management because of the large seasonal variations in crop yields (removal), precipitation, nitrogen transformations in the soil, etc. However, multi-year averages of the A/R ratio will provide valid information for assessment. [Q9]
10. Sustainable irrigated agriculture requires some leaching of the root zone to remove accumulated salts. Nitrates will of course also be leached along with the salts. Therefore, it is impossible to completely avoid nitrate deep percolation.

The recommended program is summarized on the next page.

RECOMMENDED REGULATORY PROGRAM

The key elements of the recommended regulatory program are:

1. Establishment of coalitions to serve as the intermediate body between farmers and the Regional Boards.
2. Adoption of the A/R ratio as the primary metric for evaluating progress on source control, with eventual impact on the groundwater quality. [Q9]

$$A/R =$$

Nitrogen Applied

$$\frac{\text{Nitrogen Applied}}{(\text{Nitrogen Removed via harvest}) + (\text{Nitrogen sequestered in the permanent wood of perennial crops})}$$

3. Development of a very strong, comprehensive, and sustained educational and outreach program. Such a program will require different materials and presentation techniques for different audiences, such as individuals who may need certification, managers of irrigation/nutrient plans, irrigators, and farmers/managers. [Q8]
4. Creation and implementation of nitrogen/water management plans that are truly plans rather than just a listing of best management practices. These must be customized by features such as crop and locale. [Q5][Q6]
5. Reporting of key values by farms to the coalitions. [Q9]
6. Long-term monitoring of nitrate levels in aquifers to determine trends. [Q9]
7. Targeted research that will directly help the agricultural community to maintain and/or improve yields while simultaneously decreasing the A/R ratio on individual fields.
8. Use of multi-year reported values and monitored trends by the coalitions to inform the agricultural community of progress, to improve understanding of what is reasonable to attain and expect, and to sharpen improvement efforts. [Q9]

LIST OF ABBREVIATIONS

A/R	Ratio of Nitrogen Applied to (Nitrogen Removed + Nitrogen Sequestered in Permanent Wood)
AW	Applied Water
BMP	Best Management Practice
CCA	Certified Crop Advisor
CDFA	California Department of Food and Agriculture
CDPH	California Department of Public Health
CDPR	California Department of Pesticide Regulation
CVRWQCB	Central Valley Regional Water Quality Control Board
DU	Distribution Uniformity
ESJWQC	East San Joaquin Water Quality Coalition
ET	Evapotranspiration
GWPA	Groundwater Protection Area
ILRP	Irrigation Lands Regulatory Program
ITRC	Irrigation Training & Research Center, Cal Poly, SLO
LF	Leaching Fraction
MCL	Maximum Contaminant Level
MPEP	Management Practices Evaluation Program
MRP	Monitoring and Reporting Program
N	Nitrogen
NHI	Nitrogen Hazard Index
NKWSD	North Kern Water Storage District
NMP	Nitrogen Management Plan
NTRSTF	Nitrogen Tracking & Reporting System Task Force
Panel	Agricultural Expert Panel
PCA	Pest Control Advisor
UC	University of California
UCCE	University of California Cooperative Extension
UST	Underground Storage Tank
WDR	Water Discharge Requirements
WQ	Water Quality

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1 BACKGROUND

1.1 *Call for a Panel*

Chapter 1 of the Second Extraordinary Session of 2008 (SBX2 1, Perata), required the State Water Board to develop pilot projects focusing on nitrate in groundwater in the Tulare Lake Basin and Salinas Valley, and to submit a report to the Legislature on the scope and findings of the pilot projects, including recommendations. The State Water Board made fifteen recommendations in four key areas to address the issues associated with nitrate contaminated groundwater. The key areas to address these issues are:

1. Providing safe drinking water
2. Monitoring, notification, and assessment
3. Nitrogen tracking and reporting
4. Protecting groundwater

Recommendation 14 of the State Water Board’s report to the Legislature was to convene a panel of experts to assess existing agricultural nitrate control programs and develop recommendations, as needed, to ensure that ongoing efforts are protective of groundwater quality.

The State Water Board in its subsequent adoption of Order WQ 2013-0101 also tasked the Panel with certain issues related to impacts of agricultural discharges on surface water.

1.1.1 Regulatory Context

The charge and questions below directed to the Agricultural Panel were done so in the context of the State Water Resources Control Board’s Policy for Implementation and Enforcement of the Non-point-source Pollution Control Program, May 20, 2004, and Regional Water Quality Control Boards’ Irrigated Lands Regulatory Programs as implemented through various separate orders.

1.1.2 Charges to the Panel

Assess existing agricultural nitrate control programs and develop recommendations, as needed, to ensure that ongoing efforts are protective of groundwater quality.
(Recommendations Addressing Nitrates in Groundwater, State Water Board’s Report to the Legislature, February 20, 2013)

- and -

Provide a more thorough analysis and long-term statewide recommendations regarding many of the issues implicated in State Water Board Order WQ 2013-0101, including indicators and methodologies for determining risk to surface and groundwater quality, targets for measuring reductions in risk, and the use of monitoring to evaluate practice effectiveness.

1.2 Agricultural Expert Panel

Recommendation 14 of the State Water Board’s report to the Legislature was to convene a panel of experts to assess existing agricultural nitrate control programs and develop recommendations, as needed, to ensure that ongoing efforts are protective of groundwater supply quality. The State Water Board contracted with the Irrigation Training & Research Center (ITRC) to assemble a Panel of up to 10 persons. Recommended Panel types were to include, but not be limited to:

- Irrigation Specialist /Ag Engineer – specializing in irrigation systems including drip, sprinkler, furrow, and flood irrigation systems and the use of fertigation.
- Soil Scientist – specializing in soil conservation, soil fertility management and movement of water and nitrogen through the soil.
- Hydrogeologist – specializing in aquifer contamination and contaminate movement within groundwater.
- Certified Crop Advisor – specializing in the application of synthetic and organic fertilizers.
- UC Cooperative Extension Farm Advisor – specializing in annual and perennial crops.
- Grower – experience in both annual and perennial crops
- Agronomist – specializing in California agricultural production, nitrogen uptake and yields.
- Agricultural Economist – specializing in economic analysis of California agriculture with some experience in the economic analysis of air and water quality regulations.

1.2.1 Role of Panel

The role of Panel members is as follows:

- Review the Irrigated Lands Regulatory Program (ILRP).
- Evaluate ongoing agricultural control measures that address nitrate in groundwater and surface water.
- Evaluate and address other risks to water quality posed by agricultural practices.
- Address questions posed by the State Water Board in its order regarding the petitions of the Central Coast Regional Water Board.
- Address questions developed by an Advisory Committee, other agencies and the public as approved by the State Water Board.
- Propose new agricultural control measures, if necessary.
- Hold meetings with the Advisory Committee as necessary.
- Conduct three public meetings to take public comment.
- The ITRC was mandated to write the final report on findings and summary of project discoveries and recommendations.

The Panel was given no authority or power to write regulations or requirements of any nature.

1.2.2 Panel Members

The Panel was made up of eight members that matched the qualifications requested by the State Water Board. A brief biography of each panel member is provided in **Appendix A**. Members were:

- Dr. Charles Burt (Panel Chairman), Irrigation Engineer, Irrigation Training and Research Center, California Polytechnic State University, San Luis Obispo
- Dr. Robert Hutmacher, Extension Specialist, UC Cooperative Extension, Westside Research and Extension Center, Five Points
- Till Angermann, Hydrogeologist, Luhdorff & Scalmanini Consulting Engineers, Woodland
- Bill Brush, Certified Crop Advisor, Almond Board of California, East San Joaquin Water Quality Control Board, Modesto
- Daniel Munk, Farm Advisor, UC Cooperative Extension, Fresno
- James duBois, Grower, Reiter Affiliated Companies, Santa Maria and Oxnard
- Mark McKean, Grower, Central Valley Region, Riverdale
- Dr. Lowell Zelinski, Agronomist, Precision Ag Consulting, Paso Robles

1.3 Meetings and Sessions

1.3.1 Public Comment Meetings

In May of 2014, the Agricultural Panel called by the California State Water Board held a series of three meetings to invite and hear public comment on nitrate groundwater issues, and to publicly discuss the topic. The Panel was tasked with collecting input and information that centered on 13 previously developed questions that the Panel had been asked to address. Due to the large number of people who wanted to comment verbally, comment duration was limited. Commenting time was truncated by the Chair if they appeared to deviate from the topics that were to be addressed by the Panel.

The meetings were held in San Luis Obispo (May 5-6), Tulare (May 7), and Sacramento (May 9) to facilitate public access. The meeting sessions were videotaped and posted online at www.itrc.org/swrcb/ in accordance with the Bagley-Keene Open Meeting Act.

1.3.2 Work Sessions

Three open work sessions were held at the Cal Poly ITRC (June 9, June 23, July 1) by the Agricultural Expert Panel for the purpose of developing a draft report. Public comments were invited, but were restricted to two minutes per person due to limited time. An additional work session to address comments on the draft report was held at the ITRC on August 20.

1.3.3 Additional Public Input

Written comments provided by the public, as well as the Panel meeting schedule, background information, reports, relevant agency contacts, and other notices were maintained by ITRC on a public website at www.itrc.org/swrcb/. Agendas and speaker lists for all meetings are available on that website at www.itrc.org/swrcb/Presentations/downloads.htm#Agendas.

2 QUESTIONS FOR THE PANEL

The State Water Board provided the Panel with a list of questions. The Panel was instructed that those questions (listed below) were for guidance, and that the Panel could combine answers to related questions, address other questions that the Panel members felt were important, and even question the validity of individual questions or assumptions behind the questions.

2.1 *Vulnerability and Risk Assessment*

Regulatory programs are most effective when they are able to focus attention and requirements on those discharges or dischargers (i.e. growers) that pose the highest risk or threat because of the characteristics of their discharge or the environment into which the discharge occurs. The various ILRP orders issued throughout the state by the Regional Water Boards have taken different approaches in their prioritization schemes, some using specific criteria or methodologies, others utilizing measurements of previous known impacts.

1. How can risk to or vulnerability of groundwater best be determined in the context of a regulatory program such as the ILRP?
2. Evaluate and develop recommendations for the current approaches taken to assessing risk to or vulnerability of groundwater:
 - a. Nitrate Hazard Index (as developed by the University of California Center for Water Resources, 1995),
 - b. Nitrate Loading Risk Factor (as developed by the Central Coast Regional Water Quality Control Board in Order R3-2012-0011),
 - c. Nitrogen Consumption Ratio,
 - d. Size of the farming operation,
 - e. High Vulnerability Areas Methodology (as developed by the Central Valley Regional Water Board in a series of Waste Discharge Requirements issued to agricultural coalitions in the ILRP).
3. How can risk to or vulnerability of surface water best be determined in the context of a regulatory program such as the ILRP?
4. Evaluate and develop recommendations for the current approaches taken to assessing risk to or vulnerability of surface water:
 - a. Proximity to impaired water bodies.
 - b. Usage of particular fertilizer or pesticide materials.
 - c. Size of farming operation.
 - d. High Vulnerability Areas Methodology (as developed by the Central Valley Regional Water Board in a series of Waste Discharge Requirements issued to agricultural coalitions in the ILRP)

2.2 Application of Management Practices

The application and use of management practices for the control of non-point-source pollution is a fundamental approach taken by many Water Board orders, and considered a key element in the State Water Board's Policy for Implementation and Enforcement of the Non-point-source Pollution Control Program, May 20, 2004. Management practices that are cost-effective and are easy to implement have the best chance of being adopted and successful. However, when comparing management practices, consideration should also be given to the likelihood that a management practice will be effective in reducing nitrogen loading to surface and groundwater. The Regional Water Boards have included specific management practices in their various orders, as well as requiring the growers to identify and implement management practices on their own.

5. What management practices are expected to be implemented and under what circumstances for the control of nitrogen?
6. What management practices are recommended for consideration by growers when they are selecting practices to put in place for the control of nitrogen?
7. Evaluate and make recommendations regarding the usage of the following management practices:
 - a. Nitrogen mass balance calculations and tracking of nitrogen applied to fields. This should include consideration of measuring and tracking Nitrogen:
 - i. Applied to crops or fields.
 - ii. In soil.
 - iii. In irrigation water.
 - iv. Removed from field.
 - v. Estimation of losses.
 - b. Templates for determining nitrogen balance.
 - c. The usage of nitrogen balance ratios.
 - d. Nitrogen management plans.
8. Evaluate and make recommendations regarding the most effective methods for ensuring growers have the knowledge required for effectively implementing recommended management practices. Consider the following:
 - a. Required training.
 - b. Required certifications.
 - c. Workshops sponsored by third parties such as: CDFA, County Agricultural Commissioners, Farm Bureau, UC Cooperative Extension, Cal Poly ITRC.
 - d. Usage of paid consultants – e.g., CCAs/PCAs.
 - e. UC Cooperative Extension specialists.

2.3 Verification Measures

Utilization of verification measures to determine whether management practices are being properly implemented and achieving their stated purpose is another key element to the success of a non-point-source control program. Because of the nature of non-point-source discharges, direct measurements are often difficult or impossible to obtain and other means of verifications may be required.

