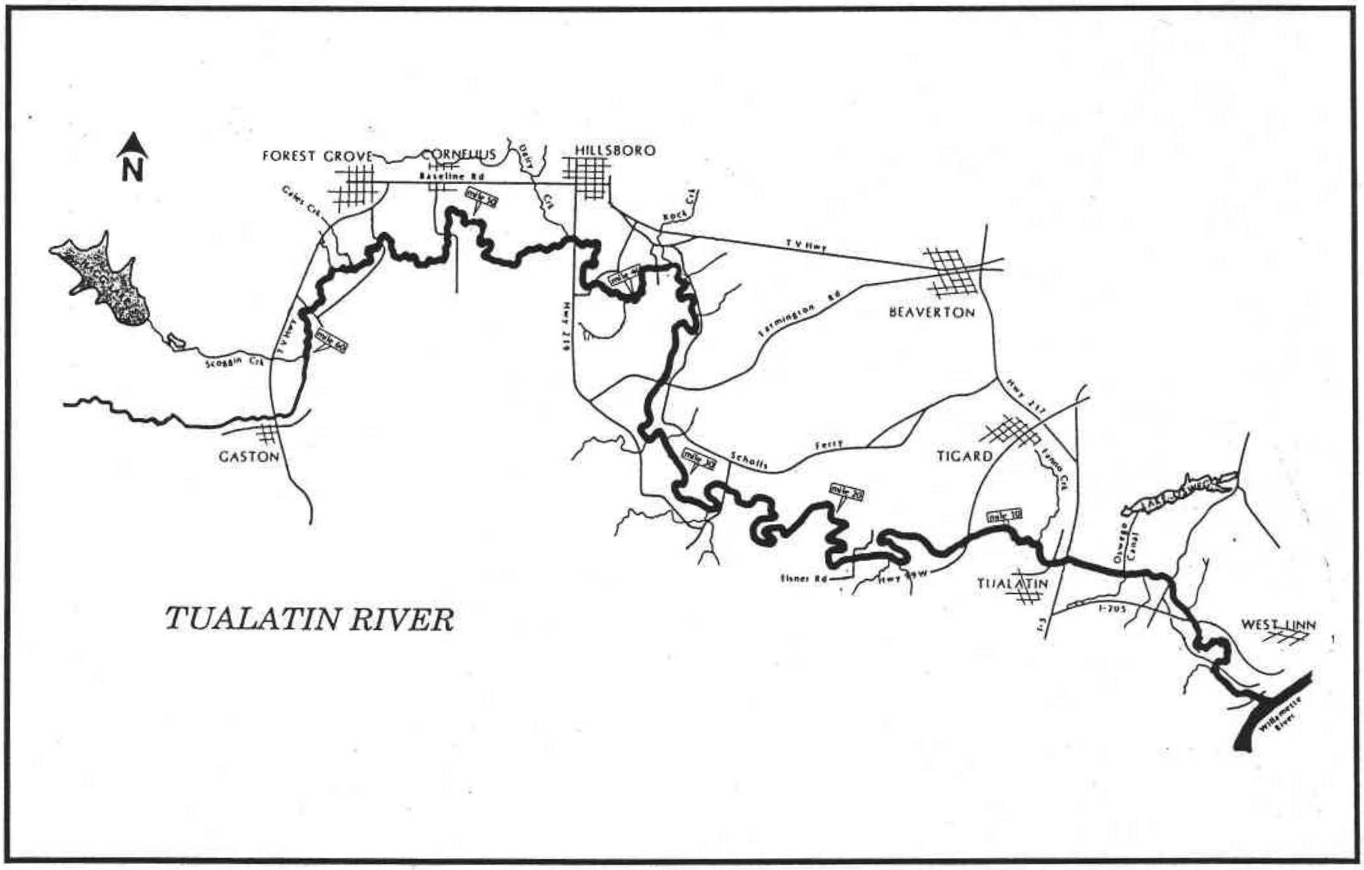
Estimated Costs of Reducing Nonpoint Phosphorus Loads From Agricultural Land in the Tualatin Basin, Oregon



August 1995

A Publication of the:

Oregon Water Resources Research Institute

TUALATIN RIVER BASIN SPECIAL REPORTS

The Tualatin River Basin in Washington County, Oregon , is a complex area with highly developed agricultural, forestry, industrial, commercial, and residential activities. Population has grown in the past thirty years from fifty to over 270 thousand. Accompanying this population growth have been the associated increases in transportation, construction, and recreational activities. Major improvements have occurred in treatment of wastewater discharges from communities and industries in the area. A surface water runoff management plan is in operation. Agricultural and forestry operations have adopted practices designed to reduce water quality impacts. In spite of efforts to-date, the standards required to protect appropriate beneficial uses of water have not been met in the slow-moving river.

The Oregon Department of Environmental Quality awarded a grant in 1992 to the Oregon Water Resources Research Institute (OWRRI) at Oregon State University to review existing information on the Tualatin, organize that information so that it can be readily evaluated, develop a method to examine effectiveness, costs and benefits of alternative pollution abatement strategies, and allow for the evaluation of various scenarios proposed for water management in the Tualatin Basin. Faculty members from eight departments at Oregon State University and Portland State University are contributing to the project. Many local interest groups, industry, state and federal agencies are contributing to the understanding of water quality issues in the Basin. This OWRRI project is based on all these research, planning, and management studies.

This publication is one in a series designed to make the results of this project available to interested persons and to promote useful discussions on issues and solutions. You are invited to share your insights and comments on these publications and on the process in which we are engaged. This will aid us in moving towards a better understanding of the complex relationships between people's needs, the natural environment in which they and their children will live, and the decisions that will be made on resource management.

