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Project Summary

Controlling Sediment and Nutrient Losses from Pacific Northwest Irrigated Areas

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Environmental protection efforts dealing with agricultural and nonpoint sources have been increased since passage of the Clean Water Act of 1977 and the subsequent implementation of the Rural Clean Water Program. As part of the research on the occurrence, movement, transformations, fate, impact, and control of environmental contaminants, data and analytical methodologies are developed to assess the causes and possible solutions of adverse environmental effects of irrigated agriculture.

Efforts to achieve water quality goals include the identification and application of best management practices (BMPs) to control agriculturally related water pollutants. This report addresses the physical factors contributing to sediment and nutrient (phosphorus and nitrogen) losses from irrigated croplands, methods of characterizing water application to and losses from such croplands, and the economic techniques and/or factors for assessing the costs of selected pollution abatement practices. The methodology and techniques described will be useful in reaching technically sound and economically feasible environmental management decisions. This report should especially benefit environmental managers as they attempt to identify and implement pollution control strategies relevant to western irrigated agriculture.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

In October of 1972, the U.S. Congress passed Public Law (PL) 92-500, the "Federal Water Pollution Control Act Amendments of 1972." The most immediate concerns of this legislation were obvious point source discharges of municipal and industrial wastes. On a more gradual time scale, however, focus was also to be directed at point source and nonpoint source urban, rural and agricultural discharges. Initial emphasis in the point source agricultural area was given to livestock and dairy operations, and to clearly defined irrigation return flows. Permits were to be required for each such discharge. Litigation concerning the minimum size of irrigated unit requiring a permit delayed implementation of point source controls for irrigated areas. Subsequently, the Clean Water Act of 1977 (PL 95-217) completely exempted irrigation return flows from the National Pollutant Discharge Elimination System (NPDES) permits and placed them directly within the responsibility of Section 208 (b), the area-wide waste treatment management planning process, to be administered by the planning agencies of each state.

Planning for the control of nonpoint source discharges from irrigated and nonirrigated agricultural lands is well underway throughout the Pacific Northwest. Such planning, as required by Section 208 of the Water Pollution Control Act Amendments, is being conducted in most cases under the auspices of county or irrigation district water quality committees. One purpose of this report is to assemble and disseminate information for use by local groups in evaluating the extent to which adoption of specific management practices should decrease the discharge of sediment and fertilizer nutrients (particularly nitrogen and phosphorus) from irrigated areas of the Pacific Northwest. An equally important purpose is to provide local planning groups with a procedure for use in evaluating the economic costs of management practice changes, so that such groups can begin to address the question of how such costs should be borne for a given degree of water quality pollution control.

Personnel from the Agricultural Research Center at Washington State University have been heavily involved for several years in water quality assessment and in evaluating economic constraints on water quality control. A detailed survey of nitrogen, phosphorus and sediment discharge from the Palouse dryland wheat region was conducted in 1969-1971. A salt and nutrient balance was conducted in 1970-1971 for the Wapato Project in the Yakima Valley, and compared to results for the same area in 1940-1941. This study was of particular value because it provided corresponding data for a typical Pacific Northwest irrigated setting before and after commercial fertilizers had been introduced and used extensively. Effects of selected management practices on nitrate leaching from irrigated soils of the Columbia Basin were evaluated during the period 1970-1974. Concurrently, economic models were being constructed, and economic evaluations of selected management practices were being made, in order to determine the cost per unit of water quality pollution control. Such work, coupled with important on-going research on water quality in other Northwest states, has produced a timely need to compile available information for use by local water quality planning committees. Objectives of the current project have been to: (1) assemble, refine and present to key personnel from the Pacific Northwest a predictive procedure for estimating sediment and fertilizer nutrient losses from irrigated portions of the area; and (2) present analyses demonstrating basic approaches and typical results when assessing the economic consequences of adopting selected pollutant control practices.

Study Approach

General cropping pattern information was assembled for major irrigated physiographic regions of Washington, Oregon, and Idaho, as well as irrigation system characterization data. Sources of soil survey and land class information were identified to aid workers in establishing model farm characteristics for comparing physical and economic effects of proposed management systems. Background information was assembled on physical factors leading to sediment and nutrient (phosphorus and nitrogen) losses from irrigated croplands, and on methods of characterizing water application rates and losses. Economic techniques and/or factors for assessing the costs of selected pollution abatement practices are also discussed.