9. What measurements can be used to verify that the implementations of management practices for nitrogen are as effective as possible?
10. Evaluate and make recommendations regarding the usage of the following verification measurements of nitrogen control:
 - a. Sampling first-encountered groundwater via shallow monitoring wells.
 - b. Direct sampling of groundwater from existing wells, such as an irrigation well or domestic drinking water well, near the field(s) where management practices for nitrogen are being implemented.
 - c. Sampling of the soil profile to determine the extent to which nitrogen applied to a field moved below the root zone.
 - d. Representative sampling of a limited area and applying the results broadly.
 - e. Sampling water in surface water containment structures for their potential discharge to groundwater.
 - f. Estimating discharge to groundwater based on nitrogen balance model and measured irrigation efficiency.
11. Evaluate the relative merits, and make recommendations regarding the usage of, surface water measurement systems derived from either receiving water or a discharge monitoring approach to identify problem discharges.

2.4 Reporting

The ILRP orders issued by the Regional Water Boards require reporting to both determine compliance and inform overall management of the discharges associated with agriculture. Also, specifically in regards to nitrogen, the California Department of Food and Agriculture convened the Nitrogen Tracking and Reporting System Task Force, called for by Recommendation 11 of the State Water Board’s report to the Legislature, which makes recommendations on a potential reporting system.

12. Evaluate and make recommendations on how best to integrate the results of the Nitrogen Tracking and Reporting System Task Force with any above recommendation regarding management practices and verification measures.
13. Evaluate and make recommendations on the reporting requirements to report budgeting and recording of nitrogen application on a management block basis versus reporting aggregated numbers on a nitrate loading risk unit level. (Definitions of “management block” and “nitrate loading risk unit” are contained in State Water Board Order WQ 2013-0101.)

3 BACKGROUND DISCUSSIONS

The Panel understands that the State Water Board is mandated to protect both surface and subsurface water quality. Legally, the State Water Board is empowered to require potential polluters to modify practices if there is even a possibility that those practices would negatively impact public health. The State Water Board can also require that potential polluters conduct research to prove that certain practices are not detrimental. On the other hand, the State Water Board must be careful to not impose unduly harsh regulations and thereby disenfranchise (in this case) the agricultural community.

The Panel understands the Panel’s mission as one of providing recommendations to the State Water Board that will improve/maintain water quality, while simultaneously engaging the agricultural community in a positive manner. The recommendations of the Panel were impacted by members’ interpretations and understandings of many background concepts and issues, which together create a picture of what is reasonable, effective, and proper.

Due to human nature, varying abilities of people to assimilate new information of various complexities, difficulty of properly communicating instructions, lack of information, etc., many changes in practices and procedures and behavior require several years, at a minimum, to properly implement. The subjects considered by the Panel are highly complex and no “one-size-fits-all” solution involving specific irrigation and fertilizer practices is possible. [Q4b] However, the Panel does recommend a universal approach in that sense that a good customized irrigation and nitrogen management plan should be required for each crop mix, and a strong education/awareness effort will be required. [Q7d] The details of what specific irrigation or nitrogen management practices are best for an individual fields can best be addressed with customized plans, rather than checking off boxes in a long list of “best management practices”. [Q5][Q6]

It can be valuable to specifically proscribe certain practices and concepts related to regulation of practices that impact groundwater nitrate, to avoid the development of ineffective and antagonistic regulatory programs. In other words, the Panel believes that the development of a good regulatory program requires an understanding of both the strengths *and* weaknesses of various approaches.

Furthermore, the Panel believes that an effective regulatory program must be developed in light of how well it will be accepted, and how effectively it can be implemented, by the regulated entities. **This is one of the essential aspects of a non-point-source pollution regulatory program related to nitrate in groundwater.** The complexity of irrigation and fertilizer management is so great that success of any regulatory program will be highly dependent upon acceptance and understanding of that program by the regulated entities. It is simply impossible for a regulatory agency to properly dictate and verify the details of irrigation and nitrogen management for thousands of individual fields; positive grower participation is an absolute requirement.

For these reasons, the Panel’s recommendations deviate from the format and specific inquiries of the questions from the State Water Board. The background discussions in this

section will address the reasoning behind the Panel’s recommendations. The recommendations themselves are detailed in *Section 4: Recommendations*.

3.1 Point-Source vs. Non-Point-Source Pollution Regulation

As mentioned previously, the questions posed to the Panel deal with a non-point-source pollution problem. There is a relatively long history of development of monitoring / regulatory approaches for point-source pollution, but the approaches are not necessarily transferable to non-point-source monitoring and regulation. In the opinion of this Panel, the approach of the agricultural orders that have been issued within the framework of the Irrigated Lands Regulatory Program (ILRP) and the Central Valley Region’s Dairy General Order has been strongly influenced by historical regulation of point-source discharges. [Q4d] Specifically, we refer to the notion that there is (or should be) a particular measurement or metric (e.g., a suite of measurements and computations) that can be used as an unequivocal “tool” to determine if an individual discharger is in compliance or out of compliance with regulations. [Q2]

To some degree, the concept of this metric or tool exists even within the framework of agricultural non-point-source discharges, specifically with respect to the deep percolation of nitrate and minerals from irrigated cropland. For instance, an example of such a tool would be the strict enforcement of the nitrate MCL in first-encountered groundwater. [Q10a] Monitoring of first-encountered groundwater has traditionally been the Regional Boards’ most important tool to determine compliance or noncompliance with Waste Discharge Requirements (WDRs). In the context of traditionally regulated units (e.g., underground storage tanks (UST), landfills) that can be summarized as point-source dischargers of constituents of concern not commonly found in natural groundwater systems (e.g., petroleum products, pesticides, other chemicals), or not in as high of concentrations (e.g., heavy metals), groundwater monitoring for regulatory compliance has proven effective.

The reason for this effectiveness is illustrated with this example: If groundwater samples retrieved from a monitoring well downgradient of a petroleum products service station shows any detection of benzene (at any measureable concentration), and the upgradient well has no such detections, it is determined that the unit is leaking. The mass rate of the UST’s subsurface emissions is not subject to debate in this case. Therefore, the Regional Board’s decision would be straightforward and would entail a requirement for corrective action including removal of the source (tank). Importantly, even if no particular remedial action were required, concentrations of the constituent of concern would be expected to eventually decline due to natural attenuation.

In the context of cropland nitrate and salt loading to groundwater, however, monitoring of first-encountered groundwater does not provide the same utility as in the example in the prior paragraph. [Q10a] From a technical perspective, this tool is limited to use in hydrogeologic conditions where the sampled groundwater volume can be attributed to a defined recharge area, which must be contained within the area where the regulated discharge occurs. This can be done in areas of very shallow groundwater tables, relatively steady groundwater flow directions, high recharge, large regulated units, and a strong introduced discharge signal (e.g., high concentration or unique chemical).

The opposites of these characteristics (i.e., increasing depth to groundwater, non-steady flow directions, lower recharge, smaller regulated units, and a weaker discharge signal) and a large array of other variables and processes that moderate the discharge signal constitute insurmountable technical limits to the applicability of this tool in large areas of the regulated agricultural landscape. These issues and limitations can be illustrated with an excerpt from UCANR (2013):

The possibility of having high chemical mass transport with a low concentration can best be described by considering salts dissolved in the water. As water is lost from the soil through evapotranspiration (ET), the salts are left behind and become concentrated. Assuming no precipitation or dissolution of salts in the soil, the concentration of salts in the water leaving the root zone (Cd) is related to the concentration of the salts in the irrigation water (Ci) by the following equation:

$$C_d = C_i/LF;$$

where LF is the leaching fraction and is defined as:

$$LF = (AW-ET)/AW,$$

where AW is the applied water that infiltrates the soil. The amount of deep percolation carrying chemicals to the ground water is equal to AW-ET. Thus, the concentration of chemical in the water leaving the root zone is inversely proportional to the amount of deep percolation. The problem is even more complex because the LF varies spatially within a field.

A conclusion that is well supported by research findings and scientific principles is that the concentration is not a valid indicator of good versus bad agricultural management practices.

In the absence of a viable, simple numerical threshold value as described above, or a different metric of similar technical performance, it is acknowledged that the regulation of agricultural non-point-source pollution becomes much more difficult and complex.

With these basic considerations in mind, the Panel recommends a comprehensive regulatory program to minimize nitrate movement to the groundwater. [Q1] A quick read of the list of recommendations in the *Executive Summary* may make it appear to be almost identical to existing programs. The remainder of this report discusses important differences, and includes many required details. The Panel also defers to the recommended coalitions, with approval from the Regional Boards, to refine many programmatic details.

3.2 Groundwater Characteristics

Although the central motivation behind the call of this Panel is the problem of nitrates in groundwater, the majority of the Panel's recommendations focus on above-ground practices and monitoring. [Q5][Q6] The basis for turning the focus of the recommendations away from groundwater monitoring stems primarily from the difficulty of correlating sub-surface contamination to surface practices.

3.2.1 Groundwater and Surface Practices

Collecting data on changing nitrate levels in the groundwater, to indicate success or failure of overlying surface N management practices on individual fields and farms directly above a data collection point, is typically problematic at best. [Q10a][Q10b] Dr. John Letey, in discussing the State Water Board’s “Recommendations Addressing Nitrates in Groundwater, Report to the Legislature” (20 Feb 2013), provides a grim view of traditional nitrogen data collection at the field level:

- a. *“... there was no significant correlation between the N concentration in the soil-water with either the drainage volume or the amount of N applied. The significance of this is that there is no value gained by measuring the N concentration in the soil-water. The concentration neither reflects the N load to groundwater nor the quality of the farm management. Indeed, as will be supported later, erroneous conclusions can be drawn from these data...”*
- b. *The amount of N leached is far greater for the higher irrigation (low N concentration) than the lower irrigation (higher N concentration). The amount of N leached is directly related to the water flux at the bottom of the root zone. This flux cannot be practically measured (tracked) in the field, especially for the great variation with time and location. Tracking the N load migrating to groundwater, and not concentration, is the most important factor to track, and it is impossible to track...*
- c. *...efforts today should be directed toward reducing the future N loads to groundwater. The load is dictated by farmer management; and therefore, the approach should be directed toward inducing good farm management, not merely tracking and reporting what is being done. This is particularly true when some of the costly tracking information is, at best, of useless value.”*

The exception would be extensive monitoring and proper evaluation of data from a shallow water table (e.g., with the water table located 5-8 feet below the soil surface), which will exhibit a rapid response to deep percolation (below the root zone) water and nitrate flows. However, even with a shallow water table, the water quality of the outflow from tile lines is often influenced by the management in neighboring fields as well as by the overlying field. And there is always the basic question that must be addressed: Just because one can examine shallow water tables and get a reasonable answer, is this the best option available for the nitrate problem?

3.2.2 Aquifer Characteristics

The following points were repeatedly discussed regarding trying to draw precise conclusions from modeling and monitoring results of aquifer water quality: [Q10]

- Lag times between deep percolation of nitrates and the nitrates reaching the top of the aquifer typically range from a year to up to extremes of several hundred years.
- While there can always be exceptions, there is very little direct correlation between deep percolation water qualities and the aquifer immediately below that agricultural surface. Instead, many explanations and examples exist given regarding the complex mixing of aquifer flows, and the heterogeneous nature of the subsurface.
- Groundwater simulation model results are only approximate even on very large scales.
- California aquifer physical characteristics are very complex and even with large studies are poorly defined. As an example, Figure 1 shows a single transect of the Modesto area

aquifer. It is obvious that the results would be quite different if different transects were displayed. Model results are only as good as the accuracy of the data and boundary conditions that are used in the model; Figure 1 illustrates the difficulty of properly identifying aquifer characteristics even after extensive studies have been performed.

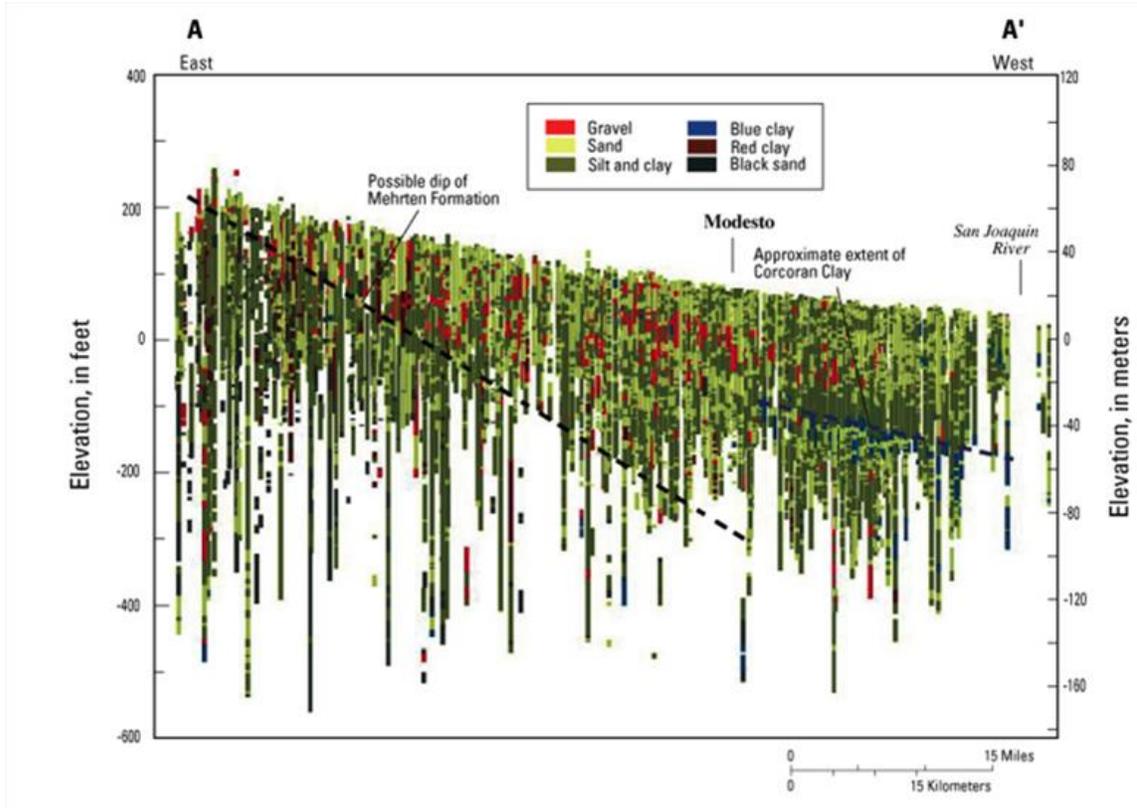


Figure 1. Cross-sectioned view of lithologic well-log data along azimuth of 50 degrees between Stanislaus and Tulolumne Rivers (Figure 10 from Burow et al. 2004)

The data collection is also complicated at the aquifer level. An aquifer typically has considerable depth, and there is unsaturated flow through the vadose zone between the root zone and the aquifer. The long travel times and the varied mixing of water of different qualities and sources within the aquifer can both result in a considerable lag time between changes in irrigation/nitrogen management practices and impacts in the aquifer. What is seen today in the aquifer is indisputably the result of historical management practices – not the result of today’s irrigation/fertilizer practices. [Q4] [Q4b] The unknowns are the lag time and the degree of mixing of results.

