AN ABSTRACT OF THE DISSERTATION OF

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The concept of ecosystem management requires that management prescriptions account for economic and environmental goals that are measured in non-commensurate units. This study examines the economic and environmental trade-offs associated with planting a riparian buffer in trees to reduce stream temperatures in the Mohawk watershed, Oregon. The detrimental effects of high stream temperatures on fish production and survival have received increasing attention from State and Federal agencies.

The cost and effectiveness of five riparian buffer scenarios and three tax policies are identified and used to construct a cost-effectiveness frontier. Specifically the study: (i) empirically estimates total welfare changes and their distribution among Mohawk residents; (ii) identifies the effectiveness of alternative buffer prescriptions and (iii) identifies cost-effective policy scenarios.

The study adopts a welfare theory framework to examine welfare changes among producers and residential property owners. A mathematical programming model is used to generate empirical estimates of welfare change. The model has two interesting features, (i) a hedonic pricing analysis is used to generate coefficients which determine

how residential property prices change in response to riparian plantings and (ii) buffer prescriptions are linked to a stream temperature estimator, Heat Source, to estimate changes in stream temperature. Data for the model are collected using a Geographical Information System, personal interview survey, aerial photograph interpretation, enterprise budgets and other sources.

Results indicate that riparian buffers are effective in achieving some reductions in stream temperature. The total cost and distribution of welfare changes across sectors differs between scenarios. Under the efficient scenarios welfare increases in the agricultural sector, decreases in the forestry sector and residential welfare both increases and decreases depending on the scenario. In general, the least efficient agricultural producers will receive the greatest benefits from the proposed scenarios. A progressively wider riparian buffer results in residential property owners bearing a greater percentage of welfare loss.

From a policy perspective the efficient scenarios reduce stream temperatures at the expense of collected tax revenues which may affect individuals outside the study area. The choice of which policy to choose from the frontier may differ depending on whether riparian plantings are voluntary or mandatory.

A Cost Effectiveness Analysis of Actions to Reduce Stream Temperature: A Case Study of the Mohawk Watershed

by

Siân Mooney

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Siân Mooney, Author

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A Cost Effectiveness Analysis of Actions to Reduce Stream Temperature: A Case Study of the Mohawk Watershed

1.0 BACKGROUND, PROBLEM STATEMENT AND OBJECTIVES

1.1 Background

Global environmental and ecological problems such as acid rain, salinization, global warming and diminishing biodiversity have focused the public's attention toward negative externalities that can occur as a result of uncoordinated international and domestic resource use. In the Pacific Northwest alone, there have been many events that serve to highlight the linkages between land management practices, resource use and environmental and ecological quality. For example, diminishing and degraded wildlife habitat has contributed in part to the listing of endangered and threatened species such as the Snake and Columbia River salmon, the spotted owl and marbled murrelet. More recently, the State of Oregon has adopted a restoration initiative[1] in an attempt to prevent some runs of coastal coho salmon from being listed under the Endangered Species Act.[2] Timber management practices have contributed to concerns regarding forest health and its influence on the safety of adjacent communities.[3] In addition, both water quality and quantity have received attention for their influence on fish, wildlife and human activities (Ebersole, Liss and Frissell 1997, Moore and Miner 1997, ODEQ 1996).

[1] Oregon Coastal Salmon Restoration Initiative.
[2] Southern Oregon coho runs were listed as threatened in May 1997.
[3] Some forested areas in eastern Oregon are dying as a result of infestations by pests. There is a very real potential for hazardous fires in many regions, in part due to fire suppression by human intervention resulting in a build up of woody debris and other combustible floor materials to dangerous levels (Quigley 1992, Wickman 1992).

Resource based industries such as timber, agriculture and tourism play a central role in Oregon's economy (Keisling 1995). In the past, Oregon's resources were managed primarily for their marketable commodities expressed, for example, in terms of board feet of lumber and animal unit months (AUMs) of forage. The environmental movement of the late 60's and early 70's changed the products demanded from these resources to include non-market goods such as recreational opportunities and wildlife habitat. The examples cited previously highlight the changing role of resources in society, from one of providing a single marketable commodity such as timber, grazing or irrigation water, to that of providing multiple commodities, with market and non-market values. An increase in the production of environmental goods is often associated with a decline in the production of market goods. However, this might not be the case in all instances. Significant efforts are underway in Oregon to provide funding and technical expertise to private landowners interested in enhancing, restoring and protecting their environment.

1.2 Ecosystem Management and Watershed Analysis/Planning

Public resource managers such as the US Forest Service (USFS) and Bureau of Land Management (BLM) have recognized the complex interactions between various ecosystem elements and the importance of biological and physical diversity in maintaining ecosystems and a healthy productive resource. Advances in the understanding of ecosystem elements and their interactions, coupled with increased public awareness and technological changes that facilitate broader scale management,[4] have prompted public agencies to develop a new management strategy, termed ecosystem management (Brooks and Grant

[4] Such as remote sensing, and geographical information systems.

