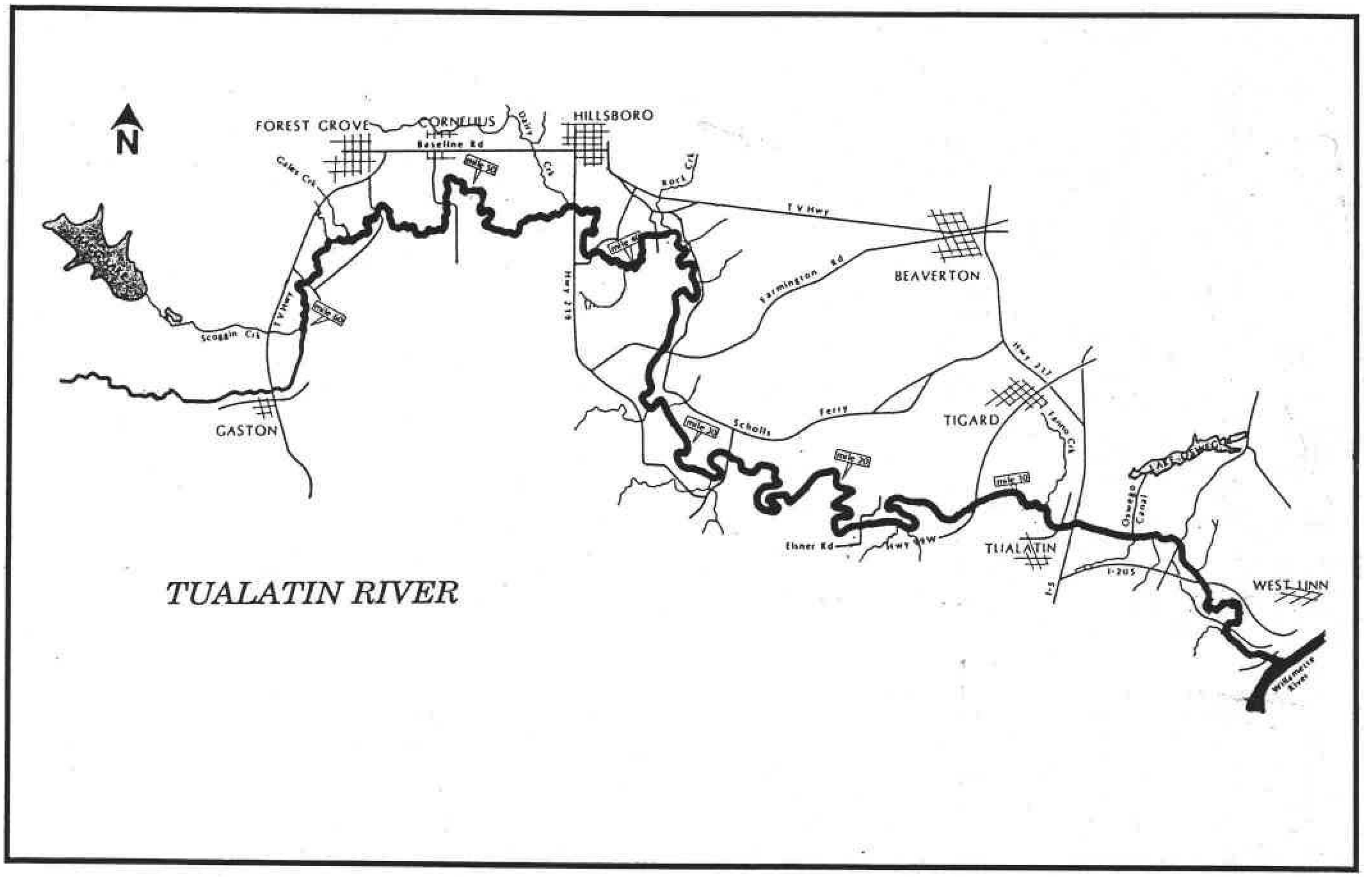
Analysis of Pollution Control Strategies for the Tualatin River



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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.

ANALYSIS OF POLLUTION CONTROL STRATEGIES FOR THE TUALATIN RIVER

by
David E. Ervin
Department of Agricultural and Resource Economics
Oregon State University

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 11**

This report was prepared by David E. Ervin, Dept. of Agricultural and Resource Economics.

Sections of the report were provided by Peter C. Klingeman, Dept. of Civil Engineering; Judith Li, Dept. of Fisheries and Wildlife; Wayne C. Huber, Dept. of Civil Engineering; Eric Knoder, Dept. of Agricultural and Resource Economics; Stanley V. Gregory, Dept. of Fisheries and Wildlife; Timothy L. Cross, Dept. of Agricultural and Resource Economics; and J. Ronald Miner, Dept. of Bioresource Engineering. Paul Adams, Dept. of Forest Engineering, provided reviewers comments.

Other members of the study team contributed suggestions for the report.

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I. INTRODUCTION

In response to Oregon House Bill 3338, the Oregon Department of Environmental Quality requested proposals in 1991 to assemble available information on Tualatin River Basin conditions to provide a scientific basis for improving river water quality. An interdisciplinary team of researchers from Oregon State University and Portland State University was asked in December, 1991 to perform the work. Over the next 24 months, the team undertook several tasks to assemble the best information to aid decision-makers in choosing actions to meet federally mandated standards and improve overall basin water quality. The major tasks included:

1. description of the aquatic health of the river basin
2. definition of the phosphorus/algae problem in the river
3. formulation of alternative strategies to improve water quality
4. development of models to simulate and evaluate the alternative strategies
5. evaluation of the probable environmental and economic effects of alternative strategies

Background papers and reports prepared for this project are available from the Oregon Water Resources Research Institute at Oregon State University.

The primary objective of the project was to identify and recommend the most cost effective strategies to attain the permissible total maximum daily load (TMDL) of phosphorus, which causes the Tualatin River's algae problems. But the evaluation also considered other river health goals expressed by the public during the project. Examples included the concern for river aesthetics and fish and wildlife populations. Though the models were not capable of formally evaluating these other river basin attributes, the effects were qualitatively assessed where relevant.

It is critical to note at the outset the incomplete database and scientific understanding that prevails about Tualatin River water quality problems. Past management actions by the Unified Sewerage Agency have addressed and substantially reduced point source oxygen demand, ammonia and phosphorus contributions from municipal sewage effluent. Further progress in meeting water quality standards must consider diffuse or nonpoint sources. Examples include runoff from urban, agricultural and forested areas, and leaching through parent geological material of groundwaters to the streams. By their very diffuse nature these nonpoint sources are difficult, if not impossible, to identify, measure and model. No systematic and comprehensive databases of nonpoint sources have been constructed for the Tualatin River Basin in the past. Thus project analyses were limited to assembling available information to build an aggregate modeling picture of the hydrologic processes affecting water quality. Such an investigation necessarily produces estimates of environmental and economic effects with varying degrees of uncertainty depending on the quantity and quality of available data.

The following analyses were conducted with the best data at hand, but further information is required. Recommendations are made at the end of this report for targeted data collections to improve future analyses and decisions. Also, it is worth noting that even with a good comprehensive database, the science of understanding and predicting water quality changes due to altered nonpoint sources is still in its early stages. Attributing even the relative share of water quality effects in a complex river system among multiple nonpoint causes is a very difficult task. It is the authors' judgment that the available data and science permit an "order-of magnitude" identification of the probable cause and effect relationships, but generally not with quantitative precision. These data and science limitations affect the recommendations offered at the conclusion.

II. ALTERNATIVE STRATEGIES AND EVALUATION FRAMEWORK

Five basic categories of strategies were identified to reduce the excessive summertime growth of algae and the associated water quality problems in the Tualatin River. They include measures to:

1) increase the summertime flow,

2) decrease the phosphorus load,

3) restore the stream corridor,

4) change instream processes, and

5) continue current load reduction strategies

Measures from the first four strategies could be used individually or in combination. The categories encompass the major additional approaches considered to have significant potential to help achieve water quality standards with the available data and science. However, they do not exhaust all possible individual or overlapping measures. Rather, they provide a scoping analysis of major alternative measures. The fifth strategy represents the choice of accepting the current path of management strategies, with minor changes.

Use of the first four strategies allows several different ideas to be explored, discussed and tested. They can be used with water quality models to study the ability to reduce summertime algae problems. Such models, as explained below, provide insights to the general likelihood that a particular strategy will make much difference in resolving water quality problems, or whether a combination of measures from several strategies may be necessary to insure significant progress toward water quality goals.

The basic study objective was to estimate the likely cost effectiveness of alternative strategies. Thus the evaluation required two steps. First, using the load delivery (HSPF) and instream water quality (CE-QUAL-W2) models, the probable environmental impacts of the strategies or measures were estimated. Key performance variables in assessing the likelihood of decreasing algal growth included acidity (pH), dissolved oxygen (DO), and chlorophyll a conditions.

Second, the likely economic impacts of the strategies or measures were estimated using cost and foregone benefit information when available. For the economic assessment, attention was given to both private and public costs and their distribution across sectors, e.g. urban and agriculture. Because of the uncertainties associated with many data and scientific processes, the sensitivities of the environmental and economic estimates were examined if the uncertainty was large and/or the variable was thought to play a key role. The economic estimates should be interpreted as short-run effects and therefore are likely the largest impacts, because socioeconomic and technological processes tend to diminish adjustment costs over time.

Figure 1 shows the basin with the tributary streams. Near the headwaters, the streams have a high gradient. The Tualatin in the flat part of the basin has a low gradient.