ESTIMATED COSTS OF REDUCING NONPOINT PHOSPHORUS LOADS FROM AGRICULTURAL LAND IN THE TUALATIN BASIN, OREGON

by
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The Tualatin River Basin Studies are being done under a grant from the Oregon Department of Environmental Quality to the Oregon Water Resources Research Institute at Oregon State University. Published by the Oregon Water Resources Research Institute.

Tualatin River Basin Water Resources Management
Report Number 9

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INTRODUCTION

About one-third of the land in the Tualatin Basin is used for agricultural production (Miner, Scott, and Wood, 1994). The variety of crops produced includes grains, specialty seeds, vegetables, fruits, berries, and nursery corps. Cattle and hog enterprises are the most prevalent livestock operations in the area (measured by number of head), with small numbers of dairy and sheep operations also present. Agricultural production can be a nonpoint source of phosphorus pollution. One alternative in helping to meet Total Maximum Daily Load (TMDL) limits for phosphorus in the Tualatin River is to decrease the loading of phosphorus from agricultural sources.

Potential sources of agricultural phosphorus pollution are from applications of phosphorus fertilizers and livestock wastes through surface runoff on sediments and groundwater interflows (Wolf, 1993). A range of best management practices (BMPs) has been identified to address these sources (Washington County Soil and Water Conservation District, 1991); most are technically feasible to implement. Documented reductions in pollution due to adoption of these practices are generally not available, but most experts agree that the practices would result in decreased levels of phosphorus loads from agriculture. This report describes a set of management practices that have been suggested to reduce agricultural nonpoint source pollution and estimates the economic impacts of adopting these practices.

DESCRIPTION OF BEST MANAGEMENT PRACTICES

Best Management Practices (BMPs) have been identified for three farm types in the Tualatin Basin: crop and livestock farms, confined animal feeding operations, and container nurseries (Washington County Soil and Water Conservation District, 1991). BMPs for confined animal feeding operations and container nurseries tend to be site-specific, and depend largely on the facilities, structures, and the management system in place on each of these unique operations. Confined animal feeding operations and container nurseries which manage or discharge waste water must obtain water pollution control facility permits from the Oregon Department of Environmental Quality. The permit process is administered by the Oregon Department of Agriculture.

We assume that adoption of BMPs by confined animal feeding operations (CAFOs) and container nurseries will result in water quality changes and economic costs at least as great as those estimated from crop and livestock farms. Many of the CAFO and nursery management changes are already occurring under action by animal and nursery operations. However, because these actions do not require any activities beyond existing permit requirements under CAFO regulation or under voluntary action, the costs are not attributable to measures considered in this study.

Due to the site-specific nature of BMPs for these operations and recognizing that water quality plans are already in place for them, the analysis that follows will focus on crop and livestock farms. These farms account for the majority of acreage and farms in the area.

BMPs for crop and livestock farms are classified according to three management objectives. The first set of practices addresses efficient management of phosphorus. Next, practices to control runoff are identified. The third classification is a set of BMPs designed to control erosion.

Cultural operations and resource requirements for BMPs analyzed below, are based on input from a panel of local experts. This panel included farmers, SCS staff, and OSU extension staff. Neil Rambo, Washington County Extension Agent, was particularly helpful in this project. The panel also identified likely environmental consequences of adopting BMPs, and incentives or barriers to adoption. Controlled experimental or other scientific information specific to the basin was not available.

EFFICIENT MANAGEMENT OF PHOSPHORUS

Phosphorus inputs in agriculture include commercial fertilizers and livestock wastes (e.g., manure and bedding). One set of practices that can be adopted addresses increased efficiency of phosphorus use. These practices include applying phosphorus at plant utilization rates based on crop nutrient requirements and realistic yield goals; applying phosphorus fertilizers at optimal times of the year; incorporating broadcast applications of phosphorus into the soil; and banding phosphorus whenever possible. Each of these practices may change expenses and/or revenues, although they would not typically require additional long-term investments at the farm level.

Changing application rates for phosphorus to no more than the amount that will increase crop yield is expected to result in slightly lower phosphorus used on an average per-acre basis. Most growers rely on fertilizer guides to determine the rates at which they fertilize, but some reduction is possible through more comprehensive soil and tissue sampling for nutrients. One limitation to adoption of this BMP is a lack of comprehensive nutrient response data. Improved knowledge of plant nutrient response rates would provide a sound basis for changing (or not changing) fertilization rates. Incentives for reducing phosphorus use include lower fertilizer costs for materials and application.

Changing the timing of phosphorus applications is assumed to have a minor effect on phosphorus loading. The purpose of this BMP is to minimize the amounts of nutrients applied when the soil is wet and leaching or erosion potential is high. For annual crops in the Tualatin Basin, this means applying the majority of nutrients in the spring rather than the fall. Perennial crops, such as grass seed and berry crops, commonly receive fall nutrient applications, but these crops do not have high erosion potential if managed properly. Also, they tend to take up nutrients in the winter and spring, reducing the possibility that nutrients are transported to waterways.

Two general changes in fertilization practices which may improve water quality are incorporating all broadcast applications into the soil and banding fertilizer near plant roots. Incorporation of fertilizers reduces the amounts of nutrients which are lost to runoff, and banding fertilizers places nutrients where they are needed and most likely to be utilized. An incentive for both incorporating and banding nutrients is that these practices may, through more efficient plant utilization, improve yields and/or quality of production. The possible additional environmental benefit of these practices is limited, however, in that they are already widely used by growers.

RUNOFF CONTROL

Most runoff control problems are associated with CAFOs and container nurseries, and they typically require site-specific solutions such as clean water diversion, manure storage and handling facilities, irrigation water management, and water reuse facilities. There are also options which crop and livestock farms can use to reduce or eliminate potential runoff problems. Vegetative filter strips and fencing around riparian areas are two methods that appear most promising for improved runoff control on crop and livestock farms.