1992).[5] Ecosystem management is a large scale, multiple use, multiple objective management strategy that crosses all ownership and geographic boundaries and considers both the environmental, ecological and economic sustainability of the resource and the surrounding communities (Bormann *et al.* 1994). Table 1.1 uses forest resource management plans to highlight some of the changes in philosophical and expected management outcomes of ecosystem management in contrast to traditional management.

Ecosystem management has been embraced by public agencies and adopted to some degree by private landowners at the watershed scale. Private landowners are not subject to federal or state mandates to participate in large scale land management endeavors. The State of Oregon has encouraged the formation of public-private partnerships to facilitate voluntary resource restoration, enhancement and protection efforts. Watershed councils[6] are an important part of these partnerships. The councils are eligible to receive funding from State programs for watershed enhancement and public education. The formation of and participation in a watershed council or its programs is entirely voluntary. The number of watershed councils that have been established in Oregon may in part reflect the creation of new funding opportunities and may in part indicate that resource users, owners and managers recognize that many watersheds are experiencing environmental problems. In many cases, these problems are reflected by environmental variables that fail to meet acceptable standards[7] and the perception that further decline or additional problems may arise if the situation is not examined and addressed. Possible explanations for this

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[5] Ecosystem management strategies have been embraced by many public agencies such as the Bureau of Land Management, United States Forest Service, Fish and Wildlife Service and National Oceanic and Atmospheric Administration to name a few (Morrissey, Zinn and Corn 1994).
[6] A watershed council is "a voluntary local organization designated by a local group convened by a county governing body to address the goal of sustaining natural resource and watershed protection and enhancement within a watershed." (ORS 541.350).
[7] For example, many streams have failed to meet the ODEQ water quality standards and are listed on the 303(d) list of water quality limited streams.

cooperation could be fear of broad sweeping environmental restrictions such as those seen at work in the Pacific Northwest as a result of the Endangered Species Act[8], a simple desire for environmental enhancement, or a desire to reduce negative externalities that occur on their land as a result of resource management decisions made by other parties.

Table 1.1. Changes in Forest Management Practices and Expected Management Outcomes

Traditional management	Ecosystem management
Individual stand management prescriptions.	Multiple stand, landscape prescriptions.
Single individual or agency making decisions.	Broader sphere of influence in decision making focusing on teams and some public involvement.
Timber production is the major use of forest resources. Other commodities or resources are a secondary consideration or constraint.	More legitimate consideration given to multiple use of resources, indicated by an increase in the profile and importance of forest resources other than timber production.
Concern with sustaining flows of goods and services.	Concern with states, stocks and flows. Focus on sustainable ecosystems and the health and uniqueness of the ecosystem itself.
Short term project focus.	Desire for longer term focus, questioning of annual targets.
Intensive plantation forestry practices, akin to monoclature.	Retain more natural levels of ecosystem complexity.

Source: Swanson and Franklin (1992), Brooks and Grant (1992), Kennedy and Quigley (1994).

[8] In April 1997, the National Marine Fisheries Service and the State of Oregon developed a memorandum of agreement to in an attempt to prevent the listing of some runs of coastal coho salmon. The State introduced the Oregon Coastal Salmon Restoration Initiative to restore natural coastal salmon populations and fisheries. Watershed councils are expected to play a prominent role in implementing restoration and protection projects.

1.3 Problem Statement

Large scale land planning on an ecosystem or watershed scale recognizes that there are complex spatial and temporal interlinkages between social, economic, environmental and ecological variables. There are a number of steps that need to be taken to conceptualize an operational decision making framework to facilitate planning and management. Perhaps one of the most important is formulating techniques and decision tools that can be used to assess tradeoffs that occur between variables that are measured in non-commensurate units. The economic and ecological consequences of a variety of technologies and management techniques need to be generated before public and private resource users can evaluate alternatives in an informed manner. Detailed economic/ecological analyses are also required to highlight opportunities to develop incentive schemes or consider institutional changes which may facilitate ecosystem enhancement without regulatory intervention.

This dissertation will address some of the general problems discussed above in the specific context of those experienced in the Mohawk watershed. The Mohawk is a watershed within the McKenzie River sub-basin, Oregon, west of the Cascade mountains (Figure 1.1). Resource owners, users, managers and residents of the McKenzie sub-basin have formed a watershed council to identify environmental, ecological, and economic concerns relating to the resources and communities. The McKenzie Watershed Council has formulated broad goals and benchmarks for resource enhancement and protection that address these concerns. Some residents and resource users in the Mohawk perceive that environmental and ecological problems exist in the watershed and further degradation is possible. Although there are many variables that can be considered in determining the ecological or environmental health of a watershed the McKenzie Watershed Council has chosen to focus upon those for which they are able to obtain some measurable indication of