In fact, an increase in nitrate concentrations at the very upper surface of an aquifer (first-encountered groundwater) may indicate better nitrate management rather than poorer nitrate management. [Q10a] This can be caused by reduced irrigation water leaching, which would result in higher concentrations of nitrate in the leachate, even though the nitrate loading may be lower. In other words, the total load depends upon both the concentration and flow (flux) of the deep percolation. Estimates of deep percolation flow rates are very inexact. In addition, due to the nature of horizontal flows, the nitrate levels at a point in a groundwater

aquifer do not necessarily indicate nitrogen practices in the field directly above that point.

[Q10b]

The graphs in Figure 2, provided in testimony by Dr. Joel Kimmelshue, illustrate how cropping patterns have changed in 20 years in North Kern Water Storage District. These cropping pattern changes are also associated with changes in fertilizer and water management. The point was that what is seen today in groundwater nitrate levels may have excellent, little or no correlation to today's surface conditions.

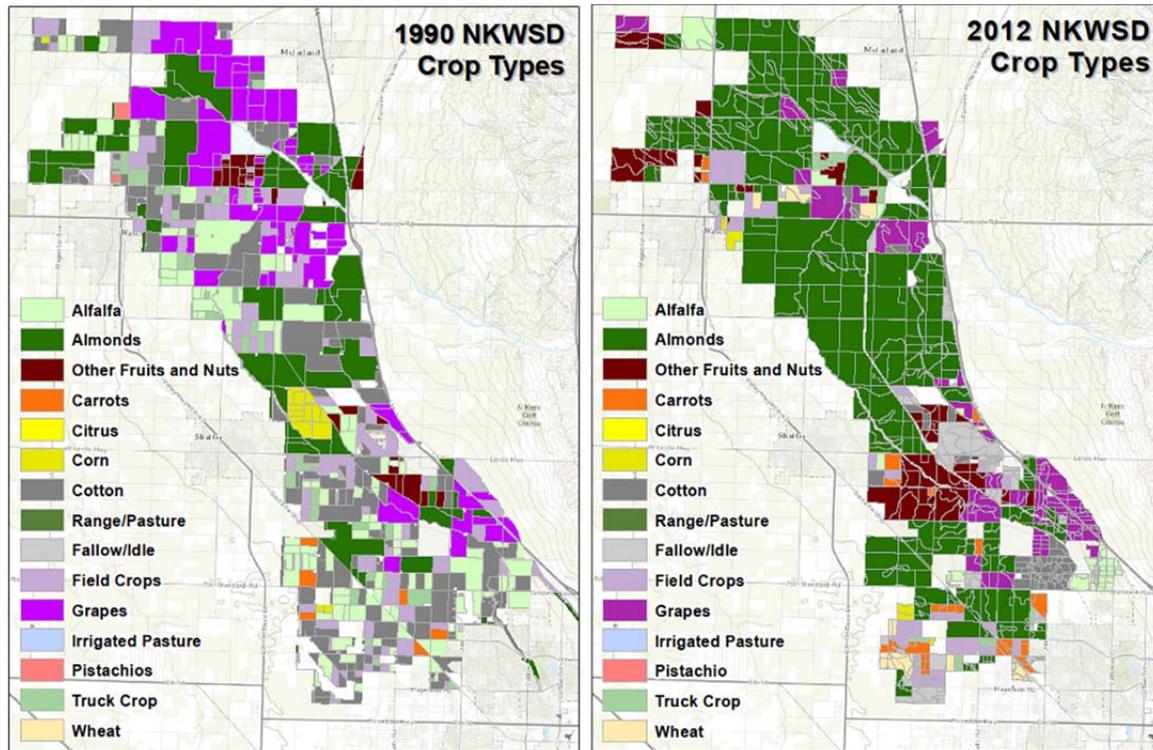


Figure 2. Crop type maps of North Kern Water Storage District, 1990 and 2012.
Provided by Dr. Joel Kimmelshue

3.2.3 Historical Changes in Farming Practices

On a broader geographic scale, there have been major changes in cropping patterns in recent years. Figure 3 through Figure 5, developed from CDFR reports, illustrate some of the major changes in the southern San Joaquin Valley. Pistachio, almond, and tomato acreages have increased, and the yields for all three crops (lb/acre) have also increased. The major changes in both acreage and yields have occurred in the last 10-15 years.

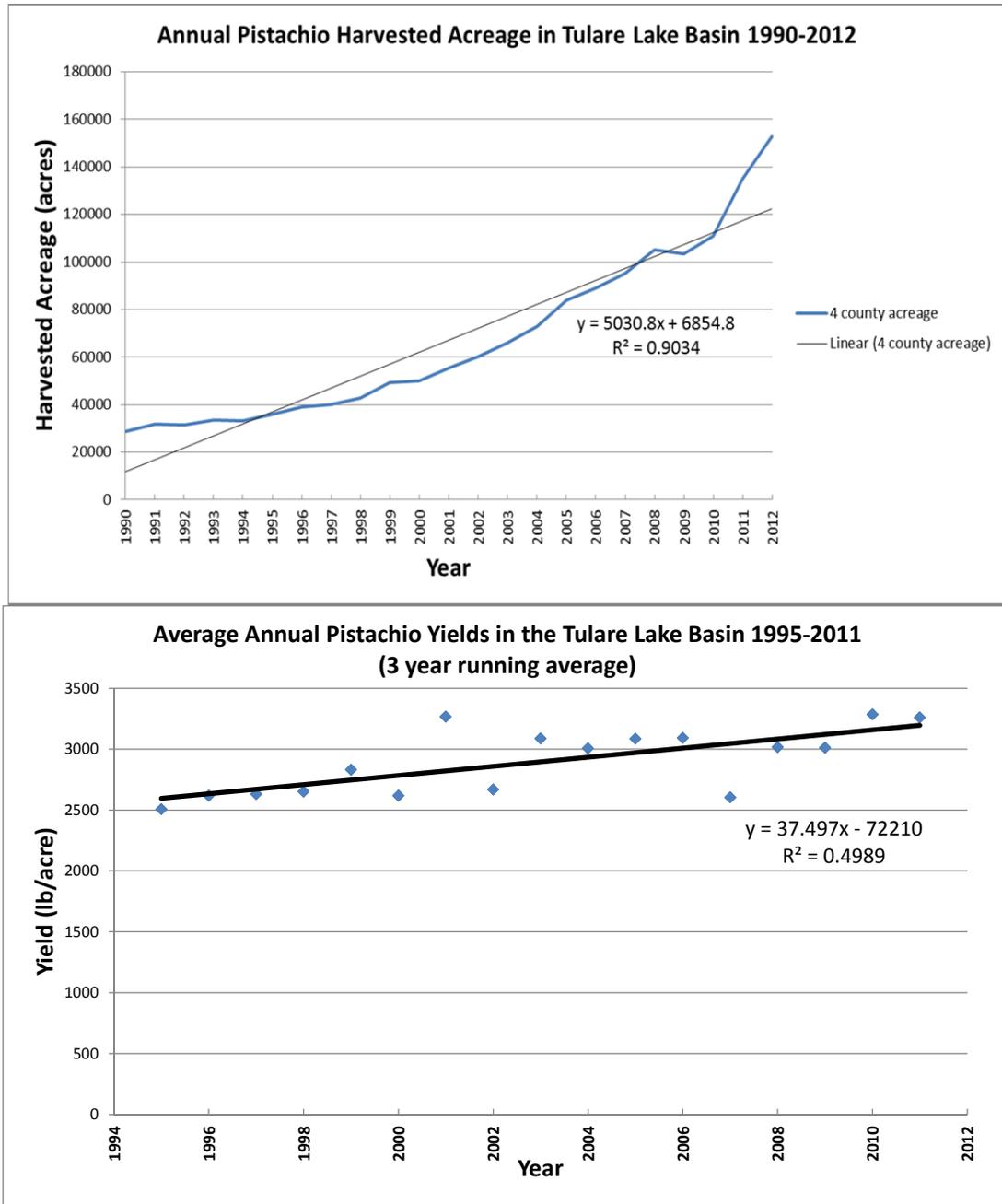


Figure 3. Graphs of changes in pistachio acreages and yield in the Tulare Lake Basin¹

¹ Data from County of Fresno (2014), County of Kern (2014), Kings County (2014), and Tulare County (2014). Includes production from young orchards officially classified as non-bearing. Pistachio production stated in terms of In-shell Equivalents.

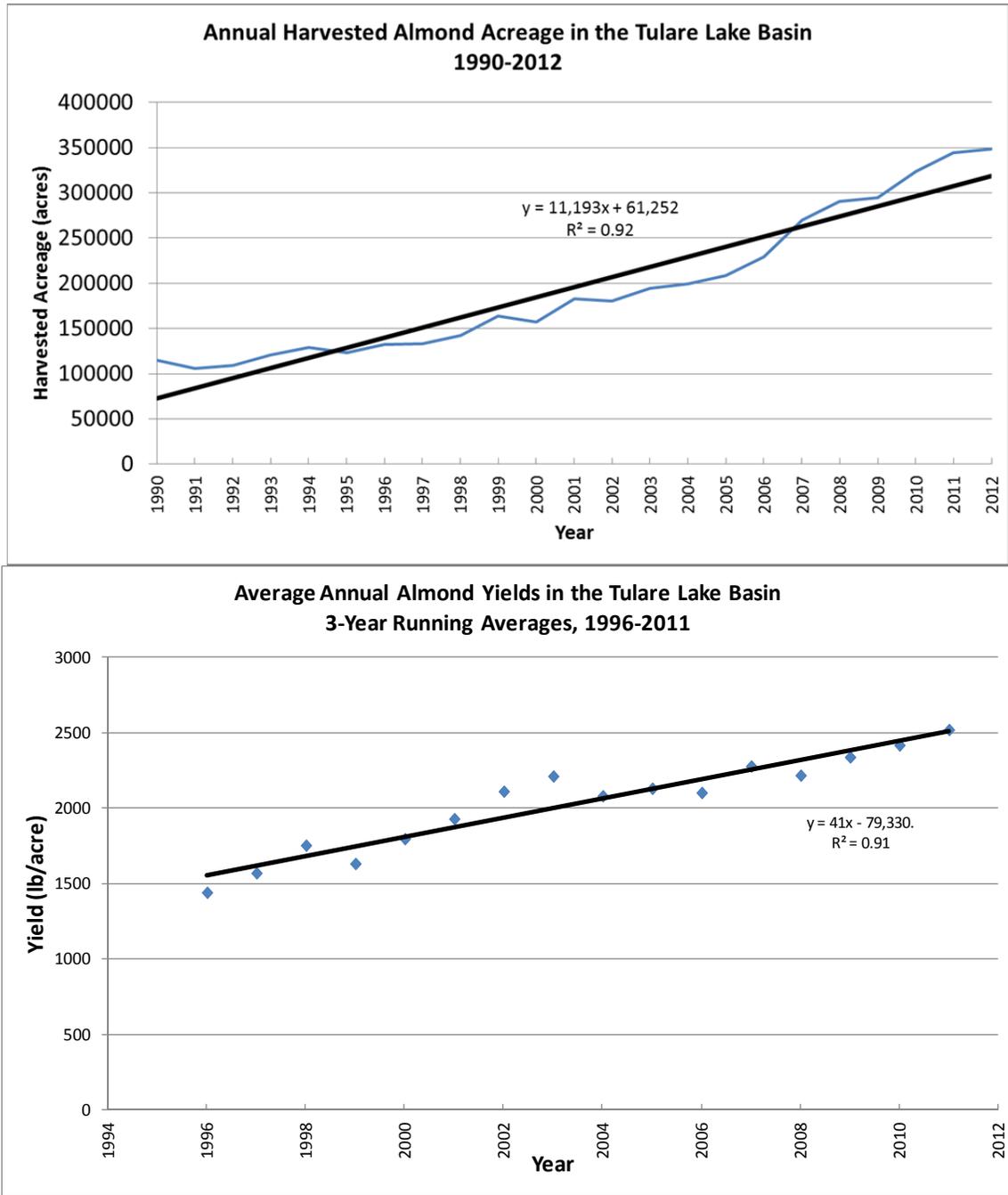


Figure 4. Graphs of changes in almond acreages and yield in the Tulare Lake Basin²

² Data from County of Fresno (2014), County of Kern (2014), Kings County (2014), and Tulare County (2014). Includes production from young orchards officially classified as non-bearing. Almond production stated in terms of Nut Meat Equivalents.