Few direct benefits accrue to farms planting filter strips, but some cost-share and tax credit programs have existed in the past. The primary barrier to adoption of filter strips is cost. Production is reduced because land is taken out of production and planted to vegetative cover. Seed must be purchased and the filter strip may need to be mowed mechanically or controlled with chemicals. Weed control may be more difficult, especially for filter strips with weed problems that can't be managed with selective herbicides. This could result in increased weed control costs on the adjoining or nearby land, and higher labor and management costs.

Livestock farms can reduce surface water problems by fencing cattle out of streams, wetlands, and riparian areas. This prevents trampling of vegetation and fragile streambanks, allowing vegetative filter strips to function by settling sediments and holding soil in place. Farm-level costs of fencing riparian areas may include the costs of fencing, reduced forage for grazing, development of alternative sources of water for cattle, and construction of stream crossing structures.

A potential problem associated with control of runoff is that it may increase water infiltration and groundwater interflows. If the groundwater interflow contains high phosphorus concentrations, phosphorus in the river during summer months may increase as a result of reduced runoff and increased groundwater interflow. Managing phosphorus sources as described above may help to minimize this problem and reduce the impact of increased groundwater interflows.

SEDIMENT CONTROL

Sediment in the stream is controlled through reductions in erosion. Erosion can be reduced by using conservation tillage, permanent and annual cover crops and mulches, filter strips, and improved irrigation management. Conservation tillage involves less disturbance of soil, resulting in more residues from previous crops. More residue means more soil cover, less exposed soil and less erosion. Permanent cover crops can be (and are) used in orchards, vineyards, and berry plantings. Annual cover crops can be used in crop rotations. Cover crops and mulches provide ground cover when the crop provides insufficient cover to prevent erosion. Filter strips may be installed at the ends of fields or adjacent to streams to capture sediments which would otherwise be delivered to streams. A final method of reducing erosion is through improved irrigation management, which may entail additional irrigation monitoring or alternative application schedules.

Conservation tillage is a term used to refer to a wide range of practices that seek to reduce the number of tillage passes, improve soil quality, and increase the roughness of soil surfaces. These practices include reduced tillage and no-till systems. Adoption of conservation tillage systems may require different tractors and/or more specialized tillage and planting equipment. Reduced tillage can result in savings of time and machinery costs. However, these savings may be offset by increased needs for chemical treatments to control weeds and insects. An incentive for conservation tillage systems is the possibility of improving soil quality over time, which may lead to increased productivity. Two barriers are the capital required to acquire any alternative equipment required for conservation tillage systems, and the increased management skills necessary to make conservation tillage practices effective.

Conservation tillage should lead to less erosion due to increased surface roughness. This in turn leads to greater amounts of water infiltration, reducing the loads of phosphorus (P) which reach waterways through sediments. Long term use of conservation tillage may also lead to reduced compaction, increasing the rate of water infiltration and reducing runoff from high rainfall events. As with reduced runoff, successful implementation of practices which reduce erosion may increase groundwater flows, which may be sources of P.

Cover crops may be used with both annual and perennial crops, and provide soil cover during times of high rainfall and reduced crop cover. More ground cover results in reduced erosion and less sediment reaching waterways. In addition, cover crops take up nutrients in the soil, potentially reducing levels of P which reach groundwater. A variety of plants can be used for annual cover crops, including grass, grains, and legumes. Use of a cover crop in an annual cropping rotation requires an increased number of cultural operations, thus increasing costs. Seed costs must also be paid. Improvement of soil quality is the primary incentive for adoption. Barriers to adoption include increased soil moisture levels and delayed planting in the spring, added costs of establishing the cover crop, and the increased costs of removing or controlling the cover crop in the spring.

Cover crops may also be used with perennial crops such as berries, tree fruits, and grapes. The purpose of cover crops for these enterprises is to reduce erosion and runoff while providing little or no competition for cash crops. Perennial grasses are commonly used to replace tillage between the rows of perennial crops. Expenses may include the costs of establishing and maintaining the cover crop, weed control in the cover crop, added rodent control costs and increased mowing. Benefits of cover crops in rows may include reduced tillage expenses and the ability to work in the rows when the ground is wet (because the sod provides a stable base to work on). These cover crops may use nutrients, improving water quality but perhaps reducing production from the perennial crops due to competition.

Field experiments are underway in the Tualatin basin exploring the possibility of interseeding cover crops with annual row crops such as sweet corn. The idea of this practice is to establish both crops, allow the cash crop to mature and be harvested in the fall then allow the cover crop to flourish throughout the winter, reducing runoff and erosion. Potential advantages of this system of cover cropping include reduced cultural operations and increased vigor of cover crops relative to the sequenced cover crop/annual crop system described above. A drawback to consider is that the inter-seeded cover crop may compete with the annual row crop and reduce production. Because of the limited data available for this system, it will not be addressed in this study.

An alternative to growing cover crops is the use of mulch. Straw mulch has been used between strawberry crop rows to reduce erosion and provide soil cover. An added bonus of this method is that the mulch can reduce weed problems. A barrier to wide-spread adoption of this method is the need for a mechanical mulcher to apply and pack the mulch between the rows. Data are also needed on the effects of the mulch in the upper layer of soil, and the extent to which the mulch ties up nutrients which might otherwise be available to produce a strawberry corp. Again, data limitations prevent economic analysis of straw mulching as a BMP. Tree fruit and caneberry crops are routinely mulched using flail choppers to mow between rows and chop small pruned branches and canes. The practice of flailing to produce a mulch is considered most effective when it is followed with a roller to adhere the mulch more firmly to the soil.

The potential for erosion problems resulting from irrigation practices is quite low, given the water distribution systems and soil types found in the basin. About two-thirds of the irrigated acreage is served by a pressurized irrigation water delivery system provided by the Tualatin Valley Irrigation District (TVID). Water from the pressurized TVID system is generally applied using lateral move, hand move, or solid set sprinkler systems on fruit, vegetable, and specialty horticulture crops. These systems generally result in little or no erosion during the irrigation season, according to the panel of local experts.