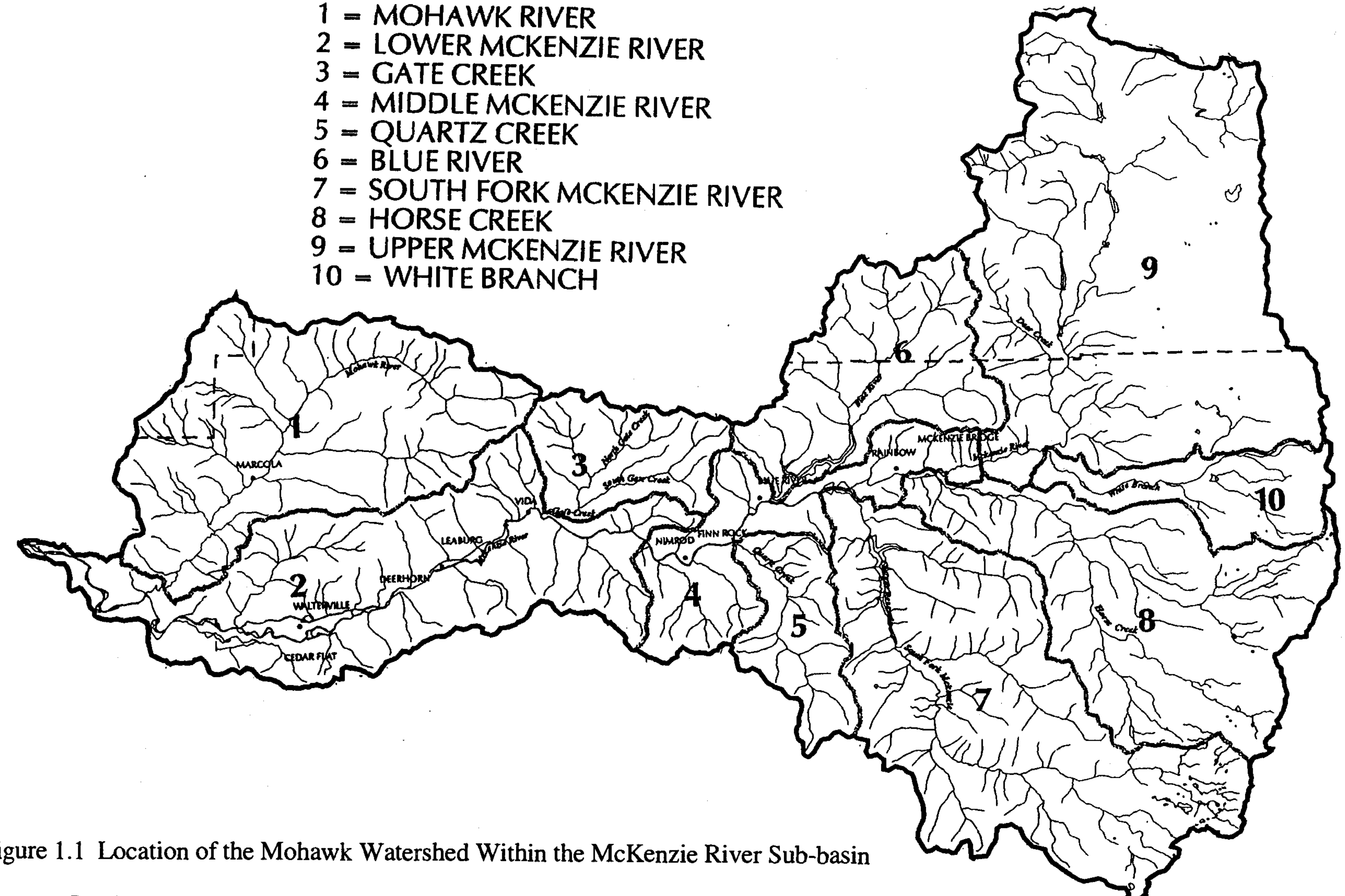

Figure 1.1 Location of the Mohawk Watershed Within the McKenzie River Sub-basin

Source: Produced by Lane Council of Governments, 1995.

improvement such as nutrients in the water, water temperature, fish habitat, wildlife numbers and several others. At the present time, Mohawk residents are unsure of the degree of improvement in selected variables that they wish to attain or the total cost and distribution of costs associated with achieving alternative levels of improvement. This dissertation will examine one important indicator that influences water quality, namely water temperature that is important for its influence on fish abundance and survival (Ebersole, Liss and Frissell 1997, Moore and Miner 1997).

1.4 Objectives

The general objective of the proposed research is to identify cost-effective actions that can be taken to reduce water temperature in the Mohawk watershed. In particular, this research will develop a conceptual framework and associated methodology suitable for analysis of the economic, environmental and ecological trade-offs associated with alternative management strategies that will be transportable to other areas with similar characteristics.

The specific objectives are to:

1. Identify practices that decrease water temperature in the Mohawk River and major tributaries.
2. Examine the trade-offs between producing market and non-market goods from a single resource base.
3. Identify the economic costs associated with practices chosen to reduce water temperature in the Mohawk River and its major tributaries.
4. Identify the marginal welfare change associated with reducing water temperature by incremental amounts.