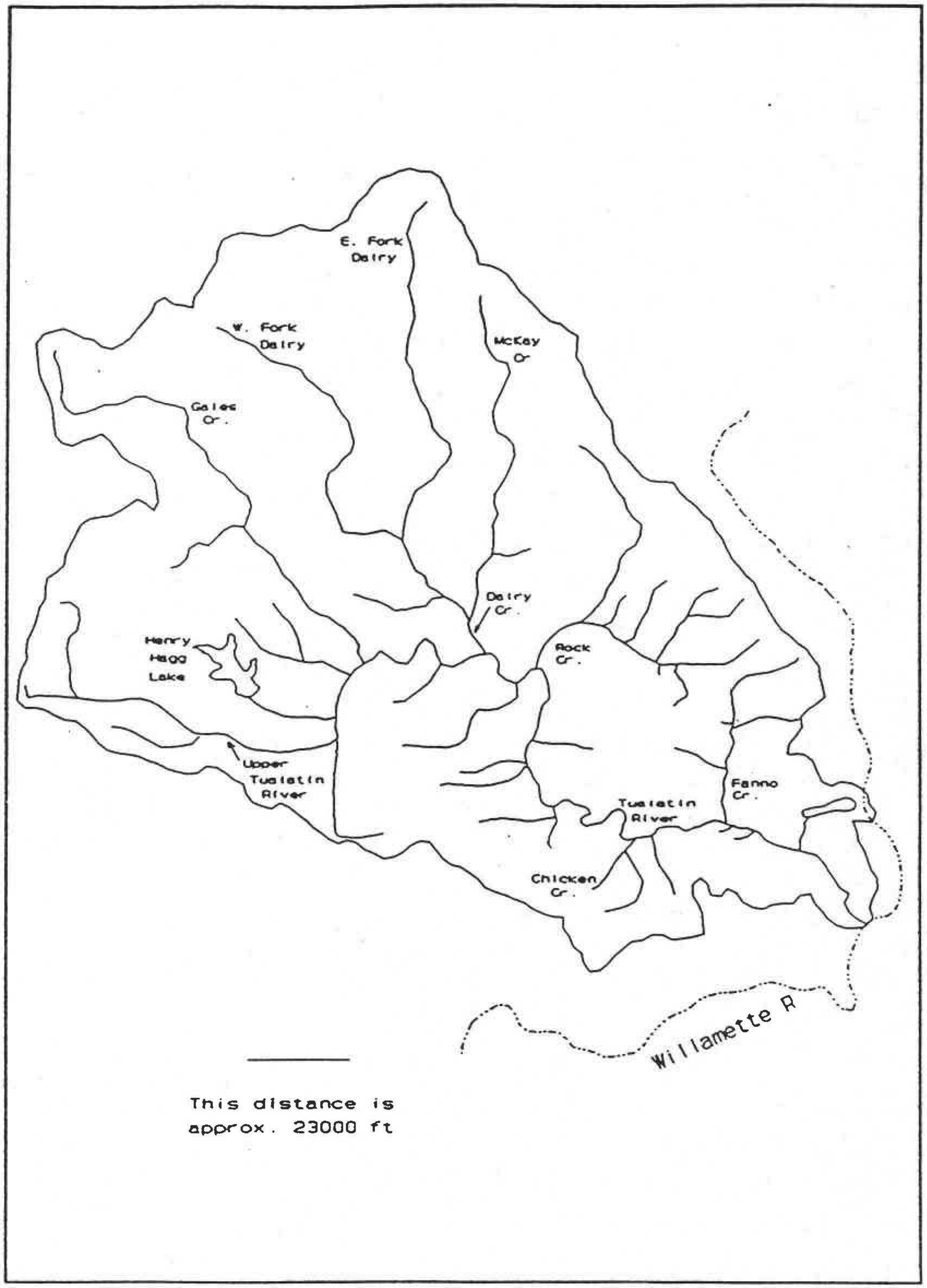

Figure 1. Tualatin watershed boundary and principal tributaries.

III. SUMMERTIME FLOW AUGMENTATION

The lower Tualatin has the worst water quality along the mainstem of the river. This may be partly due to low stream gradient and slow-moving water, a condition aggravated by backwater effects of the Lake Oswego diversion dam. This section has high concentrations of phosphorus in relatively warm water.

The goal of the summertime flow strategy is to decrease the concentration of phosphorus and reduce residence time in the lower Tualatin River, thereby reducing favorable conditions for algae populations. Decreased concentrations of phosphorus in the lower Tualatin River can be achieved by increasing the flow, which will reduce phosphorus concentrations, assuming that the supplemental water has a quality similar to that currently discharged from Scoggins Reservoir. The additional summertime flow is also expected to be cooler and to thus provide reduced water temperatures in the lower reaches of the river which would diminish the rate of algal growth stimulated by increasing temperatures over the summer months. Therefore, it is expected that the increased water discharge with its lower nutrient concentration, cooler temperature, and slightly shorter residence time will result in lower algae populations.

Flow Augmentation Goal

Estimates from the CE-QUAL-W2 model suggest an additional 100 cubic feet per second (cfs) of water is needed in the months of July and August to approach the established total maximum daily load (TMDL) for phosphorus. This is equivalent to a volume of water of about 12,000 acre feet (AF). Hence, the quantified goal for the summertime flow strategy is to develop an additional water supply of 12,000 AF that can be released to the lower Tualatin throughout the months of July and August at an average rate of 100 cfs. Scoggins Reservoir has an active storage volume of 53,000 AF and a total storage volume of 59,000 AF. Hence, a new amount of storage equivalent to about 20% of the reservoir is required.

Alternative Summertime Flow Measures to Achieve the Goal

Additional summertime water can be obtained by various means. Streamflow manipulation through storage, release and diversion of water is a frequently used approach. This generally involves constructed devices and systems to store or direct the movement of water. This approach is quite commonplace in the Tualatin Basin. Typical devices range in size and complexity from small, simple diversion weirs to the large and technically complex Scoggins Dam and Reservoir. Systems may be nothing more than an individual ditch leading to a field or may be as elaborate as the integrated management system of the Tualatin Valley Irrigation District (TVID) or the interbasin diversion scheme that brings water from the upper Trask River.

Most of the measures would augment streamflow from new storage or importing water from other areas. An alterative strategy is to reallocate available water among uses within the basin to augment summer streamflow, i.e. save 12,000 AF for instream pollution control. Such savings could be approached through implementing conservation measures, purchasing or leasing existing water rights, or other approaches. Achieving the 12,000 AF target savings amounts to nearly 23% of the Scoggins Reservoir useable capacity. While some water use efficiencies are obtainable at low cost, such a large reallocation would have substantial negative economic impact. For example, a simulated 20% reduction in irrigation water for agriculture was estimated to reduce agriculture sales nearly $15 million per year, almost 10% of Washington County annual agricultural sales. The loss in net profits could not be estimated precisely, but would be lower due to lower water delivery and other irrigation-associated costs. Losses to the municipal and other sectors would be presumably of similarly large nature. Thus it was decided to examine the storage augmentation or transfer measures first before looking in more depth at reallocation among existing uses.

It is far easier to manipulate water than it is to fully understand the consequences of doing so. Modeling offers one means for testing alternative actions to learn something about their downstream impacts. Physical quantities can be evaluated with good confidence, whereas the biological and biochemical implications are less certain. The following discussion of streamflow changes pre-supposes that if serious consideration is given to actually implementing flow-changing scenarios, a thorough investigation of ecosystem impacts is necessary beyond the estimates of environmental parameters presented here. Available literature and analyses did not permit precise analysis of ecosystem effects from flow changes.

A number of measures were considered for investigation under the general strategy of increased summertime flow. Several are suggested here, grouped in terms of a) measures for streamflow augmentation by means of reservoirs, b) measures for streamflow augmentation by interbasin water transfers, and c) other scenarios for streamflow augmentation.

Streamflow Augmentation by Means of Reservoirs

The list of possible measures under this category includes:

1. Modify size or use of existing surface-water reservoirs
   a. Raise Scoggins Dam to provide additional storage capacity in the Reservoir to catch additional winter and spring runoff for summer low-flow augmentation.
   b. Make structural changes at Scoggins Dam to allow more effective use of the stored water, including provision for selective release levels and a lowered minimum release level.
   c. Revise the storage and release schedule for water in Scoggins Reservoir to capture more water during spring months and release it during July and August.
   d. Reallocate water among users who have rights to water stored in Scoggins Reservoir to gain more stored water for flow augmentation.
   e. Increase conservation measures among those users who have rights to water stored in Scoggins Reservoir, so that more water might be available for summer flow augmentation.
2. Develop new reservoirs in the basin
   a. Add new storage on Scoggins Creek upstream of the existing reservoir.
   b. Develop a new reservoir on the upper Tualatin River, such as the Gaston or Mt. Richmond sites.
   c. Develop a new reservoir on Gales Creek.

Streamflow Augmentation by Interbasin Water Transfers

1. Increase the interbasin transfer of water from the Trask River to the Tualatin River by expanding Barney Reservoir or by adding new storage on the Trask River that can be connected to the same transfer pipeline.
2. Transfer water from other Coast Range streams that flow westward to the Pacific Ocean by pumping water from the upper reaches of these streams and delivering it to upper reaches of streams in the Tualatin Basin.
3. Transfer water from the Willamette River by pumping water from the vicinity of Newberg and delivering it to lower reaches of the Tualatin River during summer months.

Other Means for Streamflow Augmentation

1. Use wastewater with higher P concentration than the river for irrigation rather than release it to the river (water re-use based on treated effluent from waste-water treatment plants), thus offsetting some of the need for water diversions from the river and leaving more good-quality water in the river.
2. Implement conservation measures that reduce the demand on summer stream-flow, taking advantage of public benefit provisions of state law or purchasing the conserved water directly.
3. Purchase or rent water rights for existing water from basin agricultural water users and leave that water in the stream during summer months instead of allowing out-of-stream diversion.
4. Develop subsurface storage to raise water tables in shallow aquifers, both to displace surface water uses and to increase the amount and duration of water-table baseflow to streams (assuming subsurface flows have lower P concentrations than river water).
5. Develop joint surface-subsurface storage to increase volume of water stored, provide carryover buffer among wet and dry years, displace some surface water uses, and provide holding zones for treated wastewater.

Analysis of Selected Measures

Some of the above scenarios have been examined in detail, whereas others have been given only a general review. Among those most closely studied, three groups of scenarios were found to have sufficient potential and interest to be summarized in detail here. These are (1) the modification of Scoggins Dam in terms of size or store-release schedule, (2) the development of new reservoirs in the basin on Scoggins Creek, Gales Creek or the Tualatin River, and (3) interbasin water transfers from the Trask or Willamette Rivers.

Measures to Modify Size or Use of Scoggins Dam and Reservoir

Most of the water storage reservoirs in the Tualatin basin are relatively small, and are situated on small drainage basins. Modification of existing surface water reservoirs is significant only for Scoggins Reservoir.

Modifications might be considered in size, components, and operation. These are:

1. Raise Scoggins Dam to provide additional storage capacity in the Reservoir. Use this added space to catch additional winter and spring runoff. Use the stored water for summer low-flow augmentation.
2. Make structural changes at Scoggins Dam to allow more effective use of the stored water. This requires rebuilding the water intake structure at the dam so that water may be selectively released from different levels in the reservoir, allowing some control over water temperatures and turbidity levels. The rebuilt intake should also allow removal of water from lower in the reservoir than is presently possible.
3. Revise the storage and release schedule for water in Scoggins Reservoir to capture more water during spring months and release it during July and August.

Exploration of these options requires background information in several technical areas. (1) The present reservoir storage characteristics (elevation versus surface area and stored volume) must be accurately known. Several years of operation of the facility may have resulted in some sedimentation and loss of storage space; this must be determined or estimated. (2) The topographic and geologic features around the reservoir and at the dam must be known in detail to a higher elevation, if raising the dam is to be fully evaluated. (3) The as-built details of existing structural components of the dam must be reviewed, including the water intake and the spillway. (4) The reservoir operating rule curve currently used must be known in more detail than the general rule curve formulated at the time of project development. (5) The current water rights to "storage" and "natural" flows in the reservoir must be determined or verified. (6) The present allocation of stored water must be verified. (7) The basin water yield and streamflow availability must be redetermined based on several years of additional data since project formulation occurred. (8) Reservoir water quality must be evaluated, primarily in terms of temperature, turbidity, and their vertical variability in the reservoir. (9) The current and recent downriver, out-of-stream demands for stored water should be reevaluated to determine whether changes in water use practices have occurred that might increase or decrease the flexibility in use of reservoir water. Most of this technical information was not available to project investigators.