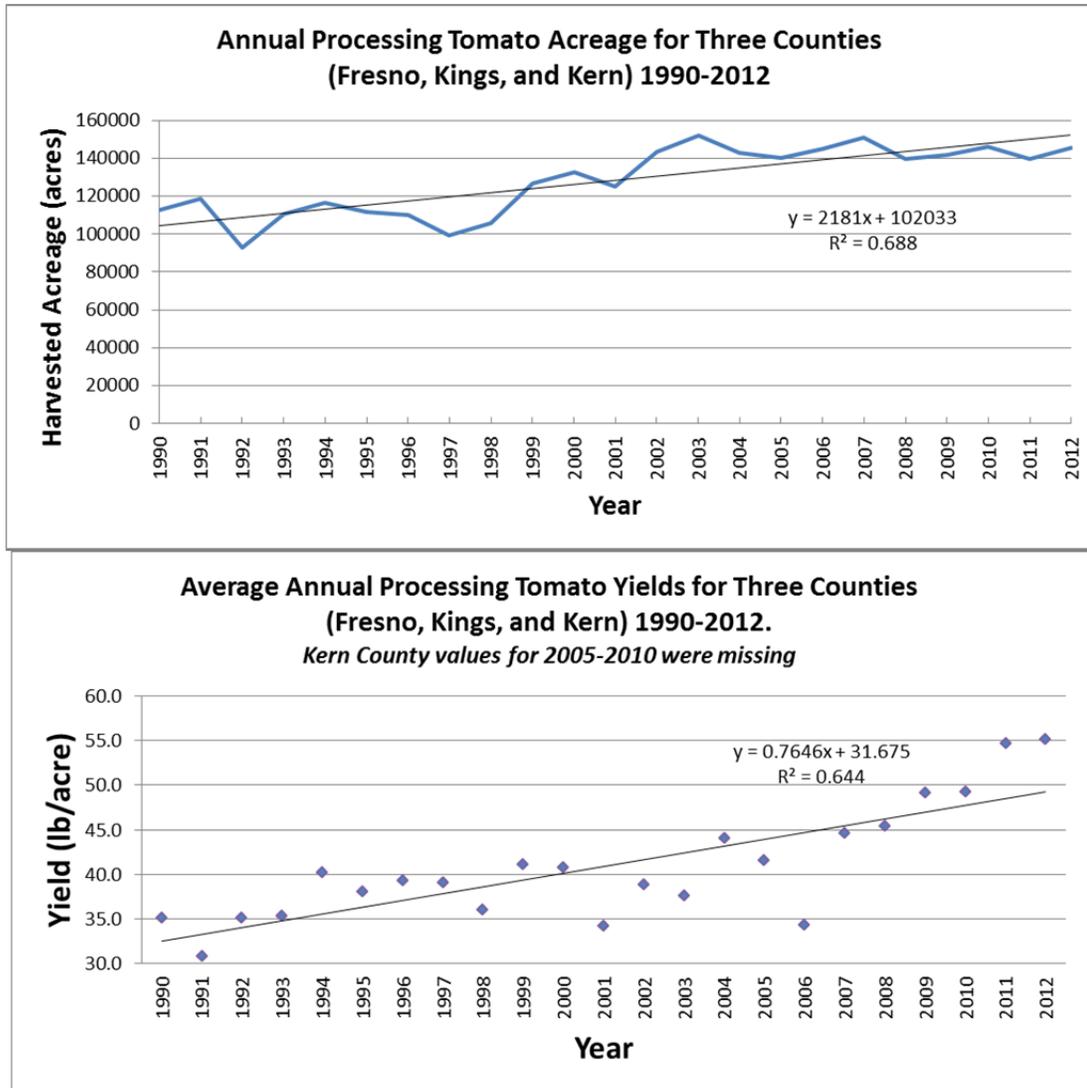


Figure 5. Graphs of major changes in tomato acreages and yield in Fresno, Kings, and Kern Counties³

Irrigation methods have also changed dramatically. While drip/micro systems have been widely used since the late 1970’s in the San Joaquin Valley, it is now difficult to find pistachio, almond, or tomato fields that are not drip-irrigated. The big shift from surface irrigation (furrows and border strip) has occurred in the last 10-15 years.

Meanwhile, reported nitrogen fertilizer sales are about the same in the Southern San Joaquin Valley, but have reportedly dropped in California (see Figure 6 and Figure 7).

³ Data from County of Fresno (2014), County of Kern (2014), Kings County (2014), and Tulare County (2014).

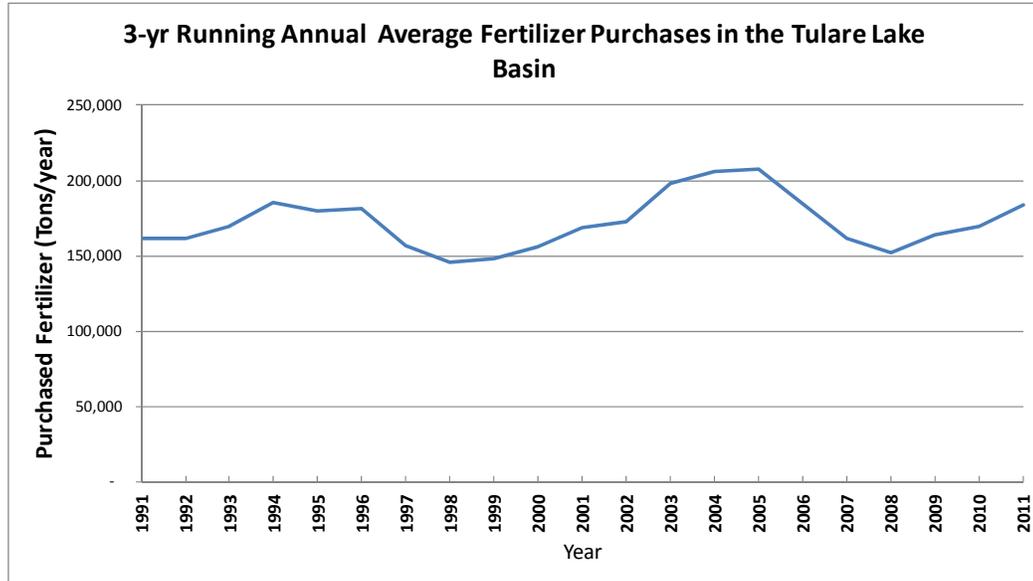


Figure 6. Three-year running annual average fertilizer purchases in the Tulare Lake Basin, 1991-2011 (data from CDFA, 2014)

State	Fertilizer purchased in 2003 (1000 kg of N)	Fertilizer purchased in 2005 (1000 kg of N)	Fertilizer purchased in 2007 (1000 kg of N)	Fertilizer purchased in 2009 (1000 kg of N)	Fertilizer purchased in 2011 (1000 kg of N)	% change from 2002-2006 to 2007-2011*
Alabama	90,956	114,387	106,729	60,319	68,225	-19%
Alaska	2,741	2,741	2,741	2,501	2,817	-2%
Arizona	96,855	89,720	71,420	89,747	60,041	-23%
Arkansas	265,684	227,586	297,798	213,021	223,361	-3%
California	792,148	694,217	670,619	609,774	672,302	-8%
Colorado	110,324	115,719	130,718	121,902	152,647	16%
Connecticut	10,791	8,284	10,634	8,889	8,480	-15%

Figure 7. Total nitrogen mass in commercial fertilizer purchased in California and other states for 2003 to 2011 (AAPFCO, 2011)

3.2.4 Quality of Data

To complicate matters further, the data that is currently available regarding nitrate levels in groundwater often comes from data sources of poor quality. While the laboratory analysis of a sample may be accurate, the samples may come from wells for which there is little information available regarding the depth of casing perforations, the depth of the well itself, the relative transmissivity of various zones in the aquifer, mixing between upper and lower aquifers, etc. [Q10b]

Without a doubt, data must be collected for monitoring and verification of regulatory efforts. However, the data collection and reporting must be limited to essential requirements to satisfy the objectives. An unhealthy regulatory environment is created if the regulated community believes that they are required to pay for collection and reporting of data that are meaningless, have an excessive expense, or can be misleading. [Q9]

3.3 Concepts of Risk/Vulnerability

The Panel recognizes that the State and Regional Water Boards have limited resources and are interested in prioritizing regulatory oversight and assistance according to the risk posed by discharges to the environment into which the discharge occurs [Q1] [Q2] [Q3] [Q4]. The State Water Board expressed this interest in response to Harter and Lund (2012) (referred to in this report as “the Harter Report”). Recommendation 6 states:

*The Water Boards will define and identify nitrate high-risk areas in order to prioritize regulatory oversight and assistance efforts in these areas.*⁴

Since then, the Central Valley Regional Water Quality Control Board (CVRWQCB) issued their first WDRs to growers within the Eastern San Joaquin River Watershed (R5-2012-0116-R2; revised October 2013 and March 2014). In this Order, the term “nitrate high-risk area” (or related) appears only once; and it is not defined. Instead, the term “vulnerability” or “vulnerable” (or related) appears 157 times, predominantly in connection with groundwater. This incongruence between the State Water Board and the CVRWQCB creates much confusion. Therefore, the concepts of vulnerability, as currently used by the CVRWQCB, and risk (as proposed to be used by the Panel) are discussed on the next few pages.

3.3.1 The Concept of Vulnerability

In the context of the ILRP and the development of its Waste Discharge Requirements’ general orders, groundwater vulnerability has become a highly controversial concept. Part of the controversy is caused by the difficulty of agreeing on a definition, plus the difficulty of

⁴ Recommendation 6 references two previous interpretive efforts that the State Water Board will invoke:

The Water Boards will develop a definition of a nitrate high-risk area, using both the hydrogeologically vulnerable areas identified by the State Water Board (http://www.waterboards.ca.gov/gama/docs/hva_map_table.pdf) as well as current CDPR Groundwater Protection Areas (http://www.cdpr.ca.gov/docs/emon/grndwtr/gwpa_locations.htm), in addition to other available hydrogeologic data. [Q1] [Q2] [Q3] [Q4]

The Expert Panel finds that neither the State Water Board’s Hydrogeologically Vulnerable Areas method nor CDPR’s Groundwater Protection Areas approach can constructively contribute to a definition of nitrate high-risk area in the context of the ILRP. For example, the Hydrogeologically Vulnerable Areas method categorically excludes the entirety of the area known to be underlain by the Corcoran Clay although groundwater extraction from above this extensive aquitard is substantial both for agricultural and drinking water supply. Further, CDPR’s Groundwater Protection Areas were delineated specifically to protect groundwater from contamination with pesticides, not nitrate. CDPR states:

A ground water protection area (GWPA) is a one-square mile section of land that is sensitive to the movement of pesticides. GWPAs can be established if any of the following are true:

- *previous detections of pesticides in that section*
- *contains coarse soils and depth to ground water < 70 feet*
- *contains runoff-prone soils/hardpans and depth to ground water < 70 feet*

Areas of pesticide application do not necessarily match those where fertilizers are applied (e.g., along railroads, highways and county roads, canals, etc.) and CDPR’s groundwater protection considerations included chemical properties of pesticides, not those of nitrate [Q4b]. Also, the inclusion of runoff-prone soils/hardpans makes sense for the control of the off-site transport of pesticides to surface waters. However, these conditions tend to decrease deep percolation of water and nitrates and should, therefore, not be included in the delineation of nitrate high-risk areas.

spatially determining areas of different vulnerability. The term itself is confusing. In many cases, vulnerability of an aquifer is better characterized as “rapidly responding” to a given input signal (e.g., a waste discharge to land) and the “degree of signal attenuation” that occurs between the point of discharge and point of interest within the aquifer system. However, some authors refer to these properties as the aquifer’s “sensitivity”. Clearly, vadose zone physical, hydraulic and chemical properties are important variables that determine aquifer vulnerability, and so are aquifer characteristics. Unfortunately, there is very little quantitative information on these properties, with the exception of highly investigated sites.

CVRWQCB defined “high vulnerability area” in Attachment E to R5-2012-0116-R2. This definition is the basis of the High Vulnerability Areas Methodology [Q1] [Q2] [Q3] [Q4] [Q4d]:

High vulnerability area (groundwater) – Areas identified in the approved Groundwater Quality Assessment Report “...where known groundwater quality impacts exist for which irrigated agricultural operations are a potential contributor or where conditions make groundwater more vulnerable to impacts from irrigated agricultural activities.” (see section IV.A.3 of the MRP⁵) or areas that meet any of the following requirements for the preparation of a Groundwater Quality Management Plan (see section VIII.H of the Order): (1) there is a confirmed exceedance (considering applicable averaging periods) of a water quality objective or applicable water quality trigger limit (trigger limits are described in section VIII of the MRP) in a groundwater well and irrigated agriculture may cause or contribute to the exceedance; (2) the Basin Plan requires development of a groundwater quality management plan for a constituent or constituents discharged by irrigated agriculture; or (3) the Executive Officer determines that irrigated agriculture may be causing or contributing to a trend of degradation of groundwater that may threaten applicable Basin Plan beneficial uses.