5. Identify the management practices or combination of practices that are cost-effective in reducing water temperature.
6. Identify which group(s) bear the costs (if any) of reducing water temperature.
7. Examine the influence of selected incentive programs on the magnitude and distribution of costs incurred to reduce water temperature.

1.5 Working Hypotheses

1. If certain practices are implemented, water temperature in the Mohawk River will be decreased.
2. If production of non-market goods increases, production of market goods will decrease (i.e., there is an inverse relationship between market and non-market goods produced from a single resource).
3. If there is to be an improvement in the quality of environmental variables this will come at some economic cost.
4. If stream temperature is decreased to successively lower levels, the cost of this increase in environmental quality increases at an increasing rate.
5. Alternative practices or combinations of practices will achieve a given reduction in temperature at different costs.
6. The welfare changes are not distributed equally over all resource users in the watershed.
7. If incentive programs and regulations are adopted it is possible to change the distribution of welfare change between resource users.

1.6 Description of Study Area: The Mohawk Watershed

The Mohawk is a multiple ownership, multiple use watershed spanning approximately 177 square miles (113,625 acres). Industrial timber lands, both public and private, dominate the higher elevations. Industrial timber land transitions through non-industrial timber lands to a mix of agricultural and residential activities on the valley floor (Figure 1.2). The Mohawk River runs along the valley floor and is fed by several tributaries (Figure 1.2). The average base flow for the Mohawk has ranged between 10 cfs and 34 cfs since 1936 (BLM 1995). An instream flow right requires a minimum flow of 20 cfs throughout the year for aquatic habitat (State of Oregon 1989). Water in the watershed is considered to be over-appropriated (BLM 1995). The Mohawk River and Mill Creek are listed as water quality limited in the ODEQ 303(d) list (ODEQ 1996). The limiting variable is water temperature. High temperatures have also been recorded on other tributaries (BLM 1995).

The watershed is covered, approximately, by US census tract 2 for Lane County. In 1990, 81 percent of the labor force commuted to work outside this census tract. Detailed published information concerning land use within the agricultural and residential areas is sparse and incomplete. A personal interview survey of Mohawk residents was undertaken to provide more information about land use practices. A brief description of the survey design, results and questionnaire is presented in Appendix A. Survey results indicate that landowners on lots of 25 acres or less are less likely to engage in agricultural or timber production than landowners who have larger lots. The main exception being that even small residential landowners engage in hay production (although yield estimates indicate that the hay produced probably does not result from careful agronomic practices as yields are extremely low). Smaller lots seem to be purchased for residential and amenity purposes rather than commercial production.