Technical Feasibility, Difficulty

Raising Scoggins Dam

Raising the height of Scoggins Dam by about 7 to 10 feet would provide storage for another 12,000 AF of water. This appears to be technically feasible. The topographic and geological conditions appear to be adequate, based on preliminary examination. However, there would be several technical difficulties. These include maintaining adequate crest width for various uses with the raised embankment. The slopes of the upper embankment could be steepened or the upstream or downstream face could be widened to accommodate the new height. Spillway changes must preserve the ability to pass the spillway design flood safely. More broadly, dam safety must be addressed for the added load of new material used to raise the dam. The dam modifications are likely to be costly and may disrupt some of the operational requirements to provide a continuing water supply downriver.

There may be some hydrologic limitations to adding more storage water behind Scoggins Dam (Chen, 1993; Kawakami, 1993). The drainage basin tributary to the reservoir is not so large as to provide sufficient inflow for storage in some years, given that the reservoir will still be drawn down in winter-spring to provide the same level of flood protection as is now the case. This difficulty may be resolvable by providing extra new space in the raised reservoir for flood control, so that more storage of water can occur in spring than presently and still provide the present level of flood control protection.

The capture of an additional 12,000 AF of runoff in Scoggins Reservoir must also be weighed against the value of that water for instream benefits during spring downriver of the reservoir. The water may presently be helping to dilute contaminants and flush them through the lower river in the spring and lessen the summer problems there. If the water is stored, the possible flushing benefit will be lost.

Modify Scoggins water intake

Modifying the water intake at Scoggins Dam also appears to be technically feasible. While the overall task is somewhat less complex that raising the dam, the amount of disruption is likely to be greater. In effect, it will be necessary to drain the reservoir and build a new intake tower with multiple ports to replace the existing single-entry intake. A nearby alternate site might be found for separate construction (with a connection made to the existing intake), but dewatering of most of the reservoir will still be required.

Revise storage-release schedule

Revising the storage and release schedule for water in Scoggins Reservoir, so that the volume of water released during summer months is altered from past/present practices, also appears to be technically feasible. Reservoir operation modifications are technically attainable. It is less complex to capture more water during spring months and release it during July and August than to rebuild the dam. However, in some years this rescheduling of storage may be very difficult or impossible. For example, in 1993 the rains continued so late into the spring that flood control continued to be of concern. Also, the reservoir was easily fillable but due to excessive inflows, much water was spilled that might otherwise have been stored to assist with summer downstream flows.

Water releases from Scoggins Reservoir presently reflect a combination of in-reservoir and downstream user needs that are tied to the calendar and are strongly seasonal. Inflow storage in the reservoir is also seasonal and depends primarily on winter-spring runoff. The plans for reservoir fill-and-release date back to the mid-1970's. Scoggins Reservoir first began flow regulation in January 1975. Experience with project operation, basin hydrology and water user demands has been gained since that time that can be used to "tighten-up and reprogram" the manner of reservoir operation. This can also be used to shift the release patterns to better accommodate downriver water quality, if sound recommendations can be formulated. Scenario-testing with a river flow/quality model is an important approach for formulating such recommendations.

Effect on Water Quality in the Basin

Release of additional amounts of stored water from the reservoir should improve downriver water quality in terms of somewhat lower phosphorus concentrations, decreased residence times, and lower water temperatures. Dilution and flushing benefits could be attained to remove undesired water constituents. Turbidity levels might also be reduced, although this could vary seasonally, depending upon clarity conditions in the reservoir. Various sources indicate that algal growth occurs in the reservoir and may result in the release of suspended solids with water during summer months. Changes in release patterns of stored water from the reservoir should also help improve downriver water quality, if carefully planned. Desirable effects might be attained in terms of somewhat lower phosphorus concentrations and water temperatures and reduced turbidity levels, as already noted.

Impacts of Measures

The major impacts of Scoggins Reservoir enlargement and intake modification are likely to be land acquisition and construction costs in the first case and construction and flow interruption in the second. The major impacts of the third scenario are likely to be some loss of flood control protection, some difficulties in meeting expectations in wet springs, and displacement-of-use among users of reservoir water during spring months.

Economic impacts

Major reconstruction of a reservoir can be nearly as expensive as the construction of new storage at an undeveloped site. Purchasing land for storage and construction operations are major expenses. General investment cost rules-of-thumb for new reservoir capacity are between $1,000 and $2,000 per AF in the Tualatin Basin. If applicable to the expansion, then total investment costs for the reservoir expansion would be between $12 and $24 million, with approximately 10% of that total for annual operation and maintenance costs. Intake reconstruction, while not as expensive, will also have a significant cost. There are also short-term disruption costs in each case because the existing facility is providing services that must be reduced or halted during the reconstruction period. Redesigning the storage-release schedule is expected to have minor economic impacts due flood control reductions or inability to store the full additional 12,000 AF in some years. Displacement of 12,000 AF among spring water users is likely to have a significant economic cost for agricultural and municipal users.

Social and political impacts

Reconstruction of an existing dam to improve river water quality conditions is more likely to receive public acceptance than would the construction of a dam at an undeveloped site. An exception to this generalization would be owners of land near the existing reservoir level who would need to be compensated for restricted use of periodically inundated lands. It is not clear than any private land would be so affected in the reservoir expansion. A major public concern is likely to focus on continuation of satisfactory reservoir recreation, an important asset of the current project. Revision of the storage-refill schedule is not likely to have major social and political impacts, except for displaced spring water users. It may offer a larger recreation area in spring to offset losses from changes in July-August reservoir levels. Displacement of a significant amount of spring irrigation withdrawals from agricultural water users is likely to reduce crop revenues, shift cropping enterprises, and/or require new irrigation technologies. Small irrigation adjustments, e.g. 5-10%, could probably be facilitated without major cost, but large shifts would impose correspondingly large costs, especially in the short run when production technology and cropping patterns are difficult to shift rapidly. Significant political resistance will likely be encountered in altering irrigation allocations without compensation.

Impacts on Overall Basin Health

Implementation of the first and third scenarios would lead to the capture and storage of additional winter runoff. Implementation of the second scenario would lead to more selective release of water and the ability to manipulate the quality (temperature, turbidity and total suspended solids) of the released water. Implementation of the third scenario could lead to more effective use of stored river runoff, in terms of river water quality. This scenario would shift the timing and amount of some downriver flow during the summer and possibly also in late spring and early fall. Such shift could be largely beneficial to river water quality during the summer.

All three scenarios would lead to greater July-August releases of water for downstream augmentation. There would be shifts in the timing of some downriver flow from spring to summer. Though such shifts would be largely beneficial to summer river water quality, they could reduce spring dilution flows for contaminants being transported and spring flushing flows that help purge the lower Tualatin River of accumulating contaminants. Therefore, the overall health might be improved and the summer health might be improved at the risk of a slight loss in the spring health of the river.

Measures to Develop New Reservoirs in the Basin

While there are several potential reservoir sites in the Tualatin Basin, it is quite likely that the most economically attractive sites have already been developed. Other sites have been identified through a variety of planning studies during the past several decades, but have not been developed for economic or other reasons.

Development of new reservoirs might be considered for sites on three streams.

1. Add new storage on Scoggins Creek upstream of Scoggins Reservoir.
2. Develop a new reservoir on the upper Tualatin River, such as at the U.S. Bureau of Reclamation Gaston or Mt. Richmond sites.
3. Develop a new reservoir on Gales Creek.

These scenarios require information much like that needed for considering modifications at Scoggins Dam, in particular, hydrologic analyses of available water and examination of potential sites based on topographic, geologic and land-use information. Also needed are tentative selection of storage capacity, optional operating rule curves, and corresponding effects on downriver water quality.

Technical Feasibility, Difficulty

In terms of storable water, most dam sites available that would not cause inundation of developed land (agricultural, rural, and more intensively developed) are so far up the streams that the drainage areas are small. This greatly limits the amount of water runoff that can be anticipated, which thus limits the size of storage facilities that can be developed with expectation of annual refill. Generally, these appear to be moderately feasible alternatives from a technical perspective. Dam-reservoir development is costly but technically attainable.

Scenario to add a reservoir upstream of Scoggins Reservoir

There appears to be a useable site available for constructing a new dam and impounding about 12,000 AF of water (Hendron, 1993). It is about one-half mile northwest of the northwestern tip of Scoggins Reservoir, where a topographic constriction occurs that will minimize the dam's size. This is the lowest feasible site on Scoggins Creek and thus has the largest drainage area to contribute inflow (about 15 square miles). However, such a reservoir will take water away from Scoggins Reservoir. Based on streamflow records generated for the site, it is estimated that in some years it will not be possible to fill Scoggins Reservoir plus a new 12,000 AF. Also, a coordinated filling schedule between the two reservoirs would be critical to successful storage of the needed amounts of inflow.

Scenario to develop a reservoir on the upper Tualatin River

The U.S. Bureau of Reclamation (USBR) has studied in detail two reservoir sites on the Tualatin River. These are known as the Gaston Dam site and the Mt. Richmond Dam site. The sites take advantage of favorable topography to provide reservoirs of greater than 100,000 AF capacity. The investment costs in 1980 dollars are about $160 million for either site. The projects are multi-functional. A 1990 review by USBR for a 105,000 AF Mount Richmond project, using April 1990 prices and 8⅞% interest rate, gave an investment cost of $172 million and total annual costs of $15 million for investment, operation, maintenance and replacement.

<u>**Scenario to develop a reservoir on Gales Creek**</u>

Several sites have been proposed along Gales Creek (Dummer, 1993), some having impoundment volumes similar to that in Scoggins Reservoir (59,000 AF). Six locations were reviewed for the present evaluation. It was found that all had suitable topography to develop impoundments, but that the two potentially largest sites would inundate developed areas. The two middle-reach sites have the potential for 25,000-30,000 AF of storage development with much less displacement of developed facilities. The upper two sites would involve very little displacement but would have such small tributary areas that not more than 10,000 AF of storage might be hydrologically feasible. The preliminary estimate for the investment cost to develop a 22,000 AF site is on the order of $50 million, based on extrapolating the 1969 Scoggins and the 1990 Gaston costs on a per-AF basis.

Effect on Water Quality in the Basin

Additional water storage projects should improve downriver water quality in terms of seasonally-increased flows (summer), somewhat lower residence times and water temperatures, and possibly somewhat reduced turbidity levels. Storage might have a positive or negative effect on winter and spring water quality.

Impacts of Scenarios

The major impacts of water storage scenarios are likely to be cost impacts and land-use impacts, with no clear idea initially about who would pay those costs nor how acceptable the land-use impacts might be in total.

Economic impacts

Construction of new storage at an undeveloped site is expensive. During the current period of budget deficits, there may not be willing taxpayers unless the benefits are quite significant. This is unlikely or the site would already be developed.

Social and political impacts

Construction of a dam at an undeveloped site is likely to receive less public and political acceptance than would the reconstruction of an existing dam to improve river water quality conditions. Displacing existing landowners with strong economic and personal attachments to their land requires significant compensation and demonstrable benefits to a wide array of users to generate political support.

Summary of How Scenarios Improve Overall Basin Health

Implementation of scenarios to develop new reservoirs would lead to the capture and storage of additional winter-spring runoff. This would shift the time of some downriver flow from winter-spring to summer. Such a shift probably would be largely beneficial to river water quality, since water quality problems are primarily summer problems. However, the scenarios could reduce spring dilution flows for contaminants and spring flushing flows that help purge the lower Tualatin River of accumulating contaminants. Therefore, the overall health and the summer health might be improved at the risk of a slight loss in the spring health of the river.