The Panel finds that:

1. This definition creates ambiguity because, arguably, in most areas of the Central Valley floor “irrigated agricultural operations are a potential contributor” to nitrate concentrations in groundwater. Further, the statement “where conditions make groundwater more vulnerable to impacts from irrigated agricultural activities” is exceedingly vague such that it carries little meaning. It also constitutes circular logic because it uses the to-be-defined term in its own definition.
2. This definition lacks technical rationale. Nitrate concentrations in water supply wells (as opposed to dedicated monitoring wells that were installed with the specific purpose of monitoring first-encountered groundwater in relatively shallow groundwater bodies) are in most cases not reflective of land uses in their immediate vicinity but rather reflect a mixture of waters of wide-ranging spatial origin and age. [Q10b] This is an amply documented fact and relates to the purposeful separation of the water intake sections from surface processes via sanitary seals; the depth, length and number of well screens; and the specific aquifers tapped; other well construction details; the integrity of the well casing; pumping rates, and total extraction volumes. Therefore, the locations of water supply wells with nitrate MCL exceedances do not provide the data needed to identify discharges or dischargers that pose a high risk or threat to groundwater resources.

⁵Monitoring and Reporting Program

3. The ILRP’s focus on groundwater vulnerability confounds the spatial delineation of “risk of nitrate leaching below the crop root zone” with the concept of “impact to groundwater” at some undefined point within the aquifer.

Based on the above assessment, the Panel recommends that the CVRWQCB abandon its definition of High Vulnerability and the High Vulnerability Areas Methodology [Q4d], except to help target initial efforts. The Panel does not feel that adequate tools exist to accurately target specific areas; regulation and education efforts should apply to all growers rather than those with specific environmental characteristics. [Q1][Q2]

3.3.2 The Concept of Risk

There are three important types of risk with respect to groundwater nitrate concentrations. All of them involve the likelihood or probability of an occurrence. [Q1] [Q2] [Q3] [Q4]

1. Human health risks (i.e., the probability of falling ill) associated with the ingestion of drinking water with nitrate-N concentrations exceeding the Maximum Contaminant Level (MCL) of 10 mg/L.
2. The risk (i.e., probability) of a particular drinking water well or wells in a certain location or area of exhibiting nitrate concentrations exceeding the MCL.
3. The risk (i.e., probability) associated with growing crops of losing nitrate (including related nitrogen components) to deep percolation below the crop root zone.

An assessment of the risks to human health (*Item 1*) is not part of the charge to the Panel and is, therefore, not discussed. The risks defined in *Items 2* and *3* involve different processes, time scales, and solutions. Further, their assessment serves different purposes. Therefore, to effectively assess these risks, they need to be separated.

3.3.2.i *Establishing Areas of High Priority for Action/Attention*

There are numerous factors that might impact deep percolation – factors that can be used to create exhaustive lists of best management practices, intrinsic soil properties, etc. Some indexes (such as NHI [Q2a]) attempt to mesh both aspects: information about the soil plus something about the irrigation method. However, the use of a single index to lump numerous complex inter-relationships together is merely a proxy to answering two basic questions: Are the nitrogen and water needs of the crop being managed in a reasonably good manner?

The measurements currently most used for determining risk are proximity or operation within an impaired water body and the use of a risk calculation such as NHI [Q2a] or Nitrate Loading Factor [Q4a]. Both of these tools create use output values to trigger a lower or higher regulatory burden, but do not give the grower much flexibility to adopt practices or otherwise make changes to operations to reduce risk or exposure. For example, a grower cannot readily change his/her crop, soil type, or irrigation source, but these are all significant and high-magnitude indicators of risk in the language of the current central coast order. At best the current tools should serve as basin, region, or coalition wide, high-level indicators of risk or as an education and awareness tool to bring attention to the magnitude of the growers’ subsequent irrigation and fertilization strategies.

The Panel does not believe that there is one excellent universal tool to define zones/areas that might be prioritized for educational and extension efforts. [Q1][Q2] However, risk level may be considered in the administration of responsibilities of growers to the coalitions.

3.3.2.ii Probability of Nitrate MCL Exceedance in Drinking Water Wells

Sampling and reporting of nitrate concentrations (among many other constituents) in drinking water wells is the responsibility of the operator of the regulated drinking water system and the review and evaluation of this information is the responsibility of the regulatory agency (the regulatory oversight of the drinking water program is presently transferred from CDPH to the State Water Board). [Q10b] The objective of this monitoring is to protect human health, and enforcement decisions are made based on actual nitrate concentrations rather than probabilities. An increased risk to water consumers is assumed when constituent concentrations reach one-half of the drinking water MCL; this has commonly been addressed by requiring operators of water systems to conduct more frequent sampling and reporting to the regulatory agency.

The existing data set, housed by the regulatory agency, may be usable to delineate areas where nitrate MCL exceedances in drinking water supply wells are thought to be more probable than in other areas based on, for example, straight-forward spatial autocorrelations. The regulatory agency may deem such effort necessary to implement notification of groundwater consumers of potential exposure to elevated nitrate concentrations in their water supply. However, this should not be an effort required of the regulated community (i.e., the operators of water systems or the farming community).

Probability of Nitrogen Deep Percolation Losses below the Root Zone

For any given crop, the probability of nitrogen leaving the crop root zone via deep percolation increases with increasing nitrogen input and irrigation/rainfall that exceed the crop uptake. Estimating this probability in a qualitative, comparative manner begins to address the groundwater nitrate issue (and the related salinity issue) and is congruent with the State and Regional Water Boards' need to prioritize regulatory oversight and assistance efforts in these areas. [Q5] To accomplish this task, the Panel recommends implementation of a basic data collection effort, as described later. The recommended approach is guided by a basic recognition:

“It is the mark of an instructed mind to rest satisfied with the degree of precision which the nature of the subject permits, and not to seek exactness where only an approximation of the truth is possible.”
- Aristotle

3.3.3 Key Points Regarding Vulnerability and Risk

The Panel agrees upon the following key points related to the question of “vulnerability” and “risk”. [Q1][Q2][Q3][Q4]

- A. There is no reliable and practical method available that is generally applicable to accurately pinpoint the sources of groundwater nitrates found at any point (horizontal and vertical) in an aquifer. [Q2][Q3]
- B. The definition of “high vulnerability area” [Q4d] by the CVRWQCB creates ambiguity, uses circular logic, and has vague wording. It also lacks technical rationale, and

- confounds the spatial delineation of “risk of nitrate leaching below the crop root zone” with the concept of “impact to groundwater” at some undefined point within the aquifer.
- C. The Panel was not confident that the designation of high or low “risk” or “vulnerability” is relevant for regulation. However, risk level may be considered in the administration of responsibilities of growers to the coalitions. [Q3]
 - D. The Panel does not believe that extensive monitoring of “first-encountered groundwater” for nitrate is appropriate because of all of the uncertainties involved in interpreting results. [Q10a]
 - E. Using a hazard index of conditions above ground such as with NHI [Q2a], or an index based on groundwater nitrate levels, are insufficient to answer two basic questions on farms/fields: Are the nitrogen and water needs of the crop(s) in the overlying fields being managed in a reasonably good manner?
 - F. The Panel recognizes that regulatory agencies and coalitions need to have some means of focusing initial education and extension efforts.
 - G. Proxy measurement such as the NHI [Q2a], groundwater nitrate concentrations, or total N applied per acre, may be used for focusing of initial efforts, only.
 - H. Long-term, the Panel recommends not using such proxy measurements, but instead focusing on using a comparison of the nitrogen applied by field/crop, against the N removal from the field by the crop. This will be discussed in more detail in other sections of this report.**
 - I. The Panel recommends against using the NHI [Q2a], groundwater nitrate concentrations, or total N applied per acre to mandate different levels of regulatory requirements.
 - J. It is incorrect to assume that accurate estimates of deep percolation on individual fields can be made from complex soil water measurements. This is an important fact in the argument to not base regulatory action and regulatory decisions on modeling efforts that involve complex assumptions regarding root zone water storage, water holding capacity, crop ET, etc. [Q2]
 - K. It is clear that deep percolation will move nitrates below the root zone. The focus should be on practical means of minimizing deep percolation, not on the development of more models. [Q2]

3.4 Nitrogen Balances

The Panel acknowledges the importance of knowing the nitrogen transformation details for certain research projects. Knowledge of the nitrogen transformation fundamentals can also help advisors and farmers in developing good nitrogen management plans. However, there are major differences between individual perceptions regarding the ease and quality of available data. Calculations of nitrogen transformations within a root zone (e.g., mineralization, volatilization, nitrification, immobilization, denitrification, fixation) are very difficult to construct, on a seasonal basis, for many crops. There are numerous unknowns and a large range in the values of components used in the computations. Detailed nitrogen cycle computations for individual fields, for a growing season, will be fraught with error and unnecessary expense. The difficulties for experts are tremendous, and are unrealistic expectations for farmers. Therefore, the Panel does not recommend that such computations and associated data collection be required as part of the regulatory process. [Q7a][Q7b][Q7c][Q10f]

Even one aspect of the nitrogen cycle – the rates of mineralization of organic residues – is tremendously complex. [Q10c] To obtain an accurate value, one would need to know the

nitrogen forms in residue, the residue concentrations at various levels in the soil, the temperatures and moisture contents in various levels, and have some indication of many key factors that influence the microbiological conversions. Similarly, nitrogen removal from the field (via harvest) is different from plant uptake. Much of the plant uptake may remain in the field after harvest. [Q7a]

As an example, one might consider the tonnage of nitrogen that is removed annually via crop harvest.

1. Almonds, with many years of focused research and simple cropping systems, have good and readily available information regarding harvested yield (meat, husks, plus shells) and removed nitrogen, plus an estimate of annual nitrogen uptake for wood growth.
2. A very similar crop – pistachios – has similar information, but that information is not readily available to the public.
3. The members of the Panel are not aware of readily available, easily usable information regarding harvested nitrogen/acre for a wide range of crops. This is especially true of produce crops (broccoli, lettuce, cauliflower) which have widely different pack-out rates, in which yield is expressed as boxes per acre rather than tons/acre, seasons are highly variable in duration, and the percentage of vegetative matter that is left in a field can change drastically depending upon the market.
4. For most crops, most farmers do not presently track the amount of harvested nitrogen. Rather, they are accustomed to a completely different way of thinking about nitrogen. Typical extension service recommendations are based on the amount of nitrogen needed to produce a crop – rather than on harvested nitrogen rates. Or, recommendations may be based on some type of leaf or petiole sample results at specific growth stages. Reporting or accounting for harvested nitrogen is a completely new concept for farmers. This represents a much higher difficulty than what they are currently doing.
5. The further one moves from the field into research and academia, testimony indicates that the idea of accounting for harvested nitrogen sounds more and more simple.

The IILRP and Dairy General Order (Region 5) data collection efforts that relate to nitrogen mass accounting (Nitrogen Management Plan, Farm Template, etc.) assume that data collected on the farm accurately document actual conditions. That assumption is often incorrect. [Q7] Even when data is available, it is often dated. For example, the Harter Report used crop and fertilizer data from 2000-2005. This is not a criticism of that report; it instead points out the difficulty of finding current, relative data/indicators to direct policy; caution must be used in making policy based on outdated data. Agronomic practices and crop mixes constantly change.