A relatively simple technique is proposed for assessing losses of nitrogen and of sediment (with associated phosphorus) from Pacific Northwest irrigated croplands. The technique attempts to incorporate dominant factors affecting erosion losses, as well as the spatial nonuniformity of nitrate leaching from furrow- and sprinkler-irrigated lands of the region. Nutrient loss estimates are generated for model farms in the Magic Valley area of Idaho and the Umatilla area of Oregon, along with an economic analysis of selected pollution abatement practices. These results are compared to those from prior studies in the Yakima Valley of Washington. The nutrient-loss estimation technique, and the model-farm approach to economic analysis, should be of aid to Section 208 (PL 92-500) planning and implementation programs in irrigated portions of the Pacific Northwest.

Presentation of Findings

In Section 4 of the final report, cropping pattern information is presented for major irrigated physiographic areas of the Pacific Northwest, and cropping pattern and irrigated acreage trends for the period 1959-1974 are summarized. These data emphasize the predominance of relatively nonpolluting hay and grain crops in many irrigated areas of the region, and assist in focusing on more highly erosive and more heavily fertilized row-crop areas. Also included are state-wide summaries of irrigation system information, and narrative highlights of irrigation system data for individual physiographic areas. These data demonstrate that furrow irrigation still predominates in the region, despite rapid conversion to center-pivot sprinkler systems. Because of the uneven nature and incomplete coverage of soil survey and land classification information for physiographic areas of the region, no specific data are presented in this category. Sources of such information and their use in nutrient-loss estimates are discussed, however.

Section 5 reviews economic concepts and policies related to the control of pollution from irrigated agriculture. Community property rights and private property rights are contrasted, and costs of pollution are illustrated via supply and demand functions for trade goods. The concepts of externalities and opportunity costs are introduced prior to a discussion of benefits and methods of pollution abatement, and of income distribution problems. The difficulties of marketplace solutions to traditional pollutant abatement problems are stressed, and the transaction costs associated with various types of liability distribution are emphasized. Selected abatement implementation policies are reviewed, including effluent standards, effluent taxes, subsidies, output taxes, and input taxes and/or limits. The section closes with a discussion of various methods and philosophies related to determining the "correct amount" of pollution abatement.

In Section 6, the background material is summarized which relates to sediment and nutrient loss estimates for irrigated lands. The determination of irrigation requirements is included as a part of the information necessary for nutrient loss predictions, with major emphasis on the concept of irrigation efficiency (E), and on the subdivision of (1-E) values into runoff, deep percolation, and evaporative losses. Rooting depths and water holding capacities are provided for selected crops and soil types typical of Pacific Northwest irrigated areas. These are combined into values for depletable soil moisture and numbers of irrigations for crop-soil combinations representative of the Magic Valley area of Idaho and the Umatilla area of Oregon. Allocation of efficiency, runoff, and deep percolation values for current and proposed irrigation systems is outlined, including correction for variations in slope class and soil type. Net irrigation requirements and seasonal water application estimates are provided for the two study areas listed above.

The effects of various factors on sediment and total phosphorus losses are also reviewed, including slope, stream size or percent runoff, tillage, set length, soil texture, and crop type. A methodology for predicting sediment losses is outlined, based upon assignment of a sediment-loss estimate for prescribed base-level conditions, and then assignment of multipliers to account for changes in sediment loss associated with variations in factors of the type just described. Total phosphorus loss is assumed to remain a constant proportion of sediment loss. This assumption will require refinement as sediment and phosphorus loss data become more widely available for irrigated areas of the region, but it serves as a suitable first approximation at present. Background information on nitrogen loss estimates (largely from University of California studies) is reviewed, and related to prior measurements for irrigated tracts in the Pacific Northwest. A methodology for predicting nitrate leaching losses is outlined, based on the amount of deep percolation and nitrogen fertilization, with corrections for nonuniformity of water application (by dealing with the amounts of deep percolation and nitrogen fertilization that might reasonably be expected for tenth-field subunits of each irrigated field) and for denitrification (as related to surface-soil texture).

Section 7 summarizes the recommended procedures for sediment, phosphorus, and nitrogen loss estimates for Pacific Northwest irrigated croplands.