Scenarios to Make Interbasin Water Transfers

The interbasin transfer of water to augment Tualatin River streamflows can be accomplished in two ways. One scenario is to pump more water from the Trask River on the west side of the Coast Range and deliver it to upper reaches of the Tualatin River. The other scenario is to pump water from the Willamette River near Newberg and deliver it to the middle reaches or upper-end of the lower reach of the Tualatin River during summer months.

Exploration of these scenarios involves examination of Barney Reservoir and other sites in the Trask River drainage basin and study of a site on the Willamette near

Newberg. The purpose would be to determine how much water transfer might be feasible and by what route. The main efforts would involve hydrologic analyses of available water, tentative selection of transfer volume and rate, topographic analyses for potential routes, selection of release points within the Tualatin Basin, and determination of effects on downriver water quality.

Technical Feasibility, Difficulty

These appear to be a moderately feasible alternatives from a technical perspective. Interbasin water transfer is costly but technically attainable. There may be hydrological constraints on the ability to obtain the needed amount of water. Streamflow in the Willamette River may be fully committed, necessitating very difficult negotiations to gain any water for diversion.

Trask River water transfer

Water is presently being transferred from Barney Reservoir, in the upper Trask River drainage, to the upper end of the Tualatin River. This transfer occurs by means of pumps, a pipeline, and a release point into the Tualatin. A planned expansion of the Barney Reservoir to increase its capacity from 1.3 to 6.7 million gallons is now undergoing an environmental impact review. If approved, the new capacity and water transfer would meet the needed inflow during in the summer months to augment flow and reduce algal growth conditions.

Willamette River water transfer

A pumping station near Newberg and a pipeline running northward to the Tualatin Basin could allow additional water to reach the Tualatin River. A low saddle of the topographic divide might be found along the route of U.S. Highway 99 that could minimize the pumping head required. Once in the basin, the diverted flow could be released into a stream such as Baker or Heaton Creek, which join together and enter the Tualatin near RM 29, or Chicken Creek, which enters the Tualatin near RM 16.

Effect on Water Quality in the Basin

As outlined above, additional water added to the basin, if of suitable quality, should improve downriver water quality for those seasons when diversion occurs.

Impacts of Scenarios

The major impacts of these scenarios are likely to be cost impacts.

Economic impacts

Construction of new storage at an undeveloped site in the Trask Basin or by enlarging Barney Reservoir is expensive. Available cost estimates are in the range of $21-$22 million. So new investment costs for the transfer would be necessary, and there would also be operation and maintenance costs of the transfer mechanism. The proposed diversion has been approved subject to environmental approval, implying the public agencies have estimated that the benefits outweigh the expected costs. The other cost of the Barney diversion is the opportunity cost of the reduced Trask River flow displaced by the diversion. Data were not publicly available to assess those effects. Construction of a pumping station and a pipeline for the Willamette transfer would also be expensive.

Social and political impacts

Interbasin water transfers may be perceived as an admission that water managers cannot solve their own problems without causing problems for someone else in a different basin. Opposition may therefore come both from within and outside the basin. Interbasin water transfers are likely to have strong political resistance from constituencies outside the Tualatin Basin if the diverted water has a high opportunity cost. Also, some groups within the Tualatin Basin may oppose the transfers if they see lower cost solutions within the basin.

Summary of How Scenarios Improve Overall Basin Health

Implementation of these water diversion scenarios would lead to the transfer and release of additional water for the basin during summer months. This would increase downriver flows for those months. This should be beneficial to river water quality through dilution effects on nutrients and contaminants. However, Willamette River water may carry nutrients and contaminants that could adversely affect the Tualatin. There may also be some cooling effects, as the temperature of the Trask River and the Willamette River waters may be cooler than water in the Tualatin.

IV. DECREASED PHOSPHORUS LOADS

The potential for reduced nonpoint phosphorus loads from agricultural, urban and forestry sources was investigated. Urban municipal sewage control of point P sources has already been achieved to a high degree. Therefore, further control must turn to nonpoint sources. The environmental effects of various measures were estimated with the loading (HSPF) and instream water quality (CE-QUAL-W2) models. Economic effects were estimated with budgeting information available for the different management practices. In the absence of detailed information, only rough estimates of costs are used here. The details on agricultural loads are in a report by Cross and Wood (1994) in this series.

Urban Best Management Practices (BMPs) for Tualatin Phosphorus Control

Urbanization increases hydrograph peaks and volumes, resulting in additional scour and sediment loads in streams. This typically results in habitat reduction for fish. Urban surfaces and illicit discharges (e.g. dumping down storm drains) contribute pollutants such as heavy metals, hydrocarbons, pesticides, and herbicides that do not occur in nature. Depending on their magnitude, such pollutants may affect aquatic life. The deleterious effects of nitrogen and particularly phosphorus are well known.

BMP Strategies

Quality control options include load reduction through public education, or physical means such as storage/sedimentation and increased infiltration. Storage may also reduce hydrograph peaks, and increased infiltration may reduce runoff volumes to lessen the impact on streams. Most of these options can be modeled, either directly (e.g. add storage to the model), or indirectly (e.g. reduce buildup parameters to simulate load reduction or cleaning). Aesthetic impacts are important in an urban area as well, since reduction of floatables and visible signs of pollution may be observed by the public, whereas reduction of chemical pollution may not. Generally, modeling will not be useful for aesthetic considerations.

For phosphorus, extended detention and "wet" ponds (ponds with permanent pool storage) have been shown to be effective in removal of total P, with removal percentages of approximately 50% and 70%, respectively (Wiegand et al., 1986). Ponds have the multi-purpose benefit of volume control in addition to quality control. In fact, most storage is implemented for volume control (e.g. flooding) and retro-fitted for longer detention to achieve quality enhancement.

BMP Cost Data

Insufficient data were available to determine site-specific cost functions for the Tualatin area. Thus, it is assumed that the Maryland (Wiegand et al., 1986) results and hydrology are not too different from the Portland area. An obvious difference is seasonality of rainfall, with uniform annual rainfall in Maryland and wet-dry seasons in Portland. However, the Maryland cost estimates were based on design storms and not on continuous simulation, so the seasonal difference should not be too important.

According to Wiegand et al. (1986), extended detention and wet ponds are the most cost effective means for removal of phosphorus under conditions typical of Maryland. These data have been extrapolated here to determine annual dollars per year per acre of control costs, assuming use of extended detention. The development of the cost functions is shown in Table 1 and Figure 2. Annual costs include operation and maintenance at 5% of capital costs, and contingency at 25% of capital costs. Annual costs are computed assuming a 20-year project life and 8% discount rate. Costs are 1985 dollars. Cost functions are listed in Table 2, as found from fitting of log-linear relationships to the data shown in Figure 2.

Application of Cost Data to Urban Areas of the Tualatin Basin

The cost of functions can be applied in a simple manner to the Tualatin Basin if urban acreage is known. Urban land use percentages are taken from OTAK (1990) for two areas considered as examples: the total Tualatin Basin, at 21% urbanization (94,080 urbanized acres), and the Upper and Lower Fanno Creek Basin (20,971 urbanized acres). The same land use percentages are applied in both cases, although the total basin has a much larger urbanized total.

Costs for 50% phosphorus reduction are then computed in Table 2, again under two options. The first estimate assumes that extrapolation beyond the 25-ac value used by Wiegand et al. (1986) in their examples is acceptable. This results in continued

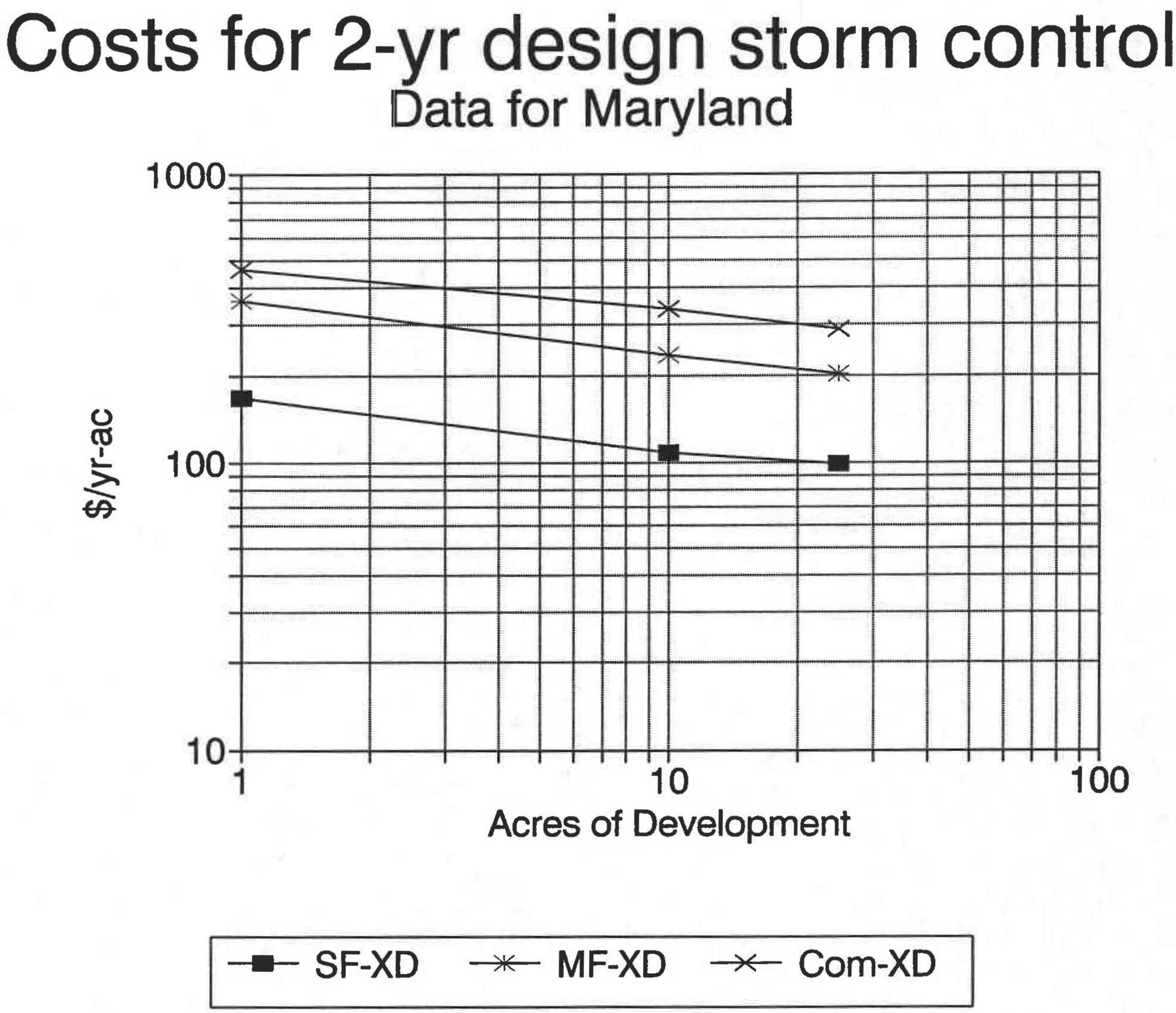

Figure 2. Data on costs for extended detention for single family (SF), multi-family (MF) and commercial (COM). From Wiegand et al., 1986.