The other primary type of irrigation system used in the basin is a big gun system with hose reel. This system delivers large volumes of water under high pressure from a single nozzle, and if it is mismanaged can result in soil erosion due to overwatering.

Close, regular monitoring and modified irrigation scheduling can ensure that this problem does not occur. The BMP panel felt that the degradation of water quality that occurred as a result of big gun irrigation was negligible and easily corrected.

In the middle part of the basin, where most of the intensive agricultural crops are produced, the soils are silty clay with high water-holding capacity. Although these soils can erode during the wet winter months, the amount of water required to produce erosion is greater than the amounts typically applied during the dry summer period. Irrigators in TVID use an average of just over one acre-foot of water per acre on crop and livestock farms (Wilson, 1993). The clay soils and relatively low rates of water application result in few erosion problems from irrigation.

ECONOMIC ANALYSIS OF BEST MANAGEMENT PRACTICES

There are three areas in which these BMPs have direct economic impacts. The first is production costs. The practices described may result in increased costs of labor, machinery operation, and other inputs used in the production process. Adoption of many of these practices requires higher levels of management, resulting in higher opportunity costs of management time. Some practices require additional investment at the farm level, such as new machinery and equipment, resulting in increased expenses for depreciation, interest, repairs, and maintenance. However, they may also entail offsetting reductions in some expenses. For example, new tractors may reduce labor expenses due to increased field efficiencies.

The second area affected is revenues. Some practices may lower yields and decrease farm receipts. Others may lower the quality of production, and therefore lower the price received for the product. Another revenue effect is a change in cropping patterns or rotations which reduces the production of profitable crops that result in high phosphorus loads. Over a long time period, some practices may increase yields because of improvements in soil quality, increased efficiency in utilization of inputs, or other related factors.

A final economic consideration is the cost of enforcing and administering programs which result in adoption of new practices. A mandatory, regulatory approach usually requires substantial investment in human resources for inspection services and sanctions, legal challenges, and administration. The alternative is a voluntary approach, which relies upon operators to adopt these management practices through education and demonstration programs, peer pressure, and self interest. Voluntary programs are less costly to administer. Cost-share programs may also be established that provide economic incentives for operators to adopt or invest in desired management practices, and they have been shown to be effective means of changing practices. To assess the cost effectiveness of alternative approaches, all costs, including administration, cost sharing, and enforcement, should be considered and related to the relative degree of BMP adoption (i.e., effectiveness) under each approach.

The economic analysis which follows focuses on the first two economic impact areas, farm level costs and returns. Administrative and enforcement costs are not included under the assumption that voluntary compliance is possible with appropriate educational programs and coordinated efforts, many of which are already established and underway. A further assumption is that adoption of BMPs will not substantially change total agricultural production in the basin, and therefore employment levels, total input demand, and value-added activities will remain approximately constant in the region. No significant multiplier effects are anticipated due to adoption of BMPs. Changes in food demand, development of alternative crops, and public policy changes will likely outweigh any long run effects of the BMPs discussed.

This analysis estimates costs and returns to the nearest dollar values only for consistency and appearance; as with most economic studies, it conveys a greater degree of precision than is achievable.

REDUCED PHOSPHORUS APPLICATION RATES

Based on land use information (Miner, Scott, and Wood, 1993), the weighted average rate of application of P in the Tualatin basin is estimated at 83 lbs/acre/year. Assuming that a 20 percent reduction in P application rates is possible, the average application rate is reduced to 66 lbs/acre/year. Total value of agricultural crop output is assumed to be reduced by an average of 5 percent due to decreased use of P and the resultant effect on yield, while livestock production values are held constant. There are no scientific data to give precise yield reduction estimates. The percent average adjustment is considered a conservative subjective estimate, but 0 and 10 percent decreases are also evaluated to gauge the sensitivity of the estimated effects to the assumed yield response.

Table 1 summarizes the average annual change in net income at the farm level. A 20 percent reduction in P application coupled with a 5 percent reduction in the value of total output is estimated to reduce net farm income by about $5 million per year. The effects of changes in the assumptions made concerning P application rates and reduced production levels are illustrated in Table 2. This shows that output reductions higher than the assumed 5 percent level have a large negative impact on net farm income. Less than 20 percent P reduction results in slightly lower reductions in net farm income. If P application rates can be reduced without reducing total production, total farm income can be increased due to fertilizer cost savings. This latter outcome would occur if farmers are over-applying P based on crop needs, or are applying beyond the optimal level as insurance against downside yield risk.

CHANGING TIMING OF PHOSPHORUS APPLICATIONS

Changing applications of P from fall or winter to spring is feasibly only for annual crops such as grain, annual ryegrass seed, and vegetable crops. The same total amount of P is assumed to be applied, with the bulk applied in the spring following winter rains and closer to the time when it will be used by growing crops. The change in timing is assumed to result in no change in returns or costs. Small cost savings may occur due to the time value of money, but if P is purchased in the fall prior to tax year-end, this savings will not be realized. Future research on agricultural practices is needed to document the current adoption rate of this BMP, which was thought by the BMP panel to be high.

Table 1. Change in net farm income due to reduced P application rate.