In Section 8, the procedures for estimating sediment, phosphorus, and nitrogen losses are applied to two Pacific Northwest irrigated areas (the Magic Valley area of southcentral Idaho and the Umatilla area of northcentral Oregon). Model farms are established for each area. Various irrigation system and cropping pattern changes are evaluated with respect to the sediment and nutrient losses, and associated economic costs, which each would produce. For the Magic Valley, the use of filter strips, sediment ponds, and pump-back irrigation would all lie on the "efficiency frontier" curve representing sediment-loss abatement at minimum cost. Use of improved furrow management, cut-back irrigation systems, and gated-pipe delivery systems would also lie only slightly above the efficiency frontier curve, but conversion to side-roll sprinklers, multiset irrigation systems, or alternative cropping patterns would abate sediment loss only at considerably higher cost.

With respect to nitrogen loss abatement for the Magic Valley, use of improved furrow management, cut-back irrigation, or gated-pipe would all be on the efficiency frontier curve, and produce approximately 50 percent abatement (in the case of cut-back irrigation or use of gated-pipe systems) at relatively little cost. Further abatement of losses would require markedly higher costs per unit of abatement, however. For the Umatilla area, over 50 percent abatement of nitrogen losses could be effected through improved management of center-pivot systems at relatively little cost, but conversion to alternative cropping patterns would abate nitrogen losses only at considerable cost. The remainder of this section summarizes the similar studies for the Yakima Valley of Washington.

The Appendix contains tabular data required for sediment and nutrient loss estimates, and economic appraisals, for the Magic Valley area of Idaho and the Umatilla area of Oregon.

Conclusions

Though considerable variation exists between physiographic regions, Pacific Northwest irrigated croplands have continued to grow relatively large amounts of hay, pasture, and small grains. These crops are relatively nonerosive and also have relatively low potentials for nitrate leaching, except for the initial plow-out period of alfalfa fields. The greatest potential for soil and nutrient losses is associated with smaller amounts of furrow-irrigated, row-crop acreage (potatoes, corn, beans, etc.). Highly erosive conditions also exist on some orchard lands of the region, if cover crops are not being used. Despite rapid conversion to sprinkler (especially center-pivot) systems, furrow irrigation remains the dominant irrigation technique for most Pacific Northwest areas.

The technique used to estimate sediment (with associated phosphorus) losses from furrow-irrigated croplands of the Pacific Northwest consists of establishing base-level conditions, with estimated sediment loss, and then revising sediment-loss predictions as physical factors (slope, soil texture, crop type, stream size or percent runoff, etc.) are changed for other areas or different management conditions. Total phosphorus is assumed to remain a constant proportion of eroded sediment. Though overly simplistic, the technique at least provides a framework with which to compare additional sediment loss values as they become available, and through which needs for refinement of the effects of various physical factors should become apparent.

Nitrate leaching estimates generated for well-characterized southern California conditions were modified for the Pacific Northwest, by incorporating an estimate of the nonuniformity of water application and a soil texture-dependent denitrification multiplier. Such refinement lowered the southern California estimates, which were two- to three-fold too large when applied directly to Pacific Northwest irrigated tracts, to more realistic levels.

Physical models of nutrient loss from irrigated croplands have been coupled to economic appraisals through a model-farm approach. Use of such an approach for three Pacific Northwest irrigated areas (the Magic Valley area, Idaho; the Umatilla area, Oregon; and the Yakima Valley, Washington) demonstrates the effectiveness and associated costs of selected pollution-abatement practices. For example, a substantial amount of nitrogen-loss abatement, 50 percent or more, can be achieved without significantly affecting farm income. Almost complete sediment-loss abatement can also be achieved at costs considerably below those of conversion to center-pivot sprinkler systems, an option which is being adopted with increasing frequency throughout the irrigated West. It becomes very costly to achieve nitrogen-loss abatement levels beyond 50 percent, however, or beyond those that can be achieved with managerial improvements, inexpensive shifts in existing irrigation systems, and sediment retention devices. The last increments of combined abatement, and particularly of nitrogen-loss abatement, are achieved only at extremely high cost.

Control practices to abate sediment losses will generally have little effect on the abatement of nitrogen losses. In order to simultaneously achieve the abatement of pollution from percolated and runoff waters, it is necessary to invest in more expensive irrigation systems and/or to change to substantially less profitable cropping patterns. The final choice of pollution control practices must be governed by the problem(s) to be solved and the available funds for pollution abatement. There is little reason to make expenditures for pollution abatement that substantially exceed derived benefits.