Table 1. Cost estimates for urban runoff phosphorus control in Tualatin Basin.*

	Single family residence $/lb-yr		Multi family residence $/lb-yr		Commercial $/lb-yr	
Acres	Extended detention	Wet pond	Extended detention	Wet pond	Extended detention	Wet pond
10	25	315	21	96	20	55
25	24	242	17	74	17	46

*Calculated by W. C. Huber. Data from Wiegand et al. (1986). In 1985 dollars. Costs for 50% P removal.

Table 2. Calculated costs for urban nonpoint phosphorus removal.*

	Single family residence	Multi-family residence	Commercial and other
Entire area			
Urban areas	43,277	3,763	3,763
Cost, $/yr/acre	30	81	137
Total extrapolated cost, $/yr	1.3 million	0.3 million	0.5 million
Calculations based on 25 ac parcels			
Number	1,731	151	151
Cost	4.3 million	0.7 million	1.1 million
Fanno Creek area			
Urban acres	9,647	839	839
Cost, $/yr/acre	38	107	172
Total extrapolated cost, $/yr	6.37 million	0.09 million	0.14 million
Calculations based on 25 ac parcels			
Number	386	34	34
Cost	6.95 million	0.17 million	0.25 million

*Data from Wiegand et al. (1986) extrapolated to the Tualatin Basin. For 50% P removal.

economies of scale and lower total costs of $2.1 million and $0.6 million, respectively for the two examples. The other extreme assumes no economies of scale beyond 25 acres, and calculates the number of 25-ac parcels for each land use and multiplies the 25-ac cost by these numbers. This is clearly at an opposite extreme, but does provide an estimate of an upper bound of $6.2 million and $1.4 million for the two examples.

Summary

Considering only the urbanized Fanno Creek sub-basin of the Tualatin River Basin, control costs for an approximate 50% removal are on the order of $600,000 to $1.4 million. This assumes extended detention; use of wet ponds would provide somewhat greater removal at somewhat greater price.

Ponds have the additional benefits of flood control and reduction of solids, nitrogen, floatables and pollutants such as heavy metals adsorbed on solids. Hence, there are additional benefits beyond phosphorus removal, but the overall cost-benefit to the Tualatin River has not been computed.

Addendum on Urban Growth and Planning

Though it was not possible to rigorously examine the role of urban growth patterns on phosphorus loadings to the Tualatin River with available data and models, the potential influence cannot be ignored. Historical examination suggests the Tualatin River did not resemble current conditions, having higher minimum flows in the summer and less effluent from developed areas. Urban development also brings unavoidable consequences of covering land with houses and pavement, but the pattern of development can be designed to minimize negative effects on river water quality. Examples include restrictions on converting riparian and wetland areas for development and minimum paved areas to promote infiltration and lessen runoff. Growth will continue in the Tualatin Basin, and planning authorities should look for innovative ways to reduce urban growth's negative effects on the river.

Forestry Sources of Phosphorus

Nearly half the Tualatin Basin is in forest cover, primarily concentrated in the upper reaches of the basin. Certain forest management practices can produce conditions that augment phosphorus delivery to tributaries and the river. Examples include slash burning and poor road design and maintenance. Changes in management on riparian areas could contribute to greater overall river health including recharge, filtering, wildlife and other goals. Although no systematic and comprehensive data set exists to assess the extent or severity of forest practice effects in the basin, partial monitoring data from selected streams do not suggest management related phosphorus deliveries are coming from the basin's forested areas. "Annual concentrations of total phosphorus for largely forest watersheds in or adjacent to the Tualatin Basin appear to range between 25 and 85 ug/L (Salminen and Beschta, 1991)."

The major measures used to reduce runoff and erosion include:

- Limiting fire use and intensity
- Limiting widespread yarding and slash piling/scarification
- Modifying road design and drainage system maintenance
- Modifying silvicultural systems (e.g. reduce clearcut harvests) in riparian areas.

Costs of implementing these practices depend upon varying forest and land conditions in the Basin. Some estimates are:

- Reduced fire use may save $100 or more per acre in labor costs, but reduce future timber yields, increase wildfire risks, and necessitate alternative treatments (e.g. piling or herbicides);
- Control of soil compaction and disturbance may or may not increase costs, depending on the specific location and practice;
- Modified road design and drainage maintenance could raise costs from $150 to $3,500 per acre, but could be partly or fully offset by savings in road drainage and repair;
- Partial cutting could increase logging costs 15 to 25% and reduce potentially beneficial stream flow increases, but would increase aesthetic and other forest recreational benefits;

- Reduced harvest in riparian areas could cost $75 to $850 per acre due to timber foregone and increased logging and road costs.

Nonpoint source pollution from forest land use is controlled by Oregon's Forest Practices Act rules. The Act's rules are implemented by Oregon Department of Forestry (ODF) personnel issuing permits for forest management and upon appeal by private landowners who feel the rules may be violated. Based on the lack of appeals, widespread violation of the Act's rules does not appear to be a problem (personal communication, Degenhardt, ODF). Thus, it does not appear that forestry management practices are playing a significant role in phosphorus delivery and associated algae growth problems in the River. For that reason no further analyses were conducted of forestry source reductions.

V. STREAM CORRIDOR MODIFICATIONS: RIPARIAN RESTORATION

Ecological Functions

Prior to Euro-American settlement, streams of the Tualatin River Basin had intact riparian zones of conifers, deciduous trees and herbaceous plants. Logging and agriculture began in the Tualatin Basin in the mid-1800's, followed by urbanization in the twentieth century. These land use practices have dramatically altered both the landscape and its waterways (Harr, 1983). Among the most important functions of a riparian zone are shade, soil stability, and filtration of nutrients (Gregory et al., 1991). Cooler stream temperatures are maintained, less soil is eroded, and fewer nutrients are added to the stream. Within the watershed, these water quality values are conveyed downstream. Cumulative downstream effects are apparent in Gales Creek, even in a preliminary examination of aerial photographs. Some examples are provided in the report "Issues Surrounding the Biota of the Tualatin River," in this series.

Recent aerial photographs of the basin indicate that riparian vegetation is very limited. In the Gales Creek reach between Forest Grove and Beaver Creek, 39% of the stream appeared to have no riparian forest on either side; 4% had riparian forest on one side (Table 3). Almost one-third was protected by forest communities on both banks of the stream. Morning temperature data for two Gales Creek sites (upstream at Highway 8 and downstream near the mainstem Tualatin) in 1990 reflect the high solar insolation as the creek flows downstream (Figure 3). The temperatures were taken between 8:00 and 11:45 a.m.; afternoon maximum temperatures would be higher. Because of cumulative temperature effects, we expect that these elevated temperatures would affect the mainstem. Temperature profiles of the mainstem Tualatin indicate consistent temperature increases from Scoggins Dam down to river mile 27.1, including the confluence with Gales Creek (Figure 4).

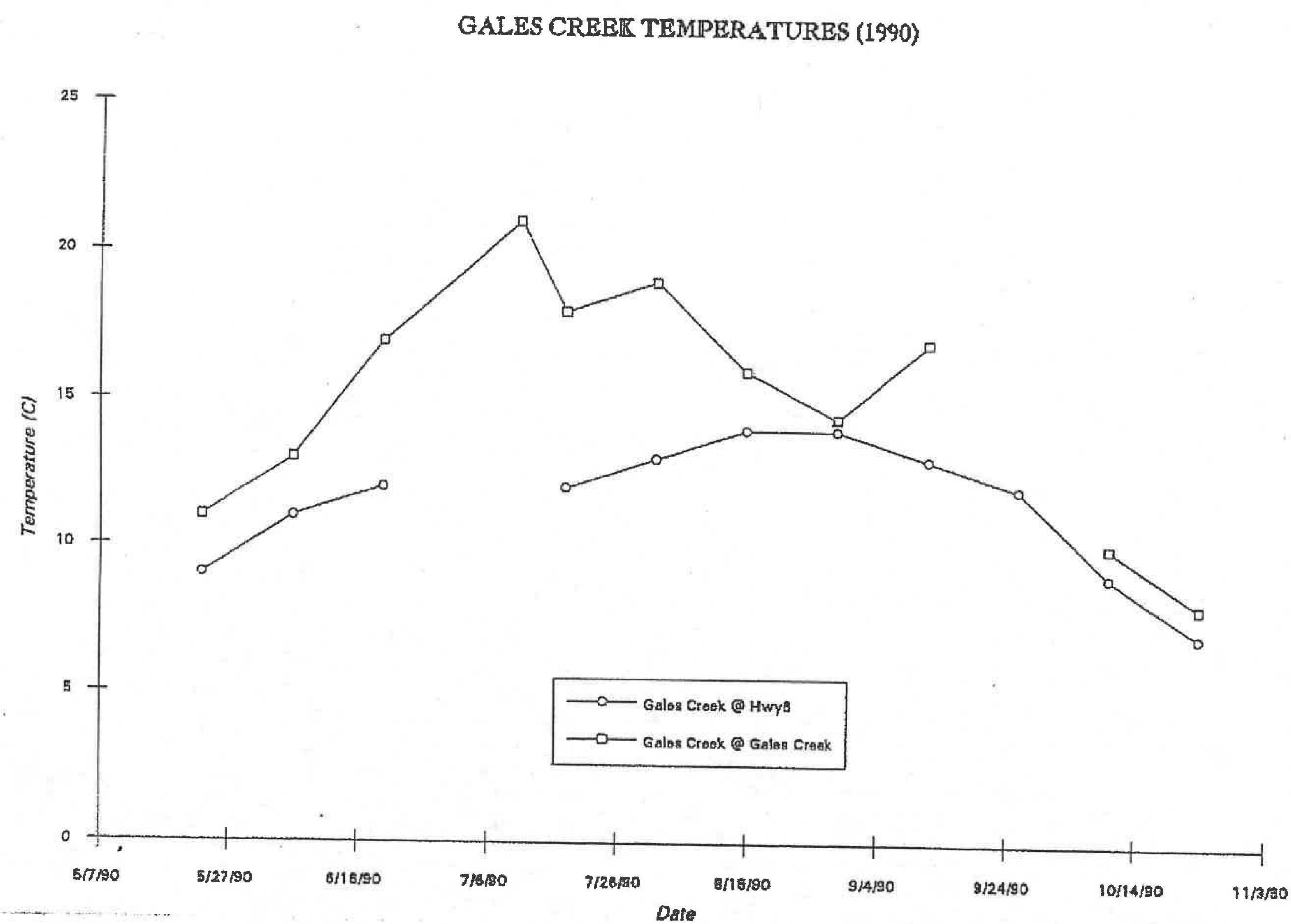

Figure 3. Morning temperature measurements for Gales Creek.

