USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Phosphorus Source/Sink Dynamics in a Flood-Irrigated Agricultural System in Central Idaho.

Focus Categories: AG, HYDGEO, HYDROL, IG, NU, NPP, ST, WQL

Keywords: Agriculture, Contaminant Transport, Irrigation Management, Land Use, Phosphorus, Pollutants, River Basin Development, Runoff, (Un)saturated Flow, Soil Chemistry, Soil Erosion, Suspended Sediments, Water Quality Management, Water Quality Monitoring

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FY 1999 Non-Federal (Matching) Funds: $32,343

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Congressional District: 1

Statement of Critical Regional or State Water Problems

Water quality protection through restoration and management of watersheds is receiving tremendous attention in the United States at all levels of government and in local communities. Since contributions of most point sources (e.g., sewage treatment plants and industrial sites) have been reduced to acceptable levels, the main emphasis presently is on the control of non-point sources originating from urban, forest, agricultural, and recreational lands. Non-point sources are covered by sections 208, 303(d) and 319 of the Clean Water Act. Approximately 1000 water bodies are currently classified as impaired or use-limited in each state in the western U.S.

Many water bodies are classified as P-limited due to their high nitrogen:phosphorus ratios (N:P >> 10) (Sharpley et al., 1994; Chapra, 1997). Consequently, water pollution abatement strategies frequently focus on reductions in P loading. State and local agencies throughout the U.S. are in the process of setting permissible load allocations, expressed as Total Maximum Daily Load (TMDL), and developing water quality management plans for all use-limited water bodies. The greatest challenge in developing these management plans is meaningful and realistic allocation of load reductions for all land uses within a watershed. Unfortunately, because these agencies operate with very limited financial resources and have an extremely challenging time line (e.g., eight years in Idaho), load reduction goals are based on minimally comprehensive, and potentially misleading, water

quality monitoring data and on a limited understanding of fate and transport of pollutants. Some perceive the process as subjective and empirical in nature.

The development of the water quality management plan for the Cascade Reservoir in Idaho exemplifies the problems described above. Water quality data have been collected at different levels of comprehensiveness for forest, urban and agricultural land uses. Partitioning the total P load into the various land uses is difficult given the lack of comprehensive data. In particular, P loading from agriculture, mainly irrigated pasture and hay land, has not been accurately determined due to extremely limited monitoring data and the lack of representative model parameters. The agricultural P load is currently estimated to be ~15,800 kg P/yr or 44% of the annual P load to the reservoir (D. Davidson, Idaho Soil Conservation Commission, personal communication). This value is determined from the area-weighted difference between the estimated total nonpoint load (~35,700 kg P/yr) and estimates for natural (~11,000 kg P/yr), forest (~5,900 kg P /yr) and urban sources (~3,000 kg P/yr).

Indirect assessment of agricultural P loading is subject to over-estimation and, therefore, is potentially unfair to agricultural land owners. During Phase II of TMDL development, agriculture as a whole would need to reduce its P loading by 30%. Major problems could arise if landowners commit to expensive Best Management Practices (BMPs) only to find out years later that their efforts did not achieve specific water quality goals. Furthermore, several studies show that loading from non-point P sources is seasonally dependent, a fact not addressed in the current Cascade Reservoir load allocations. Given the inherent uncertainties associated with estimating non-point P sources, it seems critical to pursue an improved assessment of the agricultural contribution.

The research literature contains insufficient information for estimation of P loading from irrigated agriculture. It is clear, therefore, that a comprehensive study is needed to document relationships between P loading and watershed parameters that would 1) provide a more accurate value for agricultural P loading in the Cascade Watershed and 2) provide information that would be readily transferable to other agricultural regions in the western United States. Such relationships should be developed from direct measurement of flow volumes and soil-water P concentrations monitored throughout the year to accurately determine seasonal P dynamics.

Statement of Results or Benefits

The proposed study will provide an in-depth analysis of the seasonal P contribution from irrigated pasture and hay land to the Cascade Reservoir. We hypothesize that P cycling is seasonally dependent. Hence, we will determine P loading by evaluating source/sink relationships during i) spring snowmelt and rain-on-snow events, and ii) the growing season which is characterized by subsurface irrigation. Phosphorus will be determined as total (TP), dissolved (DP) and particulate (PP). These P fractions are important in selection of BMPs to reduce P loading (e.g., total runoff reduction when DP loading is high versus erosion control when PP loading is high).