Additionally, there are no direct measurements or metrics currently available that can be used to determine good from bad management practices in the context of agricultural, non-point-source discharges related to growing crops. There are also no surrogate measurements (i.e., proxies for direct measurements) currently available that can be used to determine mass flux of nitrogens and dissolved minerals below the crop root zone on a field scale. Inherent errors and uncertainties far exceed needed precision. [Q7]

Even on a large scale, which should be considerably easier than on an individual field scale, there are challenges in exhibiting a proper nitrogen balance. For example, Figure 3 from the Harter Report is seen below. [Q7a][Q7b][Q7c][Q10f]

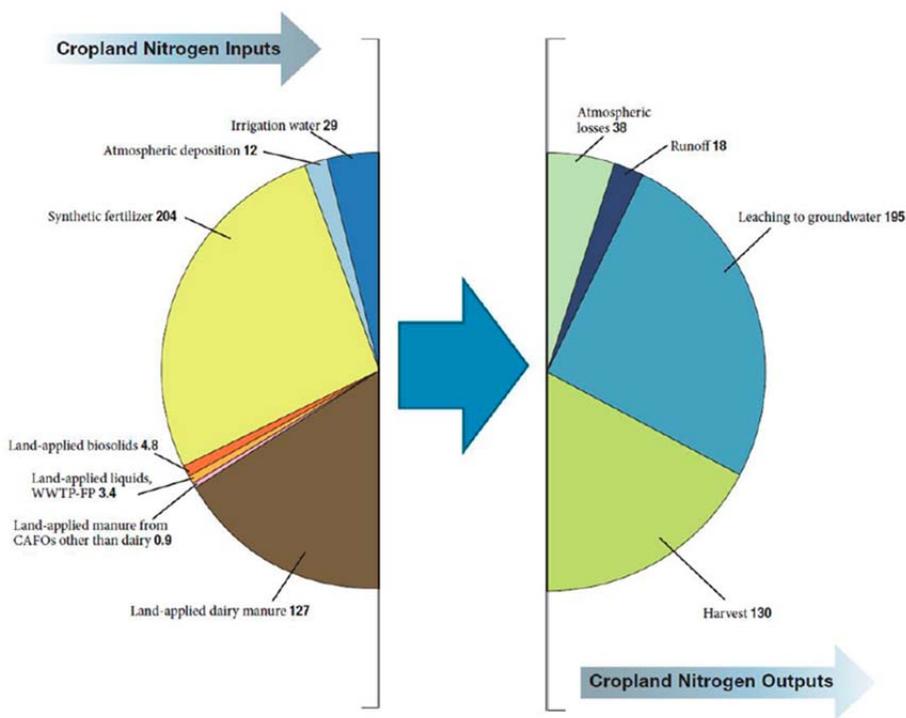


Figure 8. Mass balance of cropland nitrogen (Harter and Lund, 2012)

In the mass balance above, the “leaching to groundwater” is a mathematical remainder term, where:

$$\text{Leaching} = (\text{everything on the left}) - (\text{everything else but leaching on the right})$$

While it can be desirable to provide simple depictions such as this, a logical question is: Why does the harvested nitrogen equal the N in land-applied dairy manure? Surely some of the harvested nitrogen was destined to something other than manure. The study has numerous assumptions (which all studies must have), one of which is that all harvested alfalfa received all of its nitrogen from the atmosphere. However, alfalfa is generally planted in a rotation with other crops, and alfalfa will use readily available soil N before it fixes atmospheric N for its use. On a macro level, just the nitrogen in milk in the area of the pie chart is about 58,000 ton/yr of N – accounting for a significant part of the harvested N. In other words, the depiction of a simple conceptual nitrogen balance for one intensively studied area as a product of a multi-million dollar effort suffers from lack of clarity. The development of complex nitrogen budgets for individual fields has similar challenges, but multiplied thousands of times and without nearly the equivalent budget and level of expertise to support them.

As a side point, the graph in Figure 8 does not clearly indicate that very little manure is applied on the Central Coast (part of the study area). It would also be incorrect to extrapolate the findings from the limited study area, to other areas of the state.

Graphs and figures regarding the nitrate issues rarely delineate the uncertainties in the data. Agronomic practices and crop mixes constantly change. For example, each component of the Figure 8 pie chart’s basin nitrogen depiction (which is not really a balance because not all

major components are included) has a level of uncertainty. A casual reader may believe that such figures are more accurate than they really are. The Panel makes this point because it believes that regulations for groundwater nitrate must be developed with a clear understanding that much of our knowledge of the present status is limited.

Therefore, the Panel has formed its recommendations with the opinions that: [Q7a][Q7b][Q7c][Q10f]

1. It is possible to improve the knowledge of field-level nitrogen balances.
2. The simplest metric of good management is an examination of multiple-year ratios of applied nitrogen, versus crop-removed (harvested + sequestered in wood) nitrogen (the A/R ratio).
3. In general, the ranges (distribution) of most existing A/R ratio values are not currently known.
4. It will be a regulatory goal to learn what the ranges of these multi-year ratios are for multiple crops and situations, in order to define acceptable target values.
5. It will be a regulatory goal to reduce the average value of this A/R metric in regions.
6. There is insufficient knowledge at this time to assign target regulatory values to this ratio, but it certainly cannot be 1.0 or less (except in legume crops).
7. Pragmatic research is needed to identify attainable ratios for a range of crops and situations. Some of this research will be done by coalitions as they examine the reported data. Other research will be more traditional and will be related to topics such as rates and timing of nitrogen uptake and crop removal.

3.5 Education

[Q8]Due to the varying abilities of people to assimilate new information of various complexities, difficulty of properly communicating instructions, lack of information, etc., many changes in practices and procedures and behavior cannot be successfully accomplished in just a few years. Farming deals with large uncertainties because it combines numerous biological processes with unpredictable events and outcomes.

Testimony from Parry Klassen (East San Joaquin Water Quality Coalition) stated that it is a challenge to receive meaningful data from farmers on even simple details such as field locations. It did not appear that this challenge was because of reluctance to respond, but rather because it is a new task, requiring information from unknown sources, using unfamiliar procedures, with instructions that may not be crystal clear.

Because of the combination of scientific uncertainties plus the human element, it is essential to start slowly with attainable and meaningful steps. It may be determined later that these simple steps are sufficient in themselves. Undoubtedly, a sustained awareness and educational effort will be required.

All members of the Panel emphasize the high need for education, both in terms of educating growers as well as training the consultants and professionals who will be assisting growers in creating their management plans. Most importantly, growers must understand why the programs that are implemented are important, what the impacts will be to their specific operation, and how they can meet the requirements and recommendations that will be set forth. Additionally, any agricultural consultants, commodity groups, trade organizations, service providers, etc. need to be on the same page about the program.

Details regarding the recommended educational programming are included in *Section 4.3: Effective Educational/Awareness Programs*. In general, important rules behind an education effort for irrigation and nitrogen management plans are sometimes called the “Four Rs”:

Rule 1: Right time

Rule 2: Right place

Rule 3: Right form

Rule 4: Right amount

4 RECOMMENDATIONS

The Panel recommends a shift in emphasis in regulatory attempts to reduce nitrate levels in groundwater. The shift would be toward long-term monitoring, source control, and education. The justifications for this shift are:

- Regulations designed to improve or maintain groundwater quality must focus on source control for avoidance or minimization of problems – rather than the traditional regulatory point-source approach which depends upon detection of a problem, identification of the individual polluter/owner and discharge point, and enforcement of regulations.
- Because deep percolation of nitrates is universal with irrigated agriculture, a good regulatory program must consider not only those lands above aquifers with high nitrates, or those that in the past have historically been identified to be in a high vulnerability area, or those with a certain size farm or field. Instead, it must encompass all irrigated areas.
- [Q1] [Q2] [Q2d] [Q3] [Q4d] [Q4][Q4c]
- Nitrate flow to the groundwater can best be controlled by avoiding excessive nitrogen applications, and avoiding excessive deep percolation. [Q5][Q6]
- Because excessive deep percolation is a key element to source control, the measurement and scheduling of irrigation water depths applied must be included in any realistic source control program.
- There is no simple feedback test that can be applied to nitrogen and water management. Therefore, the development of nitrogen/water management plans for improved source control on individual fields is best done by educated, certified individuals who are able to analyze the local complexities of fertilizer, crops, weather, soils, etc. and who can develop a pragmatic customized water and nitrogen management plan [Q4b]. This is in contrast to a program that relies on farmers checking off a list of Best Management Practices.
- The Panel also understands that high groundwater nitrate levels will not be reduced immediately, and that there is a danger of focusing on areas with high groundwater nitrates (as measured by various indices), at the expense of missing potential new problem areas.

The key elements of the recommended regulatory program are:

1. Establishment of coalitions to serve as the intermediate body between farmers and the Regional Boards.
2. Adoption of the A/R ratio as the primary metric for evaluating progress on source control, with eventual impact on the groundwater quality. [Q9]

$$A/R = \frac{\text{Nitrogen Applied}}{(\text{Nitrogen Removed via harvest}) + (\text{Nitrogen sequestered in the permanent wood of perennial crops})}$$

3. Development of a very strong, comprehensive, and sustained educational and outreach program. Such a program will require different materials and presentation techniques for different audiences, such as individuals who may need certification, managers of irrigation/nutrient plans, irrigators, and farmers/managers. [Q8]
4. Creation and implementation of nitrogen/water management plans that are truly plans

rather than just a listing of best management practices. These must be customized by features such as crop and locale. [Q5][Q6]

5. Reporting of key values by farms to the coalitions. [Q9]
6. Long-term monitoring of nitrate levels in aquifers to determine trends. [Q9]
7. Targeted research that will directly help the agricultural community to maintain and/or improve yields while simultaneously decreasing the A/R ratio on individual fields.
8. Use of multi-year reported values and monitored trends by the coalitions to inform the agricultural community of progress, to improve understanding of what is reasonable to attain and expect, and to sharpen improvement efforts. [Q9]

These eight recommendations are detailed in the following sections of this chapter.

4.1 Coalitions

The Panel emphasizes that grower coalitions should be strongly encouraged by Regional Water Boards. The Panel recommends strong, local, third-party participation in all regions for the administration of whatever program is put into place.

The Panel finds that the formation of coalitions in Region 5 is valuable. The Panel recommends their formation in other areas, to serve as essential management/operation units. For example, they can collect data from farmers, organize it, and present summaries to the Regional Boards. As a local organization, they can provide strong input to the specifics of their local regulatory program formation and modification. They will also serve as the first point of contact, in notifying farmers that they appear to have a compliance problem. The coalitions can also coordinate, sponsor, and/or conduct research and education.

4.2 A/R Ratio

The mechanism of nitrate movement through and beyond the crop root zone is via water flow (irrigation and/or rainfall deep percolation). Therefore, management practices must attempt to minimize water deep percolation, and also match the available nitrogen to the plant needs at appropriate times. [Q5][Q6]

To reduce or maintain nitrate levels in the groundwater, improvements have to start at the surface, which means on-farm. Efforts to improve agricultural nitrogen fertilizer management will be challenging, in part because of common terminology and recommendations that have traditionally been provided to farmers. For example, consider the following statement in an extension publication:

Compared to most other vegetable crops, lettuce has a moderate nitrogen requirement, taking up on average only 100 to 120 lb N/acre. Many replicated trials have demonstrated that, with efficient water management, seasonal nitrogen application of about 150 lb/acre should be adequate to achieve high yield and quality; in fields with significant residual concentration of nitrates in the soil even lower nitrogen rates can be adequate. (Hartz, 2009)

Although there is mention of “significant residual concentration of nitrates in the soil”, the recommendation above clearly illustrates two common concepts: [Q5][Q6]

1. Common recommendations are phrased in terms of “requirements” or “demand” and talk about the N uptake from the soil – not the N removal from a field at harvest.
2. Common recommendations have a built-in inefficiency. For example, one could interpret the statement above to say that the plant needs 100 lb N/acre, and the recommendation of application is 150 lb N/acre – a guaranteed efficiency of 67%, not including the difference between plant uptake and plant N removed.

One important hurdle that must be overcome is that common terminology and recommendations for Nitrogen applications that farmers are accustomed to hearing (often related to nitrogen uptake), currently are not consistent in focusing on matching N applications with N removal from fields (the ratio of Nitrogen Applied/Nitrogen Removed). These terms should be defined and emphasized in the training/awareness programs that will be discussed in the next section.

There is also ambiguity when distinguishing between plant uptake of N, and harvested (or removed) N. With some crops, most farmers are very aware of the negatives associated with excess uptake of nitrogen. For example, the yield and quality of cotton and almonds will suffer from excess nitrogen. However, it is difficult to know what the efficiency of N fertilizer uptake is, and information on synchronization is not widely available. Because of this, some farmers commonly apply more N than needed as a sort of “insurance” application to avoid negatively impacting crop quality and yields. The Panel agrees that optimized nitrogen use efficiency should be the focus of management practices encouraged.

Therefore, the Panel recommends a relatively simple metric to identify progress for this particular regulatory issue. [Q5][Q6]

The metric, to be measured and reported by farmers is the “A/R ratio”, where:

$$A/R = \frac{\text{Nitrogen Applied}}{(\text{Nitrogen removed via harvest}) + (\text{Nitrogen sequestered in the permanent wood of perennial crops})}$$

“Nitrogen Applied” includes nitrogen from any source. Example sources are organic amendments, synthetic fertilizer, and irrigation water. [Q4b]

4.3 *Effective Educational/Awareness Programs*

4.3.1 General

[Q8]The Panel believes that true progress in reducing nitrate leaching will only occur if good irrigation and nitrogen management plans are developed and implemented. The Panel believes that a very aggressive, well-funded, and high-quality educational program is necessary because there simply are not enough qualified consultants and individual farmers to develop and implement good irrigation and nitrogen water management plans.

There are presently a variety of professionals who are trained in irrigation and nitrogen management. Some have academic degrees from pertinent technical university programs in soil science, agricultural engineering, agronomy, or similar subjects. Short courses are offered by universities and commodity groups. Various professional groups have certification programs. The Certified Crop Advisor program focuses on crops and nitrogen,

but is weak on irrigation systems and irrigation management. The Certified Agricultural Irrigation Specialist program by The Irrigation Association focuses on drainage, irrigation systems and irrigation management, and salinity, but is weak on crops and nitrogen.

Educational programs must address two key groups:

1. Individual farmers or farm managers who are the water/nitrogen decision makers.
2. Persons who develop the irrigation and nitrogen water management plans

The Panel believes that in many cases, a single individual will fall into both groups. However, the level of detail and specific topics to be addressed for each group will be different.