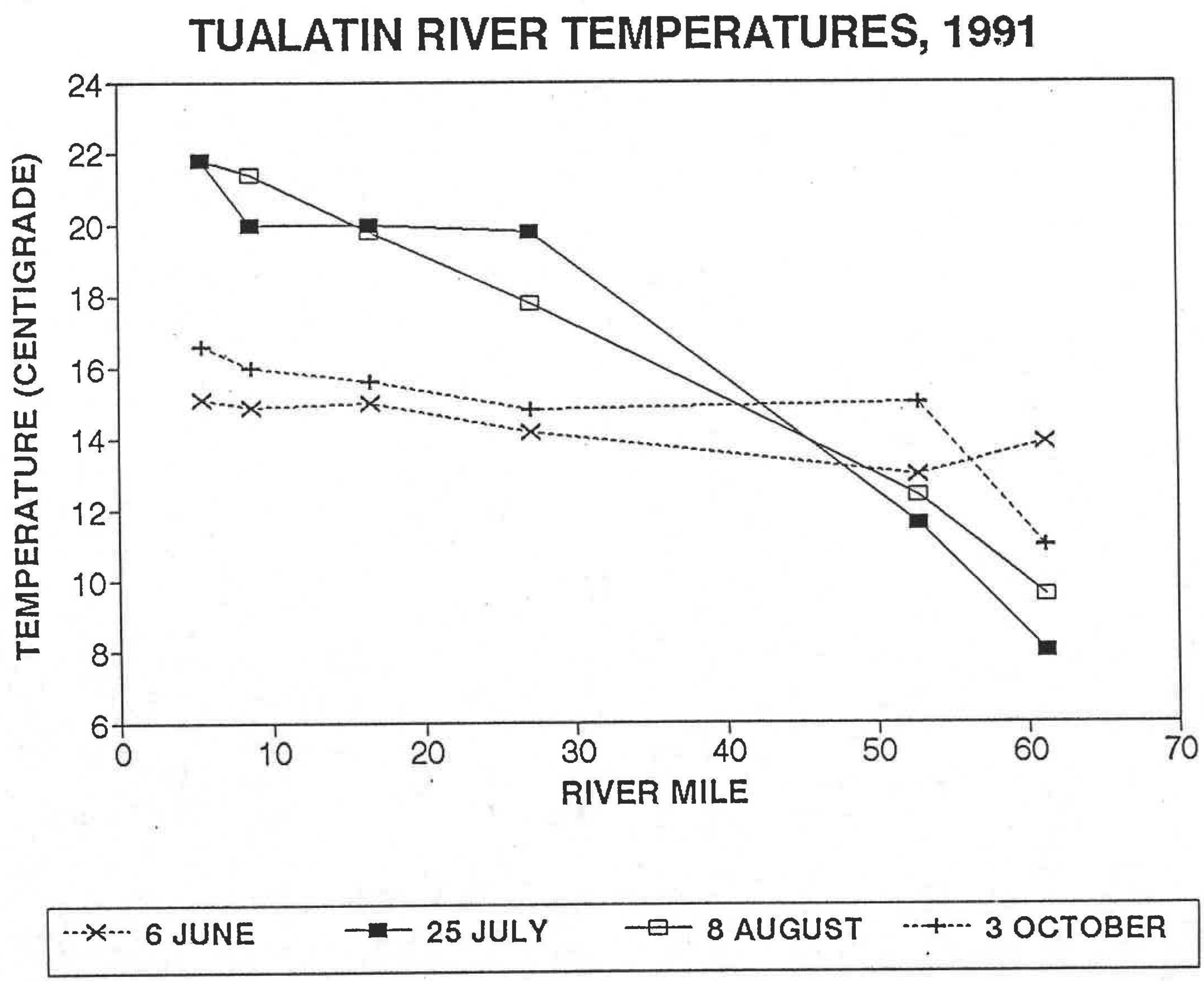

Figure 4. Temperature profiles for the mainstem Tualatin River.

Table 3. Riparian vegetation on sections of the Tualatin River and tributaries (percentages estimated by visual inspection of satellite images).

Reach	No riparian	Riparian on two banks	Riparian on one bank	Herbs	50% herbs/ 50% forest
Mainstem, Gaston to Lee Creek	58	10	7	25	--
Gales Creek, Forest Grove to Beaver Creek	39	32	4	15	10
Dairy Creek, to E/W Fork Junction	19	71	4	--	6

Estimates for Dairy Creek mainstem between the confluence of McKay Creek and approximately the confluence of East and West Forks of Dairy Creek were 19 percent of the stream without riparian forests, and 71% protected by forest vegetation on both sides (Table 3). Morning temperatures at Dairy Creek never reached the same levels as those on Gales Creek, though Gales Creek is higher up in the basin (Figure 5). Differences in stream length, discharge, and subsurface flow also affect temperature, but the slightly lower temperature in Dairy Creek suggests the cooling value of the riparian zone.

We examined Gales and Dairy Creeks because the Oregon Department of Fish and Wildlife is trying to restore wild cutthroat trout in these two drainages. Salmonids require cool temperatures as well as other water values to thrive, and recovery of native trout requires major efforts for maintaining or restoring cool water habitat for these native fish. In addition to high temperature, cumulative effects of sediment loads and terrestrial nutrient input can be reduced by well-developed riparian forests.

DAIRY CREEK TEMPERATURE PROFILES (1990)

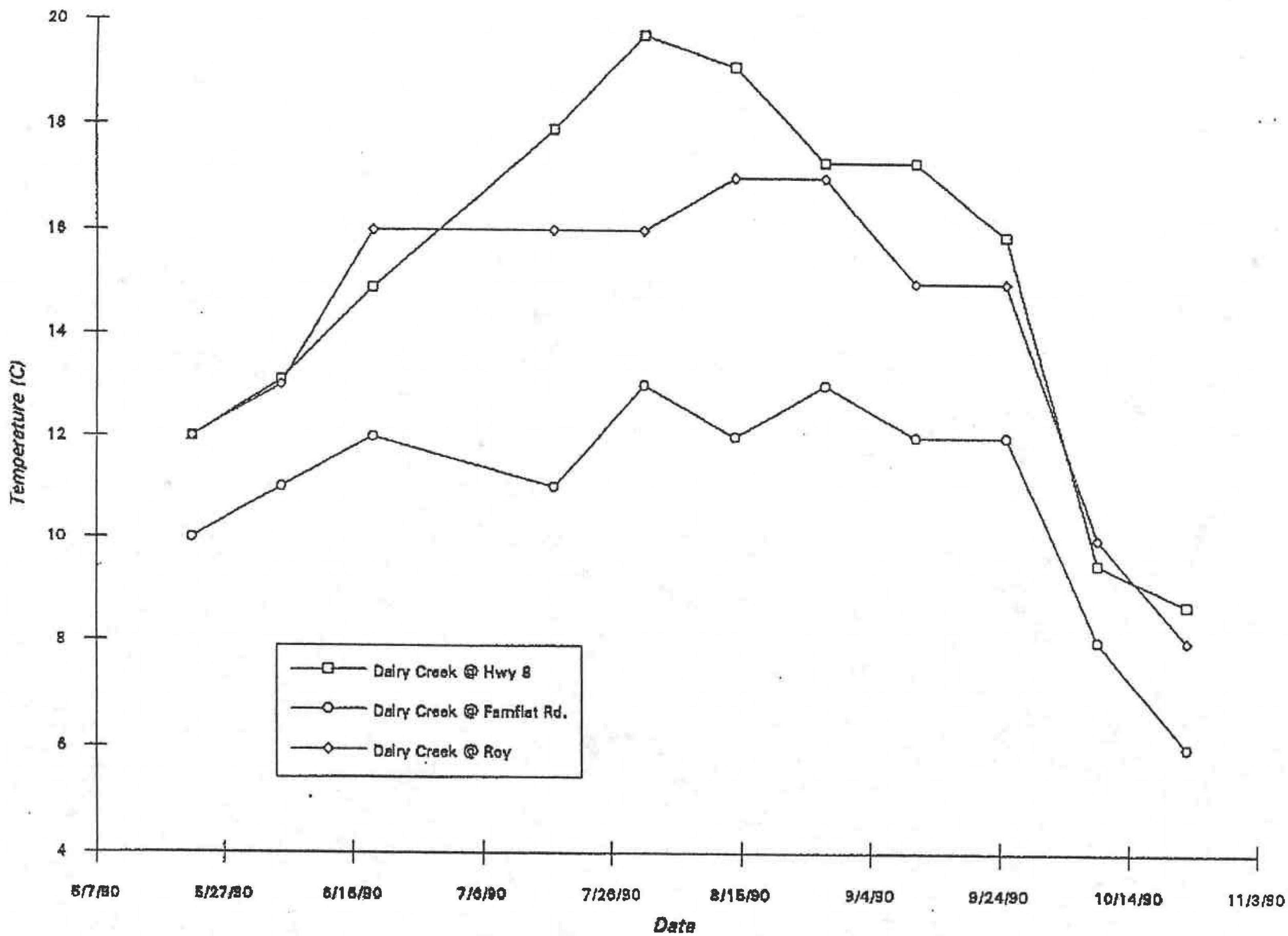

Figure 5. Dairy Creek temperature profiles.

The mainstem Tualatin River has fragmented but noticeable riparian vegetation; however, the width of the river precludes much shading or temperature control. We recommend emphasis on riparian restoration efforts in the tributaries because of the relatively greater influence of riparian canopy and stream bank processes on narrow streams (Vannote et al., 1980). Where other restoration efforts are in progress, such as those by Oregon Department of Fish and Wildlife, the benefits will be maximized.

Economic Impacts

The costs of restoring riparian areas in the Tualatin Basin have not been formally estimated (Wightman et al., 1993). Such an analysis would require an assessment of the degraded riparian habitat capable of restoration and the most cost effective practices to restore functioning riparian systems. Knoder (1994) conducted a preliminary assessment of the potential costs and benefits of re-establishing riparian areas along Gales and Dairy Creeks. The areas along each creek capable of restoration were estimated from aerial photographs and ground truthing. Then the necessary practices to restore riparian areas of 25 and 50 feet widths were identified and their costs estimated. Practices ranged from fencing to purchase of easements and land acquisition. The preliminary analysis showed relatively moderate one-time costs of approximately $95,000 and $270,000 for Gales and Dairy Creeks. Some of the costs are likely underestimated due to the unavailability of market data. However, the costs appear moderate compared to the costs of other stream improvements in the Basin and offer the potential of important benefits. The benefits could only be qualitatively assessed in this case, though the author suggests they may be large compared to restoration costs.

Social and Political Impacts

The restoration of riparian areas along creeks bordered by private property would likely be resisted by the property owners if no compensation were available. Given the broad water quality benefits enjoyed downstream, generating sufficient compensation to offset landowner costs for the example cases illustrated above would seem feasible. With appropriate compensation and without fear of restrictions of other landowner property rights, any social and political opposition may be ameliorated.

VI. CHANGES TO INSTREAM PROCESSES

Two instream measures to reduce conditions promoting excess algal growth were initially considered: (1) *in situ* mixing of water strata, and (2) lowering or removal of Lake Oswego Dam. After further technical investigation, only the alteration of the dam was analyzed. Completely lowering the flaps on the dam would drop the water level at the Lake Oswego Canal 0.6 feet and require pumping of water through the canal to Lake Oswego. Complete removal of the dam would lower the water level at Lake Oswego Canal by 2.2 feet and again require pumping to the lake, but from a lower level.

The primary effect of lowering or removing the dam would be to lower the river elevation, thus exposing now-inundated riparian areas, and to decrease residence time. Primary costs of the dam alteration are the required pumping costs from the river to Lake Oswego and the reduced boating recreational values on the river. Some areas of the river would not be navigable in the summer months. Land values along the lower river may fall initially due to the reduced boating recreating but may rise again in the longer term as natural riparian areas are re-established. Pumping costs from the hypothetical change were not estimated.