Description	Units	Baseline	BMP
Change in Return			
Farm Gate Value of Crop Sales[1]	$	110,838,542	110,838,542
Adjustment Factor	%	100	95
Total Estimated Sales	$	110,838,542	105,296,615
Change in Total Returns	$		-5,541,927
Change in Costs			
Average Application Rate, P	lbs/ac	83	83
Adjustment Factor	%	100	80
Net Application, P	lbs/ac	83	66
Agricultural Land Use	ac	174,096	174,096
Net Application, P	lbs/ac	83	66
Total Agricultural Loading, P	lbs	14,449,968	11,559,974
Average Price, P	$/lb	0.21	0.21
Total Cost, P	$	3,034,493	2,427,594
Net Change in Cost	$		-606,899
Change in Net Farm Income	$		-4,935,028

[1]Source: Miles, Stanley D. "1991 Oregon County and State Agricultural Estimates." Economics Information Office, Oregon State University, January, 1992. Total sales do not include estimated value of container crops.

Table 2. Change in net farm income under alternative rates of reduction of P and total sales.

Change in total sales	Change in P Application Rate -10%	-20%	-30%
0%	+303,449	+606,899	+910,348
-5%	-5,238,478	-495,028	-4,631-579
-10%	-10,780,405	-10,416,956	-10,173,506

INCORPORATING PHOSPHORUS APPLICATIONS

The practice of incorporating all P applications is assumed to be adopted by annual crop producers in the basin. Further, the operation of incorporating P is assumed to require one additional light tillage pass immediately following the broadcast fertilizer application. The cost of the additional tillage operation is calculated using a database of machinery costs from Willett and Smathers (1992). A 105 hp 2-wheel drive tractor is used to pull a 15' wide disk. The tractor costs $21.77/hour to operate, assuming total use of 500 hours/year. The disk costs $11.01/hour, assuming 200 hours of annual use. Total machinery costs for the added tillage pass is $32.38/hour. If labor costs $6.72/hour (NASS, pg. 6) plus 30 percent for payroll overhead costs, total labor cost is $8.74/hour. Total machinery and labor cost for incorporating the fertilizer application is $41.52/hour.

Cost per hour is converted to cost per acre based on the time required to disk each acre. At a speed of 3 miles/hour, approximately 5 acres can be disked each hour. The added tillage cost is estimated as $41.52/hour divided by 5 acres/hour, or $8.30/acre.

Total acres affected by this BMP include 34,189 acres of grains, 73 acres of seed crops, and 5,407 acres of vegetable crops. Total estimated cost for incorporating P applications is 39,669 acres of annual crops multiplied by $8.30/acre for a total increased cost of $329,253 per year, assuming no changes in total production. Thus, the estimated net change in farm income in the basin is a decrease of about $330,000.

Two key parameters that determine the total cost of this BMP are tillage cost per acre and the number of acres affected. Table 3 estimates the net change in farm income for a range of plus or minus 20 percent of the initial assumed values for these two parameters.

Table 3. Change in net farm income for varying tillage costs and total acres from incorporating fertilizer phosphorus.

	Tillage costs ($/acre) (% of assumed cost)		
Total affected acres	$6.64 (80%)	$8.30 (100%)	$9.96 (120%)
31,735 (80%)	210,720	263,400	316,080
39,669 (100%)	263,402	329,252	395,103
47,602 (120%)	316,077	395,096	474,115

BANDING PHOSPHORUS APPLICATIONS

Banded fertilizer applications serve to reduce the total nutrients applied to crops and place them closer to the root zones of crops. Tree fruit, berry, nut, hop, and grape crops can be fertilized using banded applications. A switch from broadcast to banded applications lowers the amount and cost of P, and slightly increases the cost of application. The reduction in use of P is already reflected in the 20 percent P reduction assumed in the reduced P application rate BMP. However, the higher cost of banded applications must still be estimated.

The change in net farm income from this practice is estimated as the difference between the cost of broadcast applications and the cost of banded applications, because one application takes the place of the other. The estimated cost of each application method, excluding materials, is shown in Table 4. Tractor cost is from Willett and

Table 4. Estimated costs for broadcast and banded fertilizer applications.

Description	Units	Application method Broadcast	 Banded
Tractor, 55 hp	$/hr	9.05	9.05
Spreader	$/hr	2.68	2.68
Labor	$/hr	8.74	8.74
Total Cost	$/hr	20.47	20.47
Capacity	ac/hr	5.00	3.00
Application cost/acre	$/ac	4.09	6.82
Added cost of banding	$/ac		2.73
Total acres	ac		12,175.00
Total added cost	$		33,238.00
Total added cost when capacity for banding is:			
2 ac/hr			74,876.00
3 ac/hr			33,238.00
4 ac/hr			12,540.00
5 ac/hr			-0-

Smathers (1992, p. 14); fertilizer spreader cost is based on Turner et al., (1993) and information provided by agricultural implement dealers.

Total cost per hour of applying fertilizer is the same for both methods, but the speed at which the fertilizer can be applied is reduced under the banded method. This leads to higher costs per acre, and increased total costs. Net farm income is estimated to be reduced by $33,238 for this practice. Total acres affected is based on Miner, Scott and Wood (1992). The sensitivity analysis at the bottom of Table 4 shows that as operating rates for banding increase, the added cost of banding decreases. If growers were able to band at the same speed they broadcast net farm income would be unchanged.

FILTER STRIPS

Filter strips are assumed to be used at the edges of fields bordering streams if those fields are used in production of crops which are tilled annually, including grains, seed crops, and vegetable crops. Filter strips are assumed to occur on all four sides of the field. Some fields would require filter strips on only one side, reducing the land to one fourth that used in the calculations.

For a 10 acre square field, a 5' wide strip on all sides represents 2.4 percent of the area used in production. Net farm income changes if filter strips are planted due to reduced production on 2.4 percent of productive land, increased costs of planting and mowing filter strips, and decreased variable costs of not planting cash crops on 2.4 percent of the land.

Filter strips are most effective on fields which slope and adjoin waterways. Not every field in the Tualatin Basin exhibits these characteristics. Likewise, not every field is square. Without better information, it is impossible to precisely determine the amount of land diverted from production under this practice. The sensitivity analysis which follows provides a range of outcomes given a greater or lesser decrease in land base due to alternative filter strip widths. The outcome evaluated for a 6 foot wide strip could also be interpreted as the outcome resulting from 15-foot wide strips used on only 40% of the total number of annually tilled field in the basin.