Several topics were emphasized as vital components of a good grower/farmer education program, including: [Q8a]

- Water and nitrogen needs specific to particular crops – separating uptake versus removal
- How to create an appropriate irrigation schedule
- The standing of other growers in a region. In other words, what is the range of N applications/year for crop “Z”?
- Correct timing of nitrogen applications
- “Spoon-feeding” of fertilizers and other chemicals, rather than large-dose applications. Currently, most growers have neither the equipment nor adequate education to do this; however, education about and adoption of these techniques should be encouraged.
- Lower-dose, split applications of nitrogen throughout a growing season are highly recommended to reduce N fertilizer applications (similar in concept to “spoon-feeding”)

[Q4b]

- Maintenance requirements of different irrigation systems
- Nitrogen management considerations with crop rotations
- Fertigation principles – techniques, hardware, and chemicals
- Irrigation distribution uniformity
- Irrigation scheduling

4.3.2 Designing the Venue and Materials

Although it is easy to say that education is needed, the “devil is in the details”. Funding related to nitrogen has focused on research, to the almost total exclusion of developing strong educational programs for irrigation and nitrogen management either at the university level, or for universities to develop extension materials and programs.

It was beyond the scope of the Panel’s task to develop an educational or training program, but the Panel emphasizes that an effective program must address the following: [Q8a]

1. Fill in knowledge gaps and publish them widely
2. Make a clear decision on what the obligations of individual farmers will be, as well as the justification for those obligations
3. Define the training venue
4. Identify target audience(s)
5. Develop standardized training methods, materials, and examinations
6. Define the certification process for “trainers”

These six steps are described in the next sections.

4.3.2.i Filling in the Gaps

Discussions earlier in this report identified many areas with “unknowns”. The Panel acknowledges that many growers lack the information that they will need to fulfill the requirements of the A/R ratio regulatory program. These knowledge gaps must be identified and the information need to fill them must be published widely, such as through farming magazines. The primary gaps in knowledge appear to be:

- Harvested (removed) N for various crops
- Timing of uptake of N for various crops
- Requirements for other nitrogen balances, to ensure proper N uptake
- Justification for the inherent inefficiency that is embedded in UC recommendation of fertilizer applications that assume a 30% or so inefficiency

4.3.2.ii Defining Obligations

In order to gain widespread acceptance of any new program, farmers must be clearly informed of what their individual obligations are, and why. ^[Q8a] If the obligation is to develop and implement a good but simple management plan, this will be a major advancement for many farmers. The plan, however, must be developed by a qualified individual: either a consultant, employee, or the farmer. ^[Q8d] The farmer must certify that he/she will adopt the plan and implement it fully within a specified time period or before a specified date. The key elements of each annual plan, for each representative field, could be:

^{[Q9][Q6]}

- Keep records on all nitrogen inputs and timing
- Keep records on all irrigation inputs (flows and volumes) and timing. This requires a means of measuring or reasonable estimation of the flow rates and volumes into individual fields – **which is a major advancement for most farmers.**
- Keep records of rainfall
- Have recent measurement of the distribution uniformity of the irrigation system, or from a comparable irrigation system on the farm
- Summarize, in a neat table, the inputs and the expected consumption of water and nitrogen
- A list of improvements to be made the coming year

4.3.2.iii Defining the Training Venue

If the educational and training programs are expected to be provided for the long term, there must be consistency over many years, with the ability to upgrade and expand training. Several different venues that currently exist or could be created are listed below. An ideal venue may contain various elements from several of the current programs.

1. UCCE Certified Crop Advisor Workshops

^{[Q8c][Q8e]}The UCCE recently implemented a workshop effort with Certified Crop Advisors. That workshop appeared to be quite successful because it was very quick and reached a large number of people. However, this type of effort would be difficult to sustain, and difficult to provide over the long haul with consistency because it consisted of numerous people who

were evidently pulled together quickly. In addition, there was no testing, so there was no way to objectively evaluate the effectiveness of knowledge transfer.

2. Formal, Multiple-Day Workshops

[Q8c]A possible approach would be to have formal 1-3 day workshops such as some that Cal Poly has at ITRC. These are based on structured educational material, and are usually taught by only one or two individuals. Advantages include standardized materials that ensure participants obtain a consistent message from year to year. The timing is published well in advance, so people can plan on these classes every year, and many of the classes dovetail with Irrigation Association certification programs, which require that students pass classes.

Some disadvantages to this approach are that the classes require that people travel to a centralized location with well-equipped teaching laboratories, and that because these classes are often lab-intensive, they can be expensive to provide.

3. Distance Learning

Distance learning modules that incorporate testing and accounting of registration, etc. could be developed. With distance learning, people can study on their own schedules, from any location. If the material is standardized, all participants receive the same information from year to year, and the quality of the program does not depend on the instructor of the moment. Distance learning can be augmented by written materials, or local lab exercises, or could serve as a backbone training tool for an in-person training session. That is, an instructor can be present in Merced, for example, to help stimulate discussion, answer questions, etc. – but the “distance learning module” would be used as the primary teaching tool.

Distance learning also has several disadvantages. For example, a high-quality distance learning package is much more expensive to develop than most people think. It cannot be funded by student registrations, but must be developed with up-front funds. A high-quality course also takes months to develop. It is not the same as throwing together a PowerPoint presentation or video-recording a lecture.

4. Standardized Materials Taught Locally

[Q8d]Standardized training materials could also be developed that could be presented by local qualified individuals – not necessarily from a university. Some trade associations already do this. Such a program could allow local people to get heavily involved and invested in the program, but it may also be very difficult to get qualified people to teach the courses.

4.3.2.iv Identifying the Target Audience(s)

The training methods and materials must match the target audiences. It is clear that different audiences (for example, Certified Crop Advisors, as compared to irrigation foremen) may have different learning styles and also need to know different levels of detail.

4.3.2.v Standardized Training Materials and Examinations

Once the format(s) is/are defined, standardized training materials must be developed to provide knowledge transfer to those who will develop the irrigation and nitrogen management plans. The State Water Board should approve the curriculum that will be used

by various coalitions and groups. If applicable, standardized examinations must also be developed. While the Panel understand that there must always be local customization of training, there is also a common core of knowledge that should be understood.

The specific topics must be standardized and well-defined. A key item will be to build upon existing knowledge and expertise that is already found in specific universities, rather than starting from the beginning. For example, topics might be:

- How to fill out the basic cover sheet for a management plan
- How to determine timing of nitrogen applications
- How to determine lbs/acre needed, making various assumptions about the nitrogen cycle in the soil
- How to check for adequacy
- Interaction of N with other nutrients
- Fertigation principles and equipment
- Irrigation system evaluation

4.3.2.vi Certification Process

[Q8b] The core element of the recommended policy is to ensure that decision-makers have a good irrigation and nitrogen management plan that results in good nitrogen efficiency. Unfortunately, there are currently not enough qualified specialists available to develop thorough plans. It takes many years to develop high-quality training materials, implement a full-scale training program, and create more qualified specialists. Such development and execution requires significant funding, and this funding has not been even thought about at this stage.

Of key importance is defining the process for certification of “planners”. Trainers must be well-qualified. This is a serious challenge. People who understand the plant physiology aspects of water management often mistakenly assume they also know about irrigation system design and management – a very different topic, requiring a different skill set. In a similar vein, “grandfathering” people into certification can be undesirable because many years of experience does not necessarily mean that an individual has current knowledge.

A big question is if people need to have degrees in Soil Science or Agronomy. There are likely too few people who have these degrees. Another big question is if people who make management plans should already be certified in some other program.

It is vital to emphasize that simple attendance at classes is insufficient for demonstrating knowledge. Evaluation of course effectiveness is best done by evaluating (through testing) knowledge of the class participants. A simple course evaluation based on subjective statements such as “I learned a little, a lot, or nothing” is fairly meaningless. Exams need to be standardized, but have a good selection of randomized questions to prevent cheating. Grading must also be standardized. This is a major effort.

No matter what form the certification takes, however, it will be difficult to maintain consistent momentum, year-in, and year-out. Therefore, there must be some official organization to manage any certification program.

4.3.3 **Farmer Involvement**

[Q8a] The Panel realizes that if growers (farmers) or managers do not attend some meaningful, pragmatic training as described earlier, the desired goal of reducing nitrate leaching will not be met. It was the consensus of the Panel members that compliance will be low unless there is some enforceable requirement. The Panel members struggled with defining the proper incentives for grower compliance with management plan and training requirements. A variety of ideas were discussed, without a final decision for a recommendation.

One of the stronger ideas presented was that nitrogen fertilizer sales should be handled the same way as pesticide sales, in the sense that pesticides can only be sold if a purchaser has a valid and current permit. There are testing and continuing education requirements to obtain and maintain the permit. The permit is issued and recorded by the county Agricultural Commissioner, and must be on file with the pesticide seller. In a similar fashion, nitrogen fertilizers could be sold only on the condition that farms have on record, at the fertilizer sales office, a form that certifies the completion of a satisfactory irrigation water and nitrogen management plan. [Q4b]

The Panel recognizes that there will likely be challenges in getting widespread compliance from growers with small farms. There is likely a need for special training, funding, and/or reporting requirements for this group.

4.3.4 **Other Details**

The Panel acknowledges that there are liability concerns by some specialists who might eventually develop management plans. The State and Regional Water Boards must clearly define that the developer of plans will not be responsible for the proper implementation of that plan unless that person is also the implementer. Furthermore, it must be stated that it is understood that plans will be imperfect, and will be modified/upgraded over time after re-assessment of results, and as knowledge improves.

Three important issues that were discussed, but not finalized, were:

1. The timeline for various levels of educational effort
2. Requirements for continuing education
3. Who will review whether management plans are implemented

4.4 ***Nitrogen Management Plans***

[Q7d] The Panel has chosen not to create a “laundry list” of Best Management Practice (BMP) options for growers. Such lists⁶ already exist, but generally lack sufficient detail to be effective on a site-by-site basis, and usually avoid the root of the problem. The Panel agrees that lists of any specific practices should be in the form of heightened awareness only, rather than requirements.

⁶ For examples, see the NRCS’s Nutrient & Pest Management program (www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/crops/npm/), of the Best Management Practices Studies compiled by the Coalition for Urban/Rural Environmental Stewardship (CURES) (<http://www.curesworks.org/bmp/bmpGeneral.asp>)

Instead, the Panel believes that future efforts should focus on the following four areas:

1. **Creation of irrigation and nitrogen management plans specific to each grower and similar management unit**
2. Development and execution of awareness/education programs (discussed previously)
3. Implementation of the management plans
4. Internal (private) review and assessment of the impacts (crop quality, amount of fertilizer and water used, gross costs) [Q4b]

4.4.1 Collecting Pertinent Data

[Q7d]A first step (possibly requiring 1-3 years) for many management plans will be to describe and develop the data collection process (water and fertilizer) [Q4b], and data organization procedures and tools to accomplish this. The management plans will be subject to audit. Therefore, the data must be organized so that they can be easily understood by an auditor. The Panel recommends that the coalitions define the format of the data (database, tabular, spreadsheet, etc.), and the content.

The details of these plans should be used for management only, and not for reporting purposes. The management plans should aid growers in determining the current status of their nitrogen use, as well as develop tools and practices to minimize nitrogen applications. To begin the creation of a management plan, the irrigation/fertilizer decision makers must be knowledgeable about certain data (which should be updated at least annually). These data include: [Q5][Q6]

- How much nitrogen is being applied from all sources, including fertilizers, compost, irrigation water etc., plus residual nitrogen, as well as the timing and uniformity of the applications [Q4b]
- Residual nitrogen in the soil
- How much nitrogen is removed, by crop type. The Panel considers “N removal from fields” to include both the harvested portion and the nitrogen that is used for growth expansion on perennials (e.g., a number of 25 pounds/year/acre has been quoted for almond trees).
- The volume of water applied to a field (minus recovered tailwater for surface irrigated fields).

A subsequent step should be the organization of the prior year’s irrigation and nitrogen application schedules and amounts, combined with determination of how those could be improved.

4.4.2 Creating the Plan

[Q5][Q6] [Q7d]From the collected data, an appropriate nitrogen management plan, an appropriate irrigation schedule, and a plan for irrigation system maintenance should be developed for the upcoming year/season based on system type and anticipated crop demand.

The Panel emphasizes the following points about the proposed nitrogen management plans:

- Having a well-designed and implemented irrigation water and nitrogen management plan is a fundamental and good farming practice. [Q7d] The Panel believes that the management plans must be individualized and developed by competent individuals, and that the plans must identify actions to be taken to improve performance.
- The Panel believes that the State and Regional Water Boards should agree on the qualifications of the individuals who will create and evaluate irrigation and nitrogen management plans and the requirements of these plans. It is recommended that individual plans will not require approval from the Water Boards, but must be available for Water Board staff review.
- All management plans must include estimates of nitrogen required, nitrogen removed, the volume of water infiltrated in a field (separated as rainfall and irrigation), and the ET of the crop. They must account for the fact that some of the variables change over the season.

[Q5][Q6] [Q7d] A management plan will describe processes, procedures, and/or objectives that are applicable throughout each management unit/farm. For example, items such as wellhead protection, installation of new fertigation equipment, checking distribution uniformity of systems, will fall in this category. The Panel acknowledges that describing and understanding the nitrogen management of a 160 acre almond orchard is relatively simple as compared to describing and understanding the nitrogen management of 16 – 10 acre produce crop fields. While it is recommended that the same information be reported for both situations, it is clear that requiring separate management plans for individual fields – often of an acre or less with produce crops – is unreasonable.