It must be recognized that edge-of-field nutrient losses cannot be translated directly to surface-stream water quality impairment. Sediments and phosphorus may be retained in drainage ditches and/or redeposited on other cropland. Nitrogen may be utilized by drainage-ditch vegetation or by other crops during return-flow reuse. Such redistribution of sediments and nutrients must be included in basin-wide models of surface-stream quality.

This study only illustrates a methodology that can be followed in arriving at pollution abatement solutions for irrigation return flows. Each problem area must be analyzed for its own characteristics, with specific agronomic, soils, and economic data collected and alternative control practices analyzed for efficiency and effectiveness in abating pollution. Choices must be made regarding the level of abatement to be achieved and the distribution of costs for such abatement.

Generally it will be easier to share costs incurred for capital investments in items such as new irrigation systems or ditch lining, for public investment in capital items is generally assured of a long-term change in levels of pollution. An expenditure for implementing an irrigation scheduling service or an end-of-field filter strip, however, has no assured effectiveness beyond the year of investment. If the objective of federal subsidies is to compensate the farmer for income losses, year-to-year variations in farm income due to changes in crop prices or yields can raise sizeable uncertainties about required expenditures.

This study has shown that the most cost-effective measures of pollution abatement are those of a temporary or nonstructural nature. These temporary measures will be difficult to administer, however. In the past, agencies such as the Soil Conservation Service have been reluctant to share costs of nonpermanent soil conservation practices. These and other problems must be solved before widespread pollution abatement programs can be implemented for irrigated agriculture. This report provides a current estimate of technical knowledge and abatement alternatives which can be applied to problems of return-flow pollution. Knowledge will change as experience is gained. The information herein is only a suggested foundation on which to build.

Recommendations

This study has illustrated a methodology for assessing the costs and benefits of selected pollution abatement practices for irrigation return flows. The methodology has intentionally been kept simple to permit its usage and/or visualization by relatively nontechnical groups. It is hoped that this report will encourage prior assessment of proposed management changes by Section 208 (PL 92-500) personnel in order to quantify probable abatement and cost effects of planning efforts.

Management plans should be developed with a specific view toward the elements to be abated and the desired level of abatement to be achieved. It is not useful to abate pollutants unless derived benefits equal or exceed incurred costs. This report shows that modest levels of nutrient and sediment losses can be abated rather inexpensively through management improvements or small capital expenditures. These approaches should be considered prior to employment of more effective, but more costly or energy-intensive, irrigation systems. Expensive and energy-intensive sprinkler systems should not be subsidized for abating nitrate losses, for example, if realistic management of fertilizer and water with present furrow-irrigation systems can achieve adequate abatement. On the other hand, it sometimes will be necessary to turn to a practice that is more expensive and/or more energy-intensive than others in abating a single pollutant, because of its combined effectiveness in abating more than one pollutant, such as leached nutrients and eroded sediments.

Abatement plans should emphasize education programs that will inform parties about their potential role in environmental improvement. Significant quality improvements probably can be achieved by some farmers without costly investments or reductions in net income. These efforts should be emphasized and implemented prior to the use of subsidy programs that may also affect subsequent freedom of decision making.

This study primarily provides an assessment of current knowledge for estimating effluent quantities and evaluating alternative abatement control measures. To achieve the desired level of generality for this report, data specific to all major irrigated regions of the Pacific Northwest could not be included. Hence, the data presented are intended only as a foundation upon which to build in solving problems for a particular region. Similarly, the methodology suggested for project assessment is only an example of that which might be useful or necessary in any specific situation. It is recommended that persons responsible for pollution abatement planning obtain the assistance of professional scientists (particularly in the areas of soils, agricultural engineering, and agricultural economics) to help build and evaluate alternative programs. The costs of such assistance are likely to be far less than the costs of programs improperly perceived and implemented.

Finally, it is recommended that abatement programs be developed with a careful view of the problems to be solved and the benefits to be derived from such resolution. It is not useful to expend scarce capital or to reduce agricultural outputs merely to reduce effluents that are causing virtually no problem. Similarly, there is no reason to expend large sums to abate one component, such as nitrates, if another such as water temperature is really limiting the quality of receiving waters. We must not focus on the abatement of one effluent pollutant simply because we know how to reduce its level, if other pollutants actually limit water quality. In short, we must be careful not to allow the level of program costs to escalate beyond the level of perceived and measurable program benefits.

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The complete report, entitled "Controlling Sediment and Nutrient Losses from Pacific Northwest Irrigated Areas," (Order No. PB 82-255 357; Cost: $18.00, subject to change) will be available only from:
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