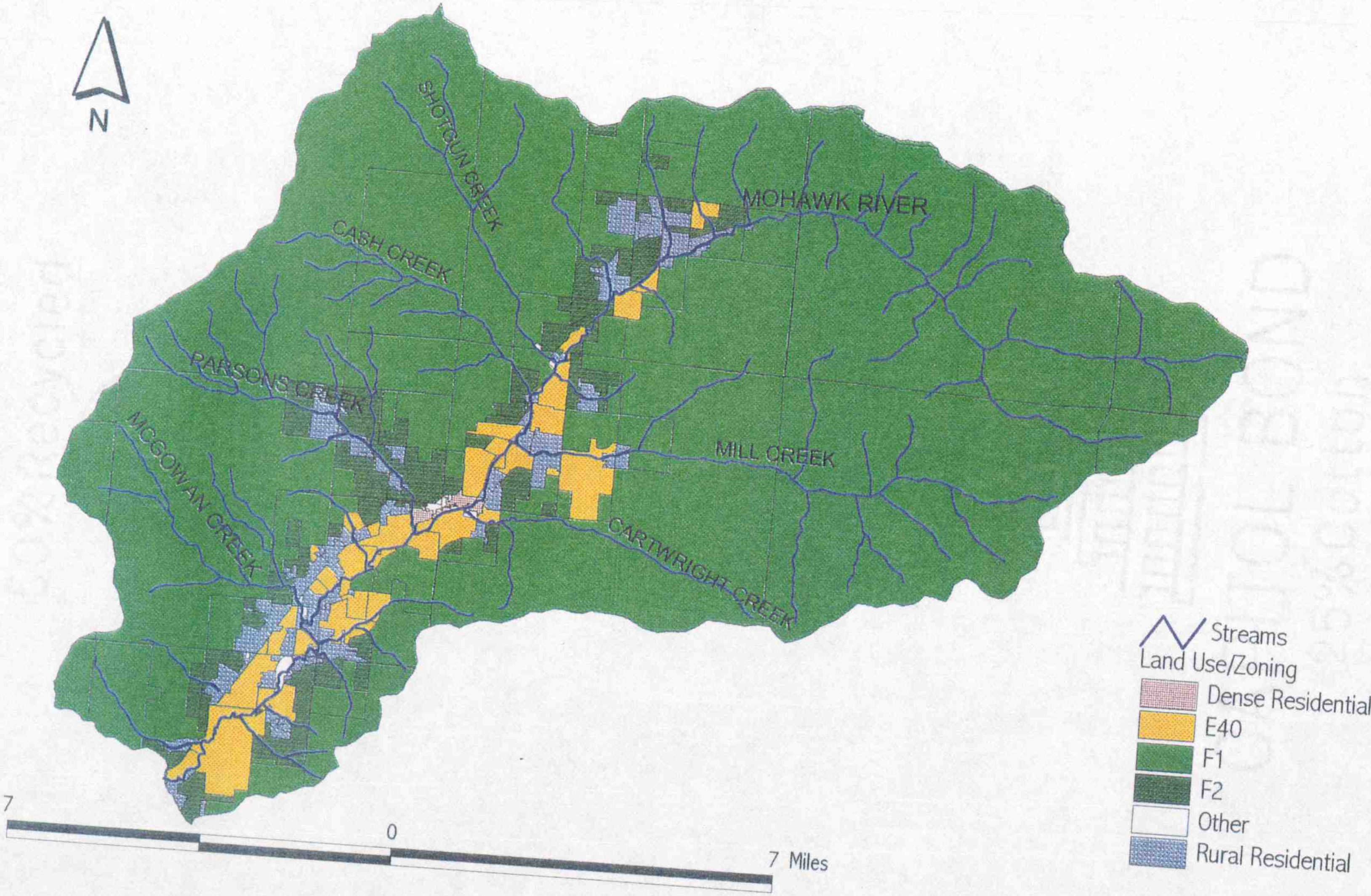

Figure 1.2. Land Use/Zoning in the Mohawk Watershed

2.0 LITERATURE REVIEW

2.1 Frameworks and Guidelines for Conducting Ecosystem Management and Watershed Analysis

In the following section, guidelines and frameworks for ecosystem management are discussed. Several features are considered including the recommended spatial and temporal scale of analysis, the inclusion or absence of alternative ecosystem elements (in particular human and economic components), recommended units of measurement for economic factors and the suggested means of evaluating trade-offs between alternative ecosystem elements.

Bormann *et al.* (1994) and the Science Integration Team (SIT 1994) proposed comprehensive frameworks for ecosystem management. Similar to the Forest Ecosystem Management Assessment Team (FEMAT 1994) they proposed an analysis that may be conducted on several spatial and temporal scales. Ecosystem management at the watershed scale falls within the scope of these frameworks as management at the local scale (Bormann *et al.* 1994) or fine scale (SIT 1994). Each framework explicitly recognized the role of human activities as an integral part of the ecosystem. Bormann *et al.* (1994: p.6) defined ecosystem sustainability as, ".....the degree of overlap between what people collectively want - reflecting social values and economic concerns - and what is ecologically possible in the long term. The overlap is dynamic because both societal values and ecological capacity continually change. We advocate that the desires of future generations be protected by maintaining options for unexpected future ecosystem goods, services and states."

Washington Forest Practices Board (WFPB 1994), Euphrat and Warkentin (1994) and Federal Agency Guide (1995) developed guidelines that focus on the cumulative impacts on resources of multiple land management practices at the watershed scale. Similar to Bormann *et al.* (1994) and the SIT (1994), the Federal Agency Guide (1995) explicitly recognized the role of humans as part of, and an influence on, ecosystem systems. WFPB (1994) and Euphrat and Warkentin (1994) had a narrower focus. They were concerned with the cumulative effects of forest management techniques in the watershed and practices that could improve water quality. Each guide shared a number of procedural similarities. In general the authors proposed that the existing ecosystem structures, processes and functions be assessed, goals and objectives be set for resource enhancement, practices to achieve the goals and objectives be suggested and any decisions that are implemented be monitored as to their degree of success. All studies are strongly in favor of adaptive management or "management as an experiment." The SIT (1994) stated that, "the general planning model for ecosystem management represents an adaptive approach that seeks to learn from experience."

The studies described above do not consider, in any detail, the means by which economic factors can be included in watershed management. SIT (1994) suggested that the economic aspects of the ecosystem be calculated as the value of forest products, forage, water and recreation in addition to the dollar value of economic impacts. Bormann *et al.* (1994) suggested that management decisions must be based on information about the societal costs and benefits of proposed practices. However, the SIT (1994) and Bormann *et al.* (1994) did not suggest how these values should be measured. The Federal Agency Guide (1995) suggested that the economic value of watershed resources could be calculated from their commercial, cultural and recreational benefits and uses. This guide went further than SIT (1994) and Bormann *et al.* (1994) and suggested the economic metric of "willingness to pay" as the appropriate means of calculating the value of off-site passive uses but, did not suggest a measure of the costs/benefits of other uses.