VII. APPLICABILITY TO OTHER RIVER BASINS

It is important to determine whether or not the methodology developed for analysis and evaluation of Tualatin River Basin water quality is transferable to other river basins with similar water quality limitations and pollution problems. Among various concerns is the practical question of being able to extend the utility of the investments made in modeling and decision-making tools.

This section of the report provides an appraisal of the ways in which the evaluation tool can be applied to other similar basins. Appraisal is also made of the effort needed to adapt the evaluation tool and of the likely success in achieving a transferred product.

Transferability of Methodology

The analysis and evaluation process relied on two distinct approaches: conceptualization and computer modeling. Conceptualization involved the development of ideas and concepts to understand and explain water quality conditions in the basin. It also involved the evaluation and testing of those ideas against available data. Computer modeling involved the logical manipulation of information to produce a description of the system. However, the computer modeling also required a very great amount of conceptualization, separate from the broad conceptualization discussed above.

Conceptualization was carried out as a collective activity of the entire research team, led by various individuals, to better understand the existing system, the strengths and weaknesses of past efforts at water quality management, and the alternatives that might be tested for making improvements. In terms of importance, the conceptualization phase is an absolute essential for any serious analysis of water quality problems in a river basin. Many of the water quality problems that still persist suffer from a lack of sufficient conceptualization to truly understand the roots of the problems.

Computer modeling was carried out as a limited activity of part of the research team, led by two individuals and guided by several others. Emphasis was placed on developing the means for producing numerical information that could be used to extend the conceptualization efforts. Computer models, being "tools," must be handled in appropriate ways if they are to be useful. Deciding how this handling could best be done was the creative task of the team's modelers. Even though the models used were general models with a "track record" of having been used elsewhere, a great deal of effort was required to make them responsive to the demands of the team for testing alternative scenarios to improve water quality.

The computer modeling phase is actually an extension of the conceptualization phase. Any computer model that is able to portray a system well must have a solid basis for simulating processes that have been well thought out during development of the model. The main advantage of computer models over conceptual models is that they can manipulate and integrate large amounts of complex physical and chemical data and produce numerical results. The brain of the conceptualizer can use the same approach but is unable to develop the numerical values. Surprisingly, good conceptualization often produces good "order-of-magnitude" estimates that the computer model then refines.

Transferability of Findings

The problems of the Tualatin River are not shared by all streams in Oregon. A few other river basins in the state, such as the Yamhill and Bear Creek, also have disproportionate shares of the summertime river flow impacted by return flows and treated effluent. Many developed basins, such as the Willamette as a whole or the Sandy, have ample high-quality streamflow originating from headwater sources. Therefore, the numerical findings for the Tualatin may apply directly only to a few other basins. The Tualatin is also an indicator of conditions that can develop if efforts are not made early to address the control of contamination of surface waters and interconnected subsurface waters.

The alternative solutions proposed for the Tualatin, on the other hand, are underlain by general principles and have broad applicability. The ability to control nutrients and contaminants in a river requires basic understanding of the processes involved and the stream ecosystem impacted, together with ideas for using the natural system to advantage or reestablishing some of that system. Technology also has an important role, through wastewater treatment, control of the flow of potential contaminants, or manipulation of water stored in reservoirs.

Therefore, our evaluation suggests that the findings are transferable. They are applicable in the sense that they are the kinds of solutions that may be considered elsewhere. If they are not transferable as specific numbers describing the conditions likely to be found elsewhere, they serve as warning indicators of levels to which conditions might evolve.

VIII. EVALUATING THE ALTERNATIVE POLLUTION CONTROL STRATEGIES

The four categories of strategies identified to improve Tualatin River water quality were:

1. Augment summertime flow
2. Decrease phosphorus load
3. Modify stream corridors
4. Change instream processes

A fifth category would be to continue the present pollution control activities.

The different measures under each general strategy were analyzed for technical feasibility, anticipated effects on river aquatic health, expected economic costs where available, and finally the possible political and social impacts of implementing the measures. The primary purpose of the analysis is to identify order-of-magnitude cost effectiveness of the alternative measures to reach TMDL targets. The changes in resource conditions not amenable to economic quantification are described qualitatively. Economic benefits have not been estimated for resource quality improvements, such as increased recreation use. Their omission does not imply their lack of importance, rather the study's focus is cost effectiveness of meeting the TMDL targets.

This analysis of alternative strategies provides information to policy makers and the public to gauge impacts and tradeoffs. Assessments of the social desirability of one strategy over another are not made by the study team. Those judgments and policy choices properly remain with the individuals and groups politically responsible for water quality management. It is assumed in this analysis that all agriculture, forestry, and urban activities affecting water quality will meet existing legislative requirements such as the Forest Practices Act and Confined Animal Feeding Operation statutes.

Augment Summertime Flow

Estimates from the instream water quality model suggest that a volume of more than 12,000 AF of storage is necessary to produce the additional 100 cfs flows in July and August necessary to approach the TMDL for phosphorus. Stream flow alteration has traditionally been achieved through constructed devices and systems, such as Scoggins

Reservoir. Other options include changes in management (e.g., timing) of existing water flows to reduce quality problems. Three groups of measures to increase summertime flow were found to have sufficient potential to merit evaluation. They are presented in order of magnitude of increasing expected costs.

Divert Water from Western Slopes

Plans are moving forward to enlarge the capacity of Barney Reservoir on the Trask River. The added 16,000 AF of water would be delivered to the headwaters of the Tualatin through an existing tunnel. The added capacity could be allocated to municipal uses, including water for instream dilution to meet quality standards. Approval of the added Barney capacity must await an environmental impact assessment. Depending upon the allocation of the added capacity, the increased flow could contribute significantly to meet the TMDL in the short run.

The expansion is estimated to cost $21-22 million and many of the costs have been incurred (i.e. sunk costs). Other costs are not expected to be large because the original project planned for the expansion, and infrastructure and land are already in place. Inundation of project land will diminish wildlife habitat and other former uses. Another implicit cost is the lost opportunities for instream uses of the water in the Trask River. Beneficiaries of the interbasin transfer are Tualatin River users in the summer months, including recreationists, riverside residents, and others. There may be considerable political opposition to such an interbasin transfer because it implicitly suggests the Tualatin Basin cannot solve its water quality problems without importing external water.

Reallocate Scoggins Reservoir Capacity

The 53,000 AF of usable capacity of the reservoir is currently allocated as:

23,000 AF	Tualatin Valley Irrigation District
14,000 AF	Municipal uses
12,000 AF	Unified Sewerage Agency
4,000 AF	Other

Irrigation in the Tualatin Valley uses modern sprinkler technology for the most part. Current irrigation efficiency studies suggest irrigators can increase efficiency by small amounts without significant cost (e.g. through better scheduling). Large-scale savings in water use would require changing cropping patterns and probably significant short-run costs. Reducing irrigation water by over 50% to gain the instream water quality effect would significantly decrease revenues and increase cost, requiring new capital investments (e.g. drip technology) plus changes in cropping patterns. Changing the timing of water releases to increase summer (July and August) flows would also require changes in irrigation practices, or foregone revenues.

The potential for reallocating municipal water to save reservoir capacity for instream water quality uses is uncertain. Because current water pricing schemes rarely charge the full opportunity cost of water, some (social) inefficiency is probably present. Reaching the water quality target through diverted municipal sectors coupled with diverted Trask River water could produce enough capacity at low cost. The United Sewerage Agency allocation is already used for pollution control purposes.

Build New Reservoir Capacity in the Tualatin Basin

A final approach to increase summertime flows is to build new capacity dedicated largely to instream quality uses. The expansion of Scoggins Reservoir (by raising dam height 7-10 feet) or building new reservoirs on tributary streams are possibilities. Over 12,000 AF is necessary at present to push the river's flow to a level consistent with the TMDL target. Costs of adding this new capacity include land purchase, construction, and other significant opportunity costs. Initial investment costs would likely fall in a range of $12-$24 million. Because the water must remain in the river, revenues from irrigation and/or municipal uses cannot be collected to offset the project costs. It has been difficult recently to justify new capacity either economically or politically, even with the sale of some capacity. New reservoir capacity in the Tualatin perhaps costing $20 million is probably no exception to this trend.

Decrease the Phosphorus Load

Phosphorus enters the Tualatin River from wastewater effluent, industrial sources, urban runoff, erosion and through leaching from soils and parent material via groundwater flows to stream. Point sources from municipal effluent can be largely controlled during the summer by the Unified Sewerage Agency. Nonpoint sources from urban, agriculture and forestry activities entering through surface or groundwaters are the remaining challenge. However, as evidence grows that groundwater concentrations of P exceed those in the river, the primary focus should shift to activities with the potential to decrease P that eventually flows through groundwaters to the river. In contrast to flow augmentation measures, these source reduction measures attempt to reach concentration targets by lowering loads rather than diluting the existing concentrations with more water.

Alter Agricultural Practices to Reduce Phosphorus Delivery

Based on recommended rates, farmers, ranchers, and horticulturists are estimated to apply approximately 14.5 million pounds of phosphorus fertilizer annual (83 lbs/acre/year) in the Tualatin Basin. Some of the phosphate is used for crop growth, some runs off the surface attached to sediment or organic matter, some leaches to the groundwater and most of it is stored in the soil. A 20% reduction in the rate of phosphorus applied was analyzed in "Estimated Costs of Reducing Nonpoint Phosphorus Loads from Agricultural Land in the Tualatin Basin" by Cross and Woods (1994) in this series of publications. Several measures are available to reduce phosphorus loads to streams including:

- Applying phosphorus at lower rates
- Incorporating broadcast applications of phosphorus into the soil or banding phosphorus applications.
- Applying manures and other wastes uniformly and at recommended rates to soils that are not saturated, followed by incorporation.
- Installation of clean water diversions and more efficient treatment and handling facilities in confined animal feeding operations.
- Reducing nursery runoff through better irrigation management, clean water diversions, and water reuse.
- Reducing erosion by conservation tillage, cover crops, mulches, and filter strips.
- Improving irrigation management, through new water distribution techniques and alternative application schedules.

Application of these practices to basin cropland is estimated to cost approximately $6.5 million per year, but could range significantly below or above that figure. In general, the short-run cost impact is greater, given opportunities for adjustment in the longer term. Much of the cost burden would probably fall on specialty, grain, berry, and fruit and nut production.

Phosphorus budgets for the river are not yet sufficiently precise to know how much comes from runoff or leaching through agricultural land. Indications from summer concentrations in the tributaries are that most of the phosphate comes in subsurface water. Phosphate applied to the soil surface reaches groundwater in tens of years. Changes in phosphate use contribute to long-term solutions, but not to short-term solutions.

Control Urban Phosphorus Applications and Runoff

Urbanization covers approximately 21% of the Tualatin Basin and is concentrated near the lower reaches of the river, the areas that experience excessive summertime algal blooms. Urbanization increases stormwater runoff volumes and peak flows, leading to additional scour and reduced baseflow, and contributes additional phosphorus loads and sediment to the river. Also, urban activities can result in illicit discharges, such as heavy metals, pesticides, and hydrocarbons. All of these urban pollution sources diminish water quality and degrade fish habitat.