[Q5][Q6] [Q7d] Within the management plan more detail will be provided for individual reporting units. The plan for individual reporting units will include an estimated fertilizer application schedule (amounts, timing), irrigation schedule (amounts, timing), and irrigation maintenance program. It will also define what/how data will be collected to estimate nitrogen and water application requirements. The process to annually evaluate the effectiveness of the plan should be described; this should focus on basic indicators such as the N applied versus removed.

4.5 Data Collection/Reporting

The recommended program involves the reporting of certain numbers. The Panel also assumes that these same numbers may have value to farmers in reducing fertilizer and/or water costs, and possibly improvements in yield. However, the numbers must be collected properly to have value. [Q9]

Some Regional Water Board testimony distinguished between data that needs to be collected, versus data that needed to be reported, versus data that needed to be maintained on-site for inspection by a farmer. Some speakers seemed to imply that as long as data were not reported, the cost to obtain that data would be small. The Panel believes that the cost and hassle of data collection for a farmer is similar whether it must be reported or not.

The Panel also acknowledges that much data that could be useful is often either not easily attainable, or simply unknown. For example, applied water volumes to individual fields are

not known in many cases with a high degree of accuracy. Many irrigation districts in California are currently struggling to meet a +/- 12% accuracy standard for measurement of annual volumes at district turnouts. Once district water is beyond the turnout, it is often split, applied to a large number of fields, mixed with groundwater in common pipe systems, and is generally not measured to individual fields.

Therefore, the Panel is proposing a data collection effort that is simple, yet effective.

4.5.1 Purpose of Data Collection

The Panel emphasizes that reporting by growers and any data collection requirements should be coordinated by third-party coalitions where feasible, rather than having farmers report directly to the Regional Water Boards. Coalitions should be allowed to define protocols for sampling of key values such as harvested nitrogen.

The Panel clearly recommends that the data collected be used for education and later development of management plans, not for enforcement initially. Grower understanding and improvements are vital, and growers will be reluctant to participate in programs if they fear self-incrimination. In particular, current groundwater conditions should not trigger reporting or regulation of above-ground activity. Current groundwater conditions can likely be useful for grower awareness by providing:

- Awareness of key components of on-farm nitrogen management about which they need to be knowledgeable
- Knowledge of whether his/her farm is in an area that has high nitrates in the groundwater
- Knowledge of the level of nitrates in the groundwater that he/she is using as his/her irrigation water

The basic data collection effort proposed by the Panel provides several compelling benefits to farmers, the ILRP, and groundwater quality in the long term. [Q9] It gets to the root of the nitrate issue in a simple, timely, and attainable fashion. This data collection effort serves two main purposes:

1. Development of baseline nitrogen application information, crop-specific, and integrated regionally. This provides the basis for comparison of regional nitrogen application differences and addresses the probability of nitrogen leaving the crop root zone via deep percolation. [Q10f]
2. Identification of multi-year trends as the data collection is continued.

4.5.2 Reporting

4.5.2.i *What Data Should be Reported*

Any improvements in nitrogen management on the ground must require the development and implementation of simple and pragmatic nitrogen and water management plans by farmers. A key element of any field/farm nitrogen management program is a record of the nitrogen applied to fields. [Q7a]

The recommended data collection/reporting effort seeks basic information, aggregated over the course of one year (e.g., calendar year or crop year), on a reporting unit scale. This effort purposefully limits data collection to basic information that can be easily obtained and all

farmers need and should be knowledgeable of as part of their nitrogen management. The data collected should be:

1. Crop (e.g., lettuce, wheat, almond)
2. Crop acreage (acres) – The crop acreage is the total acreage on which a specific crop is grown. If three different crops are grown in succession on the same field, this field's acreage is used to compute the nitrogen inputs for each of the three different crops. Nitrogen inputs to multiple plantings of the same crop are aggregated over the year.
3. Nitrogen applications for each crop (lbs/acre) including organic applications (e.g., manure, compost), synthetic fertilizer applications, and nitrogen in irrigation water [Q4b]. This requires separate estimation and documentation of these three nitrogen sources. The nitrogen application computation should include the total nitrogen applied as:
 - Organic applications (manure, etc.)
 - Synthetic fertilizer applications
 - Irrigation water

The Panel acknowledges that this method (reporting applied N) is imperfect. For example, a crop planted after alfalfa is removed will have a smaller nitrogen requirement than one that does not follow a legume. Nitrogen requirements will depend upon many factors. But as stated earlier, multiple years and multiple fields will create an averaging effect.

The Nitrogen Tracking & Reporting System Task Force (NTRSTF) provided a Final Report in December 2013 that listed recommendations for reporting. [Q12] Their list and this Panel's list are short. There is only one significant difference: The NTRSTF recommends a reporting of annual residual soil nitrogen credits. The Panel does not include residual nitrogen in its reporting recommendations.

4.5.2.ii Reporting Units

A “reporting unit” could be defined in one of two ways: (i) on a crop basis, which could include multiple fields that have similar soils, irrigation methods, irrigation water nitrate levels (not defined by the Panel), and irrigation/nitrogen management styles; alternatively, (ii) a reporting unit could be defined as an individual field. The Panel recommendation for grouping of multiple fields is more restrictive than the “nitrate loading risk unit” [Q2b] [Q13], or “management block” defined by Region 3.

This proposed data collection effort provides the flexibility to consider multiple fields that may receive nitrogen applications simultaneously but without the infrastructural means to separate their applications. It gives the flexibility to vary the field sizes between crops and seasons. It does not necessitate mapping or farm-scale spatial analysis.

4.5.2.iii Possible Grower Concerns

The Panel understands that details about the blends of fertilizer and the timing of fertilizer applications are considered to be the same as a trade secret by most farmers. Details of this type do not need to be shared for any reasonable nitrogen management reporting program.

It was discussed whether a program that requires reporting nitrogen concentration in groundwater might provide a disincentive for farmers to use high-nitrate water. The Panel

members believe that there should be no disincentive to pump high-nitrate water, and coalitions and Regional Water Boards must be especially careful to finesse guidelines that emphasize this point.

4.5.3 Timelines

The time period for a report should encompass a 12-month period, and should consolidate monthly or short-season values into single reported values. However, it is recommended that this annual data be evaluated on a multi-year basis. It is emphasized that the collected data should be used to examine regional, multiple-year conditions and trends of nitrogen applications. Analysis of these data on too-short time frames (e.g., year-to-year) will introduce random error and potentially misleading results because many confounding variables, such as residual soil nitrogen and nitrogen removal rates, vary by year and by crop rotation. These differences tend to even out over multiple years. It is also emphasized that the data should not be used for regulatory enforcement because the possibility of regulatory consequences will negate the accuracy of the data.

The Panel strongly recommends not assigning a regulatory value to the A/R ratio on an annual basis. Such ratios have merit for categorizing fertilizer management using multi-year averages. The Panel also emphasizes that the A/R ratios are not known at this time, that farmers, extension agents, and crop advisors need time to learn about these ratios, and we do not yet know the ranges of these values by region or by crop. Therefore, it is strongly recommended that such ratios not be used for regulatory action at this time.

4.6 *Monitoring*

The points below define the conceptual framework for an effective program that includes regulation, verification, and positive results. [Q9]

4.6.1 Farmer/Coalition Components

Farmers must be required to develop and implement good irrigation and nitrogen management plans (described previously). [Q7d] This recommendation comes with the caveat that certain groups (such as the rice growers on clay soils) may be considered for exemption because of very unique chemical situations, and that the groundwater quality of some areas may be de-designated from beneficial uses related to drinking water. This Panel asserts that a good irrigation plan, which requires measurement of volumes of water and the development of reasonable irrigation schedules, belongs in the program. The only way nitrates can move below the root zone is via deep percolated water.

The Panel recommends that reporting by farmers to the coalitions should be required, and be simple yet effective. The basic elements of reporting are reporting unit location, total nitrogen applied, estimate of nitrogen removed from the field by the crop, and acreage. Because of nitrogen transformations, and stored water and nitrogen (in the root zone), reporting should contain annual (or crop cycle) values rather than more frequent data. Multiple years of data (minimum of 3 years) are likely needed to ascertain trends and patterns. [Q9]

Irrigation water and rainfall volumes are not required for reporting, because the impact of good water management is evidenced by the nitrogen applied versus removal ratio. Those volumes are essential elements of an irrigation and nitrogen management plan, however. Individual fields can be grouped into units for reporting purposes, in which all fields have the same crop (or very similar crops as designated by coalitions; this is primarily targeted toward produce crops), same irrigation and nitrogen management plan, same irrigation water quality, same irrigation method, similar soils and same general geographic area.

4.6.2 Regional Monitoring

The monitoring of first-encountered groundwater is problematic, expensive, inconclusive, and in general would require a diversion of resources from important source control efforts. [Q10a] There are also serious limitations to drawing conclusions from single-year monitoring values. Such trends will not be useful for correlating the impacts of specific field practices on individual fields to underlying aquifer water quality. However, long-term monitoring of aquifer nitrate levels is important to assess the long-term effectiveness of the regulatory efforts. Multi-year values are necessary to smooth out the random fluctuations that occur on an annual basis. They also allow for the use of simplifying assumptions regarding changes in nitrogen pools within the root zone. [Q9]

The Panel does not recommend the development of a “scientifically based evaluation of the link between (a) proxy metric and actual discharge via a ‘Representative practice evaluation’”, which appears to be the concept behind the Management Practices Evaluation Program (MPEP) in the Central Valley RWQCB ILRP Orders (found on page 17, Attachment B, Tulare Lake Basin Order R5-2013-0120). Instead, the Panel recommends the use of the A/R ratio, averaged over multiple years after implementation of comprehensive, customized nitrogen/water management plans. [Q9]

4.7 *Targeted Research*

Pragmatic research is needed to identify attainable ratios for a range of crops and situations. Some of this research will be done by coalitions as they examine the reported data. Other research will be more traditional and will be related to topics such as rates and timing of nitrogen uptake and crop removal. The Panel also believes that research must be conducted to define sampling intervals, sampling density, and other factors. [Q10d]

4.8 *Verification*

The Panel recognizes that the State and Regional Water Boards must have some way of measuring progress over time on a regional basis. However, deep groundwater nitrate levels, examined over periods of less than 10-20 years, cannot be expected to demonstrate such an impact. A different metric must be used. [Q9]

Many factors, such as residual nitrogen and nitrogen removal rates, vary by year and by crop rotation. These differences tend to even out over multiple years. In collecting initial data, the Regional Water Boards will be able to report to the State Water Board a specific multi-year baseline for future comparison. This baseline can be used to indicate progress in the long term. Similarly, when viewed on a regional basis, areas with a relatively high nitrogen use can be easily identified based on this data. [Q9]

The Panel agrees that the trend monitoring of groundwater nitrate concentrations (not first-encountered groundwater) should occur, in order to track general aquifer conditions over multiple years. [Q10a] This can be done with water samples from existing wells. [Q9]

The metric that is recommended by the Panel is the long-term trend of the relationship (A/R) between nitrogen applied and nitrogen removed from the field, using information reported by farmers to the coalitions. Verification will consist of knowing if the A/R is reduced. [Q9]

4.9 Surface Water Discharges

Monitoring the water quality of surface discharges from individual fields/farms, as a general policy, has the following problems [Q3] [Q4] [Q10e] [Q11]:

1. Water quality tests are quite expensive, even with individual samples.
2. Periodic sampling of water runoff as opposed to extensive sampling has serious challenges with being able to identify events that might cause pollution of streams, because: [Q10d][Q10d]
 - a. The timing of individual sample collection might not coincide with pesticide applications, or with events of high sediment runoff.
 - b. It is difficult to identify, in advance, exactly when (time of day, and day) there might be surface runoff. This is because irrigation schedules constantly change as field crews shift operations.
 - c. Typical labor schedules for samplers require that samples be collected during daylight hours, from M-F. Other times/days may be more important.
 - d. The schedule of lab operations, and constraints of sample hold times, may not coincide with irregular timing of surface discharges.
3. Continuous water sampling equipment (to collect samples, and in some cases to also analyze samples) is available for some constituents, but it is very expensive, complicated, and subject to vandalism.

With surface water discharge monitoring, there is a special appeal for some type of coalition effort because it meets the recommendation of the Panel on how to address monitoring. If individuals do not belong to a coalition, there does not seem to be alternative to expensive sampling of every discharge point. The recommendation is to take sufficient samples in the watershed streams to detect if problems do indeed exist. The sampling should be of sufficient density (spatially and temporally) to identify general locations of possible pollution. For example, a single measurement point at the downstream discharge of a very large watershed would be insufficient. When/if problems are identified, sampling should move upstream with sampling to locate the source of the problem.

Recommendations of the exact density and timing of sampling are not provided by the Panel, because the details will depend upon the size and complexity of the watershed, and upon the results of data that are collected. If, for example, an initial and sparse network of sampling points at watershed bifurcation points indicates that there are no problems, it would be unreasonable to require a more intensive sampling point network.

For surface water issues, the Panel recommends water quality monitoring of receiving water and that the watershed hydrology be understood. Sufficient samples should be taken in the watershed streams to detect if problems do indeed exist. The sampling should be of

sufficient density (spatially and temporally) to identify general locations of possible pollution. This is recommended rather than sampling at each discharge point.

Individual point discharge measurements/monitoring would be used only if individual points are identified as being serious contributors to water quality problems, based on working upstream in the watershed.

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