Federal Agency Guide (1995), Bormann *et al.* (1994), SIT (1994), WFPB (1994) and Euphrat and Warkentin (1994) all acknowledged that there are tradeoffs between different ecosystem elements. However none of these studies suggested a means for evaluating these trade-offs. In the economic literature there have been numerous studies that seek to evaluate tradeoffs between goods measured in different metrics. Two techniques that are commonly used to examine economic trade-offs, cost-benefit analysis and cost-effectiveness analysis, are discussed below.

2.2 Evaluating Trade-offs: Cost-benefit and Cost Effectiveness Analysis

Cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) are techniques that are commonly used to evaluate the relative economic efficiency of alternative project proposals. CBA compares the economic costs against the economic benefits generated by a project. If the benefits are greater than the costs, societal welfare is increased and the project is a desirable one, all else constant.

The ecosystem management concept described in section 2.1, requires an economic analysis of alternative projects that could be implemented to achieve predetermined environmental goals. The practice of ecosystem management determines *a priori* to undertake projects that will enhance the health and sustainability of the ecosystem. This *a priori* decision to achieve an environmental goal vastly simplifies the economic assessment procedure. If each project provides the same (or very similar) outcomes, the benefits generated by each project can be assumed to be equal and do not need to be calculated in order to compare the projects.[9] In cases where outcomes are clearly defined, cost-effectiveness analysis (CEA) can be used to evaluate and calculate the relative costs of alternative projects.

2.3 Factors and Practices Influencing Stream Temperature

One of the goals identified in the Mohawk watershed is that of reducing stream temperature. The ODEQ (1995) stated that aquatic life, in particular salmonid fishes and some amphibians, is sensitive to water temperature. High stream temperatures have been shown to reduce the survival, growth and reproduction rates of steelhead trout and salmon (Hostetler 1991) and reduce the available dissolved oxygen for all aquatic biota (Boyd 1996).

There are many factors that influence stream temperature (Beschta *et al.* 1987). As water flows downstream its temperature is influenced by net radiation, evaporation, convection, conduction and advection (Brown 1983), in addition to channel characteristics (such as stream width and depth) and morphology (Sullivan *et al.* 1990, Boyd 1996, USFS 1993).

The primary source of energy for heating streams during the summer months is incoming solar radiation (Beschta *et al.* 1987). Evaporation, convection and conduction, as means of transferring energy, are typically low throughout the year in forested streams (Beschta *et al.* 1987, Brown 1969). The following discussion identifies the major factors influencing stream temperature and some practices that can mitigate their effects.

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[9] In cases where projects provide a range of different benefits in addition to the project goal, these benefits need to be accounted for when comparing the costs of alternative projects.

The volume of water in a stream is an important variable affecting stream temperature. A stream with a small water volume will change temperature faster than streams with a larger volume of water (Moore and Miner 1997, Beschta *et al.* 1987, Sinokrot and Stefan 1993). Flows on some steams could be increased by reducing water withdrawals for irrigation or other purposes (Moore and Miner 1997). The Oregon legislature has recognized this by allowing sales of water for instream flows and encouraging more efficient irrigation techniques.

Stream width for a given water volume is also an important factor influencing stream temperature. Wide streams have a greater surface area and thus receive more solar energy and increase in temperature faster than a stream with the same water volume that is narrow and deeper (Moore and Miner 1997, Beschta *et al.* 1987). Land use activities that knock down stream banks result in streams with a greater surface area and greater proclivity for heating. Stream bank stabilization and/or more careful management of activities that are likely to erode or harm stream banks are actions that could reduce stream heating and result in lower stream temperatures.

Stream temperature can be moderated by reducing the direct beam solar radiation that strikes the water (Beschta *et al.* 1987, Boyd 1996, Sullivan *et al.* 1990). Brown (1983) indicates that net radiation under a continuous canopy may be only fifteen percent of that received by an unshaded stream during daytime conditions. The shading effect of riparian vegetation (which reduces solar radiation striking the water) is thought to reduce stream temperature (Brown 1983, Beschta *et al.* 1987, Sullivan *et al.* 1990, Boyd 1996). A great deal of emphasis has been placed on stream shading as a way to reduce stream temperatures; for example the Oregon Forest Practices Act and the Oregon Coastal Salmon Restoration Initiative.

In addition to the incidence of shading, the location of shading is important (Beschta *et al.* 1987). Once the temperature of the stream has increased, the heat is not easily dissipated even if it subsequently flows through a shaded reach (Beschta *et al.* 1987) indicating the importance of maintaining shade along the headwaters and tributaries of the stream in addition to the mainstem.

Riparian buffer strips[10] can be planted to provide shade and lower stream temperatures. Mohawk residents are being encouraged to adopt riparian plantings by the East Lane Soil and Water Conservation Service and the McKenzie watershed council. The quality and quantity of shade provided by a riparian buffer is a combination of several components including canopy cover, tree height and buffer width. These factors influence the vegetation density, the time period during which a stream is shaded throughout the day, and the stream side vegetation through which solar radiation must pass to reach the stream surface (Boyd 1996). Taller trees increase the period of time that the river is shaded during the day. Dense vegetation and a wide riparian buffer strip will decrease the intensity of solar radiation striking the stream surface.