At least three "best management practices" (BMPs) could reduce phosphorus load deliveries to the Tualatin River:

- Increase infiltration through land use planning by maximizing contact of runoff with pervious areas, e.g. through minimal use of curb and gutter construction.
- Construct stormwater detention and "wet" ponds for flood peak reduction, sedimentation and phosphorus removal.
- Reduce loads through public education and physical means.

Costs of these measures vary depending on needs for land, volume of water treated, and personnel and equipment needs. Available data permitted only an appraisal of the likely costs constructing of detention and "wet" ponds. Cost estimates range from about $3 to $7 million for establishing the practices.

Urban BMPs are commonly employed in new development, where the cost is borne by the developer. Cost of retrofitting existing development with BMPs could be spread over all urban residents and water system users, a number currently exceeding several hundred thousand households in the basin, possibly by means of a stormwater utility. Because the demands for improved water quality stem from downstream areas, the costs of control may be fully or partially offset by increased benefits to local citizens.

Control Forest Practices that Deliver Phosphorus

Nearly half of the Tualatin Basin is in forest cover. Nonpoint source pollution from forest land management is controlled by Oregon's Forest Practice Rules (FPA). Evidence from lack of FPA violations and from partial stream monitoring data suggests that forestry activities are not a major contributing factor to phosphorus problems in the river. There may be local situations, however, in rural and urban areas, that cause unnecessary water quality damage. Application of the following measures can reduce surface runoff and erosion from forestry activities:

- Limit fire use and intensity
- Limit widespread yarding and slash piling/scarification
- Modify road design and drainage maintenance
- Modify silvicultural systems (e.g. reduce clearcut harvest)
- Reduce harvesting of riparian areas

Costs of the measures vary widely, in part due to varying forest and land conditions in the basin. As with agricultural practices, the short-run cost adjustment would be considerably larger than long-term costs due to enhanced education and technology which lessen the effects of practice restrictions. No formal modeling analysis was conducted of these practices, given the minor perceived role of forestry in river water quality problems.

Stream Corridor Modifications

A healthy watershed is a cohesive ecosystem including tributaries, the mainstem, and the instream environment with adjacent riparian zones and floodplains. The Tualatin River ecosystem has been altered by extensive land use changes first to agriculture and then to urban over the past century. Alterations on the landscape and in the stream affect phosphorus delivery and retention via riparian zones, habitat availability for biota within the stream and along the shore, and biological productivity within these interacting zones.

Three measures would enhance stream function and aquatic health:

- Lower the Lake Oswego Dam to restore natural hydrology
- Restore riparian zones
- Restore and develop wetlands

The dam at Lake Oswego raises the river level by 3 to 4 feet and holds water and phosphorus for longer periods in the lower quiescent stretches. Lowering the dam would add costs of pumping into Lake Oswego. Precise estimates of these costs were not available. Lowering river levels 3 to 4 feet would decrease riverside property values initially; however, landowners would benefit from increased floodplain lands along the river that would be revegetated naturally within a few years. Recreational values may change, possibly limiting boating in some areas, but enhancing nature watching activities not only in the areas adjoining the diversion dam, but also downstream where little water flows in the summer at present. Short-term costs of this measure would be concentrated on riverside landowners, boating recreationists, and those paying the pumping costs. In the long-term, added value to riverside properties, increased survival of salmonid fishes migrating through the mainstem and improved crayfish fisheries would offset some of the costs.

Restoration of vegetation in riparian zones would increase the interception of surface water runoff carrying sediment and/or phosphorus. Riparian vegetation would also intercept phosphorus in subsurface flow. Riparian vegetation and soils would hold wintertime rains for infiltration, which would augment summer recharge of the river. Where riparian canopy covers the channels of tributaries, temperatures can be reduced through shading effects.

Because of cumulative effects accruing downstream, riparian restoration in tributaries probably would provide improved water quality downstream more quickly than major efforts on the mainstem. Gales Creek, one of two creeks identified by ODFW for restoring wild runs of cutthroat trout, is a good candidate for restoration or riparian canopy. Where riparian areas are developed for agriculture, riparian restoration could be a join effort with local, state and federal programs. The limited extent of development on Gales Creek suggests that restoration started here would be more economical than in more developed areas. A preliminary assessment indicates costs in the neighborhood of $95,000 for restorable riparian lands along Gales Creek. Some type of trading regime in which urban development that degrades riparian habitat would purchase rural riparian habitat restoration may be feasible to generate financing.

Dairy Creek, which is more highly developed in agriculture and urban uses, has also been targeted for restoration of cutthroat trout. Riparian vegetation on McKay and Dairy Creeks would provide badly needed filters for sediment and nutrient loads off the landscape. Satellite imagery indicates scarce riparian protection at present. The preliminary analysis suggests approximate costs of about $270,000 for restorable riparian areas along the West Fork of Dairy Creek.

Where riparian areas are in agricultural uses, conservation easements could be purchased that permit compatible commercial use while protecting riparian vegetation. In extreme situations, re-establishing riparian zones may require full land purchase. Fewer additional costs may be required in forested reaches because of guidelines for riparian areas in state and private forested lands. In urban areas along tributaries and on the mainstem, planting of riparian vegetation and reduction of chemical use should be encouraged through education and public cost sharing.

Restoration of more wetlands in the Tualatin Basin would provide natural filters for runoff waters carrying sediment and phosphorus to tributaries and the mainstem. High priority might be given to the river section between Forest Grove and Jackson Bottom, where floodplain restoration, particularly on public lands, might be relatively less difficult. The lands are less developed than further downstream, and a value for wetlands has been established. The addition of wetland function in these areas would improve connectivity to Jackson Bottom and the Hillsboro landfill; these recently restored wetlands would provide excellent colonizing populations of birds and wildlife. Recreation values, including nature watching and hiking, can be expanded into newly acquired lands that can also lead to an associated tourist industry in the basin. As with riparian areas, wetlands would require conservation easements or full purchase for already developed wetlands.

Changes in Instream Process

Phosphorus concentrations, flow levels, and temperature continue to produce the undesirable algal growth. An instream measure could reduce the conditions promoting excessive algal growth.

Removing or lowering the flaps on the Lake Oswego Dam will lower the river depth, increase water velocity, promote better mixing, and may reduce stratification in deeper pools. The improved quality will come from lower residence times. The costs for removal would include one-time cost of dam destruction, pump costs to Lake Oswego, plus the reduced land values along the lower river due to lower summer depths, and the reduced summertime recreation values. As the natural river habitat is restored, more riverside land will be available and different recreation uses will occur, which will partially or fully offset the short-term costs. Lowering the flaps on Lake Oswego Dam would incur the same type of costs but to a lesser degree, because the river would fall only about 2 feet rather than the approximate 6 fee with dam removal.

Continue Current Pollution Control Strategies

Another approach to dealing with the water quality problems in the Tualatin Basin is to continue to pursue present pollution load reduction strategies. This approach has limited costs and has been successful in avoiding a water quality problem of drastic proportions that would otherwise have occurred. Had not each of the major segments of the basin actively pursued load reductions, the Tualatin River would by now have had periods of absolute oxygen depletion during the summer months and algal blooms for more severe that have occurred. Having had the Unified Sewerage Agency construct phosphorus removal facilities has avoided more severe water quality problems. Although these efforts have not improved the aesthetic quality of the river, they have prevented more drastic water quality limitations.

Among the steps required to pursue this strategy are:

- Continue to practice phosphorus removal from the sewage treatment plants.
- Actively pursue nonpoint pollution control strategies through BMPs in the agricultural, forestry, and urban portions of the basin.

- Promote combined compliance with Confined Animal Feeding Operation Rules and Regulations.

While continuing in this way for another few years may avoid significant deterioration, it will not achieve significant improvement.

IX. REFERENCES

Chen, H. Long-Term Streamflow Characteristics at a Station. Oregon State University, Civil Engineering Class Assignment. May 1993.

Cross, T. L. and M. Wood. Estimated Costs of Reducing Nonpoint Phosphorus Loads from Agricultural Land in the Tualatin Basin. OWRRI Tualatin Project. Oregon Water Resources Research Institute, Corvallis, OR. August 1994.

Degenhardt, D. Oregon Department of Forestry. Personal Communication.

Dummer, J. Gales Creek Dam and Reservoir. Oregon State University, Civil Engineering Class Project. June 1993.

Gregory, S. V., F. J. Swanson, W. A. McKee and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. Bioscience 41:540-551.

Harr, R. D. 1983. Potential for augmenting water yield through forest practices in western Washington and western Oregon. Water Resources Bull. 19:383-393.

Hendron, J. Proposed Upper Scoggins Reservoir Hydrologic Feasibility Study. Oregon State University, Civil Engineering Class Project. June 1993.

Kawakami, B. Scoggins Dam storage capacity analysis, with upstream alternate site. Oregon State University, Civil Engineering Class Project. June 1993.

Knoder, E. Evaluating the potential costs and benefits of riparian improvements in the Tualatin Basin. Graduate Internship Report. Oregon Department of Environmental Quality. OWRRI Tualatin Report. 1994.

Morgan, D. Scoggins Dam storage-release analysis. Oregon State University, Civil Engineering Class Project. June 1993.

OTAK, Inc. Tualatin Basin Nonpoint Source Plan, Technical Appendix 2, Modeling of Runoff Quality Using SIMPTM. Report to City of Portland Bureau of Environmental Services, March 1990.

Salminen, E. M. and R. L. Beschta. Phosphorus and forest streams: The effects of environmental conditions and management activities. Report to Oregon Department of Forestry. 1991.

Swanson, F. J., S. V. Gregory, J. R. Sedell and A. G. Campbell. Land-water interactions: The riparian zone. In R. L. Edmonds (ed.) Analysis of coniferous forest ecosystems in the Western United States. US/IBP Synthesis Series 14. Hutchinson Ross Pub. Co., Stroudsburge, PA. 1982.

U.S. Bureau of Reclamation. Tualatin Project, Oregon; Plan Report. Boise, Idaho. July 1970.

U.S. Bureau of Reclamation (Water and Power Resources Service). Tualatin Project, Oregon; Second Phase Report. Field Draft Report. Boise, Idaho. April 1980.

U.S. Bureau of Reclamation. Tualatin Project, Oregon; Second Phase Report. Planning Report/Draft Environmental Statement. Boise, Idaho. Undated (possibly May 1983).

U.S. Bureau of Reclamation. Tualatin River Basin Working Paper. Willamette River Basin Water Optimization Study, Oregon. Boise, Idaho. September 1990.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell and C. E. Cushing. 19880. The river continuum concept. Can. J. Fish. Aquatic Sci. 37:130-137.

Wiegand, C., T. Schueler, W. Chittenden and D. Jellick. Costs of Urban Runoff Quality Controls. In B. Urbonas and L. A. Roesner (eds.) Urban Runoff Quality, Impact and Quality Enhancement Technology. Proceedings of Engineering Foundation Conference, ASCE, New York, June 1986. pp. 366-380.

Wightman, W., L. M. Eisgruber and F. W. Obermiller. Riparian area enhancement--Its effect on private and public net benefit. Working Paper, Agricultural and Resource Economics, Oregon State University. 1993.