Given total value of annual crop sales of $16.8 million, a 2.4 percent reduction in output reduces net farm income by $404,173. The added variable cost of planting filter strips is $31.02/acre (Turner et al., 1993) or $29,533 total cost based on planting 952 acres of filter strips (2.4 percent of 39,669 acres of annual crops). The filter strips are assumed to be mowed 3 times per year using a 55 hp tractor and a 5' rotary mower. The tractor costs $9.05/hour, the mower costs $3.31/hour (Willett and Smathers, 1992, p. 69) based on one-half of 10' rotary mower cost at 200 hours of annual use, and labor costs $8.74/hour. Total cost of mowing is $21.10/hour, and mowing capacity is 3 acres/hour. Mowing cost per acre is $7.03, and total cost for all acres mowed is $6,693. The reduced cost for not producing annual crops on 2.4% of annual cropland is based on the average variable cost of producing wheat, (Taylor et al., 1990) annual ryegrass, (Cross et al., 1993) and broccoli (Cross et al., 1988), weighted by acreage. Average reduced cost per planted acre is $5.63, and total reduced cost is $223,336 for all planted annual crop acres.

The estimated change in net farm income after adopting filter strips on annual cropland is summarized in Table 5. This shows that the estimated total change in net farm income is $217,063 for 5' wide strips. Table 5 also shows the sensitivity of estimated changes in net farm income based on the key variable used in this analysis--width of the filter strip. Narrower filter strips take less land out of production, but may be less effective at reducing runoff trapping sediments, and using excess nutrients. Wide strips may have greater positive environmental impacts, but also entail greater reductions in agricultural income.

Table 5. Summary of changes in net farm income when filter strips are adopted on land used to produce annual crops.

Source of change	Amount ($)
Reduced output	-404,173
Increased cost of planting filter strips	-29,533
Increased cost of mowing filter srips	-6,693
Reduced cost of land taken out of production	+223,336
Total change in net farm income	-217,063
Change in net farm income if filter strips are:	
2' wide	-175,300
5' wide	-217,063
9' wide	-345,800
12' wide	-963,060

LIVESTOCK FENCING

There are about 1,615,000 feet of streambank for the main tributaries in the Tualatin Basin and about 876,000 feet of shoreline on the Tualatin River. Over 63,000 acres of grazing are used by cattle, horses, and sheep, representing 14 percent of total land use in the basin (Miner, Scott and Wood, 1993). Fencing livestock away from streambanks in areas with high livestock concentrations is expected to contribute to improved water quality. Using data from Miner, Scott and Wood, eight subbasins were identified as meeting at least one of two criteria chosen to represent intensive livestock grazing areas. The first criterion was 1,500 acres or more used for pasture. The second criterion was 20 percent or more of land use in the subbasin was pasture. All subbasins on the main stem were excluded, assuming most river front property was not used for livestock grazing. Table 6 shows the subbasins selected and the estimated feet of shoreline for main tributaries in each.

Assume that on average, 30 percent of pasture land use is contiguous to tributary streams in these subbasins. Also, assume half of this streambank length is already fenced. That leaves 15 percent of the 881,760 feet of shoreline to be fenced, a total of 132,264 feet or about 25 miles.

The cost of constructing fences to keep livestock out of streams is estimated in Table 7. These cost estimates are based on using 3 to 4 inch wood posts placed one rod apart, heavier wooden brace posts, and 4 strands of 4-point barbed wire. The labor cost estimate is based on National Agricultural Statistics Service (NASS, 1993) estimates for hourly labor used in the northwest region for livestock workers and assumes 1 hour of labor is required per rod of fence constructed. Labor requirements for fencing are quite variable due to differences in soils, topography, and the amount of mechanization used in construction. Prices for wire and posts are from NASS (1993, p. B-21 to B-24). Total cost for fencing in the selected subbasins is $130,732. The total investment is annualized by estimating depreciation and interest using the cost recovery approach (Kay, 1974). An amortized cost is estimated assuming a 5 percent real interest rate, 25 year life, and $0 salvage value. This results in an annual

Table 6. Estimated amount of streambank in subbasins identified as livestock grazing intensive.

Subbasin number[1]	Subbasin name	Tributary	Streambank in tributary (feet)	Percent of tributary in subbasin	Streambank in subasin (feet)
10	Middle Rock	Rock Ck.	200,640	50	100,320
11	Upper Rock	Rock Ck.	200,640	50	100,320
14	Lower McKay	McKay Ck.	253,440	60	152,064
16	Middle Dairy	Dairy Ck.	105,600	80	84,480
17	Lower E. Fork Dairy	E. Fork Dairy Ck.	221,760	40	88,704
19	Lower W. Fork Dairy	W. Fork Dairy Ck.	221,760	70	155,232
22	Lower Gales	Gales Ck.	295,680	50	147,840
25	Lower Scoggins	Lower Scoggins Ck.	52,800	100	52,800
Total					881,760

[1]Following Miner, Scott and Wood, 1993.

Table 7. Estimated riparian area fence construction costs.

Item	Unit Cost	Number Used	Cost
Wood Posts, 6-7', 304" dia.	$3.79	320	$1,212.80
Wood Brace Posts, 8', 5" dia.	$5.00	20	$100.00
Wire, 4 strands, 12.5 ga., 4-point	$38.60	16	$617.60
Labor, hours	$10.31	320	$3,298.88
Cost/Mile			$5,229.28
Miles			$25.00
Total fencing investment cost			$130,732.00
Amortized annual cost (5%, 25 years)			$9,276.00

Table 8. Change in net farm income for riparian area fencing for varying fencing costs and miles of construction.