Results will include (1) a continuous, three-year record of DP and PP loading from two 18 ha, irrigated pasture/hay fields, (2) semi-empirical quantification of surface and sub-surface contributions to P transport using enrichment ratios and P desorption, (3) an improved understanding of in-situ P sorption-desorption as a function of seasonal soil saturation and temperature, and (4) the dynamics of P transport beyond pasture fields in irrigation ditches. We will use the data from Year 1 to develop tentative export coefficients (kg/ha) and P source/sink relationships for pasture fields and ditches. These relationships will be tested and further refined in Years 2 and 3. The combined results of fields and ditches will also be extrapolated to estimate P sinks and sources at the watershed scale.

The immediate study area in Idaho affects Cascade Reservoir which is designated on the 1994 303(d) list as a high priority water body. Results of this study are directly applicable to the 20,000 ha of sub-irrigated pasture and alfalfa hay lands, affecting almost all water bodies within the Cascade Reservoir watershed. Collectively these water bodies are limited for cold water biota, contact recreation, domestic and agricultural water supply and salmonid spawning. Results will also be relevant to improved watershed management of thousands of hectares of irrigated pasture and alfalfa hay in the Intermountain Region of the western United States.

Nature, Scope, and Objectives of the Research

Estimates of phosphorus (P) loading from agricultural land use in western states are needed for remediation of water quality problems as well as for long-term sustainable watershed management. Although P loading has received considerable attention in the research literature in the past two to three decades, annual estimates of P loading from subsurface/flood or sprinkler irrigated pasture land have not been reported. Many reports available on non-irrigated pastures are mostly applicable to soils in the eastern and midwestern portions of the United States (e.g., Edwards et al. 1996; Austin et al. 1996; Beaulac and Reckhow, 1982; Loehr, 1974; Harms et al., 1974). Miller et al. (1984) reported net loss of P from flood irrigated grass and alfalfa hay land in Nevada, but measurements only covered the irrigation season, ignoring P loading during spring snowmelt.

The principal investigators have one completed and one ongoing research project in the study watershed. McGeehan (1996) conducted a study on P sorption and desorption in seasonally saturated soils from the Cascade area documenting the potential for changes in P sorption and desorption that occur in response to changing soil redox conditions. Both PI's are involved in a mass balance study of two fully instrumented field sites in the watershed in collaboration with the Valley County Soil and Water Conservation District (VSWCD). This project received funding from the Idaho Department of Water Resources to evaluate P export from agriculture in irrigated pasture/hay fields for water quality improvement with emphasis on sprinkler irrigation as a BMP and includes mass balance measurements, cost-benefit analyses and other socio-economic aspects.

Since an isolated field experiment falls short of documenting the temporal and spatial variable P loading at the watershed scale, we will expand the ongoing project to include P transport from the pasture fields to irrigation ditches connecting the fields to Willow Creek. Important questions we attempt to answer are: "What are the relative magnitudes of P sources from agriculture in the Cascade Reservoir watershed ?", "What time of year do these sources release the greatest P loading?", and finally, "When is the impact of an individual source noticeable in downstream aquatic ecosystems?".

The overall objective of this proposal, therefore, is to develop seasonal P source/sink relationships for irrigated pastures. We hypothesize that P cycling is dynamic and seasonally dependent, and requires evaluation at a scale larger than the field scale. Hence, we will compare P source/sink relationships during i) spring snowmelt and rain-on-snow events, and ii) the growing season which is characterized by subsurface irrigation. Source/sink relationships will be determined by measuring enrichment ratios and P desorption in soil/sediment samples and dissolved (DP), particulate (PP), and total (TP) for water samples. Detailed field data will be collected for three years from two fields and associated ditches in a subwatershed of the Cascade Reservoir watershed in central Idaho.

Specific research objectives are:

Objective 1. To determine surface and sub-surface P inputs and outputs on a seasonal basis for two subsurface irrigated pasture/hay fields.

Objective 2. To measure P desorption as a function of soil depth, total soil P, soil temperature and soil saturation history in the same fields as in Objective 1.

Objective 3. To develop seasonal P transport relationships for dissolved and particulate P and predict annual P loading.

Objective 4. To determine the dynamics of P transport beyond pasture fields in irrigation ditches.