Brown, Swank and Rothacher (1971) concluded that a sufficiently wide riparian buffer (25 feet to 100 feet) can be as effective as undisturbed forests for protection of water quality. This conclusion is supported by Beschta *et al.* (1987) who stated that "buffer strips of 30 meters or more generally provide the same level of shading as that of an old growth stand."[11]

In addition to providing stream shade, riparian buffers provide many other functions. O'Laughlin and Belt (1995) list the following beneficial functions: providing

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[10] A riparian buffer strip is a protective area adjacent to a stream that shields it from the effects of harmful management practices.
[11] 30 meters is approximately equal to 100 feet.

shade, organic debris, regulating sediment and nutrient flow, stream bank stabilization, moderating riparian micro-climate and providing wildlife habitat. The manner in which a riparian buffer provides these functions is described in O'Laughlin and Belt (1995).

Riparian plantings, rather than measures to increase flow or reduce channel width are examined in this study for two reasons. Firstly, riparian plantings are being encouraged in the watershed and secondly, state policies have stressed the importance of maintaining a riparian buffer.

2.4 Evaluating Economic and Environmental Trade-offs

Many different modeling techniques have been used to estimate the economic consequences of a change in resource use and management. Several studies are reviewed in sections 2.4.1 and 2.4.2 that examine the economic impacts on producers and/or consumers as a result of changes in resource endowments or costs. Models that estimate stream temperature change in response to various parameters are reviewed in section 2.4.3.

2.4.1 Environment and Production Value

Many studies have used mathematical programming techniques to calculate the costs and management changes that occur as a result of changes in resource use from market to non-market goods. Connor, Perry and Adams (1995) used multiple objective programming to evaluate the cost-effectiveness of policies targeted at reducing one externality when multiple externalities are present. Trade-offs between objectives were generated by running the model with parametrically varying levels of minimum net revenue and environmental objectives and plotting the solution points. Prato, Xu and Ma

(1994) used multiple objective programming to generate efficient combinations of net returns, soil erosion and nitrate available for leaching for a case study farm. Output from the programming model was used to generate economic and environmental trade-off frontiers similar to Connor, Perry and Adams (1995). Thomas and Boisvert (1995) used a dynamic, chance constrained, farm level programming model that maximized expected net revenue from agricultural production. Production practices chosen by the model were linked to groundwater nitrate concentrations which allowed a relationship to be constructed between farm production, nitrate leachate, and economic returns. Prato and Wu (1995) formed a chance constrained programming model to evaluate economic impacts at the watershed scale resulting from progressively greater reductions in water contaminants such as nitrogen and sediment. Net returns in the watershed were calculated by the model given a range of constraints on the environmental goals. Prato, Fulcher and Xu (1995) used a multiple objective programming model to generate changes in economic profit at the watershed scale associated with different levels of soil erosion and chemical leaching. Turner (1996) used farm level non-linear programming models to estimate the amount of water that a producer might provide for instream flows at alternative purchase prices. The models were solved repeatedly with alternative water purchase prices to construct a water supply curve.

There is a large literature that uses operations research techniques to address the economic impacts of a change in production practices in response to constraints on environmental variables. However, there are also other methods that have been used to assess trade-offs. Garber-Yonts (1996) examined the trade-off between the cost of efforts to aid recovery of Columbia River salmon and their probability of survival. Economic costs for alternative levels and types of recovery measures were obtained from previous studies. Two fish models were used to calculate changes in the probability of salmon survival given varying levels and combinations of salmon recovery measures. Cost estimates for the alternatives examined were the sum of all costs generated by each action included in the alternative. The corresponding actions are used in the fish models to calculate the probability of survival of salmon stocks. The models are run repeatedly using different combinations of activities to generate a cost-effectiveness frontier. Unlike the programming techniques discussed in the previous section, this technique assumes that there is no change in the original combination of activities in an area and does not generate the optimal economic response to a change in production costs. Montgomery and Brown (1992) and Montgomery, Brown and Adams (1994) calculated welfare losses resulting from a reduction in timber supply in response to lower harvest levels to preserve habitat required by the northern spotted owl. Welfare losses were calculated using an econometric timber assessment market model (TAMM). Welfare losses in the wood products market for a given probability of owl survival were plotted to obtain the marginal cost curve of owl survival.

The majority of studies reviewed above used mathematical programming techniques to calculate changes in economic measures such as profit and returns as a result of constraints on input use or production activities. As the constraints were changed the economic models calculated the combinations and levels of activities that were most profitable given the change. A technique such as that adopted by Garber-Yonts (1996) required that costs for alternative measures already be calculated and assumed that the same combination of practices continued into the future. The econometric model used by Montomery and Brown (1992) and Montgomery, Brown and Adams (1994) is useful if the relationship between an economic activity and the environmental or biological outcome can be established and used to drive the model.