	Fence construction cost (% of assumed cost)		
Miles of Fence (% of assumed miles)	$4,183/mile (80%)	$5,229/mile (100%)	$6,275/mile (120%)
20 (80%)	-$5,936	-$7,420	-$8,904
25 (100%)	-7,420	-9,276	-11,131
30 (120%)	-8,904	-11,130	-13,357

change in net farm income of $9,276. This cost ignores the added expenses of alternative water sources, new stream-crossings, and additional forage requirements. It also excludes machinery costs for installing the fence. Table 8 reports the sensitivity analysis for the change in net farm income given alternative levels of fencing cost and varying miles of fence construction.

CONSERVATION TILLAGE

Conservation tillage practices are assumed to be adopted for annual grain crops. Net farm income changes are due to a reduced number of tillage operations and a need for larger, more specialized tractors and implements. The changes in costs associated with conservation tillage are estimated on a per-acre basis for wheat, (Taylor et al., 1990), and totaled based on total annual grain crop acreage in the Tualatin Basin.

The wheat enterprise budget developed by Taylor et al. (1990) includes 6 tillage passes prior to planting: disk 3 times, plow, cultipack, and harrow. A conservation tillage system would typically reduce the number of tillage operations by at least two. Assuming that one disking and the plowing are omitted results in savings of $14.58 in variable costs and $8.24 in fixed costs or a total of $22.82/acre.

Adopting a conservation tillage system was assumed to require four-wheel drive tractors, which are more costly to operate on a per-hour basis. Specialized tillage implements may be needed which are also more expensive than standard tillage implements. These cost increases may be partially offset by increased field capacity of specialized machinery. Assuming machinery fixed and variable costs increase by 40 percent (after accounting for increased field efficiency) results in added cost of $25.16 (40 percent of $62.91, the total machinery cost per acre after eliminating the cost of 2 tillage passes).

Table 9. Change in net farm income due to adopting conservation tillage practices on annual crops for varying levels of machinery cost increases.

Increase in Machinery Cost	Change in Net Farm Income ($)
30%	+134,944
40%	-80,002
50%	-295,222

Net farm income is increased by $22.82/acre from reduced tillage passes and reduced by $25.16/acre from higher machinery costs. Therefore, net farm income declines by $2.34/acre on 34,189 acres of annual grain cropland, for a total reduction in income of

$80,002. A critical variable in this cost estimate is the percentage change in machinery costs which results from acquiring the machinery needed to perform conservation tillage practices. A range of values for this variable and the resulting changes in net farm income are shown in Table 9.

COVER CROPS

Cover crops may be used with both annual and perennial crops. This study assumes that cover crops are to be planted only on annual vegetable crop acres in the Tualatin Basin. Adoption of conservation tillage practices is assumed to eliminate the need for cover crops on annual spring grain crops. Annual winter grain and seed crops are seeded in the fall, and hence cannot use cover crops. They are also assumed to be produced under conservation tillage.

Adding winter cover crops to vegetable acres is assumed to require 4 additional cultural operations. The land must be disked, then disked again and harrowed, and planted to a cover crop in the fall. Finally, the cover crop is flail chopped in the spring prior to seedbed preparation. A contact herbicide is used to kill the cover crop prior to flail chopping, but this spray would also be used on fallow ground without cover crops so it does not add cost to adoption of cover crops. The panel felt that additional herbicides may also be required over time due to increased weed seeds being introduced with the cover crop, herbicide selectivity, and reduced use of soil fumigation. However, this cost was not included because of a lack of data and experience.

Estimated costs of adding winter cover crops to annual vegetable crops are shown in Table 10. All machinery costs are from Willett and Smathers, (1992). Clover seed is planted at the rate of 20 lbs/acre. Labor and machinery hours are based on typical operating speeds and width of implements. Labor cost was taken from NASS (1993) for hired field labor, plus 30 percent payroll overhead cost. The estimated total cost is $54.38/acre. If winter cover crops were used with all acreage of annual vegetable crops, the total change in net farm income is estimated as -$294,033. The bottom

Table 10. Estimated change in net farm income associated with planting winter cover crops on annual vegetable crop acres.

Operation	Resource	Cost/unit	Unit	Rate/acre	Total ($/acre)
Disk	Tractor, 105 Hp	21.77	$/hr	.20 hr	4.35
	Disk, 15'	11.01	$/hr	.20 hr	2.20
	Labor	8.74	$/hr	.20 hr	1.75
	Total Disk				8.30
Disk & Harrow	Tractor, 105 Hp	21.77	$/hr	.20 hr	4.35
	Disk, 15'	11.01	$/hr	.20 hr	2.20
	Harrow, 15'	6.82	$/hr	.20 hr	1.36
	Labor	8.74	$/hr	.20 hr	1.75
	Total Disk & Harrow				9.66
Plant	Tractor, 105 Hp	21.77	$/hr	.33 hr	7.18
	Drill, 12'	13.05	$/hr	.33 hr	4.31
	Seed	0.50	$/lb	20 lbs	10.00
	Labor	8.74	$/hr	.33 hr	2.88
	Total Plant				24.37
Flail Chop	Tractor, 105 Hp	21.77	$/hr	.33 hr	7.18
	Flail, 8'	6.02	$/hr	.33 hr	1.99
	Labor	8.74	$/hr	.33 hr	2.88
	Total Flail Chop				12.05
Total cover crop cost, $/ac					54.38
Annual vegetable crop acres					5,407
Total change in net farm income					-294,033
Net change in farm income when cost per acre is:					
80% of $54.38/ac					-235,226
100% of $54.38/ac					-294,033
120% of $54.38/ac					-352,839

portion of Table 10 reports the change in net farm income when the cost of winter cover crops varies from 80 to 120 percent of the estimated value.

Cover crops in perennial crops are assumed to consist of 5' strips of perennial grass planted between rows of trees and berry vines. Only two operations are assumed to be required to establish and maintain the grass strips, and the costs of these are summarized in Table 11. Machinery costs for the tractor and sprayer are from ^AWP and ^AWP, (1992). The drill costs is from Turner et al., (1993), increased 20 percent to reflect the cost of operating a 5' wide drill (a 4' wide drill was reported by Turner et al., 1993). The weighted cover crop cost assumes that planting costs are spread over 10 years, so the annual cost of planting is 10 percent of the total estimated planting cost of $69.85/acre. This reflects an average life of perennial crops.

The weighted cost of using cover crops in these perennial enterprises is $27.65/acre/year. Total acreage of tree fruits, nuts, and berries is 11,768, resulting in a decrease in net farm income of $325,385. The bottom of Table 11 shows the change in net farm income under different weighting factors for perennial crop stand life. As stand life decreases, the percent planted annually increases, causing larger decreases in net farm income. The added costs of mowing grass between rows is assumed to exactly offset the savings in cultivating and tilling between the rows which is performed in the absence of cover crops.

TOTAL COST OF ADOPTING ALL BEST MANAGEMENT PRACTICES

If all BMPs are adopted, the estimated annual cost to the agriculture sector is $6,344,892. The largest cost is incurred when phosphorus application rates are reduced by 20 percent and the consequent (assumed) decrease in production levels occurs. The estimated impact on agriculture ranges from an increase of $44,388 to a decrease of $13,468,310 in annual net farm for the range of values analyzed. The estimated cost of adopting all BMPs was calculated by adding the estimated cost of each BMP. The lowest and highest estimated costs from the sensitivity analyses of

Table 11. Estimated change in net farm income associated with planting permanent cover crops on tree fruit, nut, and berry crop acres.

Operation	Resource	Cost/Unit	Unit	Rate/Acre	Total ($/acre)
Plant	Tractor, 55 Hp	9.05	$/hr	1.0 hr	9.05
	Drill, 5'	2.06	$/hr	1.0 hr	2.06
	Seed	1.00	$/lb	50 lb	50.00
	Labor	8.74	$/hr	1.0 hr	8.74
	Total Plant				69.85
Weed control	Tractor, 55 Hp	9.05	$/hr	.33 hr	2.99
	Sprayer, 300 Gal.	14.54	$/hr	.33 hr	4.80
	Herbicide	20.00	$/Gal.	.50 Gal.	10.00
	Labor	8.74	$/hr	.33 hr	2.88
	Total Weed Control				20.67
Acres planted annually, %					100%
Acres sprayed annually, %					100%
Weighted cost of planting					6.98
Weighted cost of spraying					20.67
Total weighted cover crop cost, $/ac					27.65
Tree fruit acres					1,995
Nut acres					6,156
Berry acres					3,617
Total affected acres					11,768
Change in net farm income					-325,385
Change in net farm income when:					
5% of acres are planted annually					-284,344
10% of acres are planted annually					-325,385
15% of acres are planted annually					-366,544

each BMP were added to estimate the potential range in changes for net farm income. Values used are provided in Table 12.

Annual net farm income for Washington County in 1991 was estimated at $71,965,000 by the Bureau of Economic Analysis (1993). This suggests that annual net farm income could decline by about 9 percent if all BMPs are adopted as discussed. The annual percentage change varies from an increase of less than 1 percent to a decrease of 19 percent.

The costs of adopting all BMPs are unequally distributed among the various agricultural enterprises. Adoption of some practices is limited to appropriate enterprises as noted above each BMP description. Specialty crop producers are estimated to have the greatest burden. The impact to nurseries comes solely from the revenue reduction caused by reducing phosphorus application rates by 20 percent and the assumed yield decrease. Many nursery facilities have already adopted practices to control phosphorus discharges, and the impact to this industry may be overestimated. If the impact to nursery enterprises is excluded, the total estimated cost to all other enterprise types is $3,568,613 with an estimated range from a cost of $467,743 to a cost of $7,403,616. Distribution by enterprise type for adopting all BMPs is analyzed in Table 13.

Over time, improved management and technology may mitigate some or all of the reductions in annual net farm income estimated in this study. When faced with increased expenses or decreased revenues, firms will logically react to minimize their losses and capitalize on unforeseen opportunities. Thus, the budgeted reduction in net farm income would likely decline over a 10 to 20 year time period as new practices are developed and adopted.

Table 12. Total estimated annual change in farm income from adopting agricultural BMPs in the Tualatin Basin.

Practice	Lowest Estimate	Estimate Used	Highest Estimate
Reduced P Applic.	+910,348	-4,935,028	-10,780,404
Incorporating P. Applic.	-210,720	-329,252	-474,115
Banding P Applic.	-11,554	-33,238	-74,876
Filter Strips	-175,300	-217,063	-936,060
Livestock Fencing	-83,660	-130,732	-188,250
Conservation Tillage	134,844	-80,002	-295,222
Annual Cover Crop	-235,226	-294,033	-352,839
Perennial Cover Crop	-283,344	-325,544	-366,544
Total	+44,388	-6,344,892	-13,468,310

Table 13. Distribution of changes in net farm income by enterprise type.

Enterprise Type	Lowest Estimate	Estimate Used	Highest Estimate
Grains	-120,982	-967,552	-2,420,868
Forage	+26,406	-143,149	-312,704
Seeds	+51,047	-281,582	-615,505
Fruit and Nut	-145,172	-527,125	-922,303
Berry	+36,956	-783,474	-1,609,773
Grapes	-7,184	-26,673	-46,822
Vegetable	-225,154	-708,327	-1,287,396
Specialty	+512,131	-2,776,281	-6,064,694
Livestock	-83,660	-130,732	-188,250
Total	+44,388	-6,344,894	-13,468,315

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