Each of the above analyses used physical or biological process models in conjunction with, or embodied within,[12] economic models to calculate economic/environmental or economic/biological tradeoffs. This literature review did not identify any studies that considered a trade-off between economic activity and stream temperature.

2.4.2 Environment and Consumption or Amenity Value

Although many environmental attributes are not sold in the market, consumers implicitly account for these attributes when making a purchase decision. Residential property values have been widely used to estimate the benefits or costs to property owners of changing the quantity or quality of a non-market attribute on their property. The hedonic pricing technique is based on the premise that observed differences in property values are a consequence of differences in the attributes possessed by each property (whether real or imagined by the purchaser). Otherwise identical properties can have different sale prices as a result of different levels of environmental amenities at each location. Hedonic pricing has been used since the late 1960's to estimate the effect of a change in the quantity or quality of an environmental attribute on property price (Ridker 1967, Freeman 1971).

Kulshreshtha and Gillies (1993) used a hedonic pricing approach to estimate the implicit price of a river view. They found that a river view has a positive value to property owners that is reflected by the higher prices commanded by these properties. Mahan (1996) used hedonic pricing to estimate the value of wetland environmental

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[12] For example Turner (1996).

amenities in the metropolitan area of Portland, Oregon. Results suggested that wetlands do influence residential property values. Price differentials as a result of proximity to a wetland varied across wetland types. Streiner and Loomis (1996) used hedonic pricing to estimate the influence of stream restoration measures on residential property values in areas of California. Their analysis indicated that projects that maintain fish habitat, establish educational trails or are related to stream bank stabilization[13] have a positive influence on surrounding property values. No literature was discovered that examined the influence of measures to reduce stream temperature (such as planting riparian buffers) on property values.

2.4.3 Estimating Changes in Stream Temperature

There are two main classes of stream temperature models, reach models and basin models. Reach models predict temperatures over a relatively short stream reach (hundreds to thousands of feet) by characterizing conditions within the reach (Sullivan *et al.* 1990). Basin models attempt to predict temperature for entire watersheds.[14] A thorough review and comprehensive evaluation of several models is presented within Sullivan *et al.* (1990).[15]

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[13] These projects include clearing obstructions, revegetating stream banks and clearing debris from the stream (Streiner and Loomis 1996). Their study did not consider the impacts on property values of a riparian buffer planted in trees.

[14] Sullivan *et al.* (1990) indicated that basin models are often difficult to use.

[15] Sullivan *et al.* (1990) reviewed the reach models TEMPEST (Adams and Sullivan 1990), SSTEMP (Theurer, Voos and Miller 1984), TEMP-86 (Beschta 1986) and Brown's Equation (Brown 1970). Basin models included in their review are QUAL-2E (Brown and Barnwell 1987), SNTEMP (Theurer, Voos and Miller 1984) and MODEL-Y (developed by the Temperature Work Group who are Sullivan *et al.*; no reference was provided for this model).

SHADOW (USFS 1993) is a "physically based model designed to be used within the time constraints of most project planning efforts." The model can be used to examine an individual stream reach or stream network and runs on a personal computer using Lotus 1-2-3. The temperature sub-model calculates the five-day average maximum summer temperature based on inputs such as canopy shade, solar declination, stream width and the reach length. Heat Source (Boyd 1996) uses an energy balance approach based on the physical processes of heat transfer to describe and predict changes in stream temperature. The model calculates temperature change over a reach. However, it is possible to extend the model predictions over a wider area by using final temperature predictions for one reach as initial temperature conditions for the next reach and running the model iteratively from the headwaters downstream.[16] Given temperatures at the upstream point of the reach, the model calculates a full day temperature profile for the downstream point of the reach using variables that describe the geographic location of the reach, stream flow, width, depth and velocity, vegetation height, buffer width and canopy cover. The model provides plots and numeric tables listing upstream and downstream temperatures and the difference between the two. Heat Source can be operated on a personal computer running Windows 95.

2.5 Suggested Standards for Riparian Plantings

There are many programs in Oregon that promote riparian plantings for the purpose of enhancing fish and wildlife habitat, stream bank stabilization or other reasons.[17] Most programs offer cost share, favorable tax benefits and/or technical

[16] Personal communication with Matthew Boyd, developer of Heat Source.
[17] See Pacific Rivers Council (1994) for a description of many of these programs.

assistance to landowners adopting riparian plantings. Few programs require participants to adopt mandatory buffer widths, relying instead on widths suggested by technical personnel from the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) and local Soil and Water Conservation District (SWCD) technical staff or staff at similar agencies. In many instances restoration measures are conducted in conjunction with a watershed plan developed by the local watershed council. Some lower bound estimates to recommended riparian buffer widths can be obtained by examining the recommended practices and guidelines for riparian plantings on private lands adopted by the USDA, NRCS and also by examining other programs that have developed explicit requirements for riparian buffer widths.

The USDA, NRCS promotes the use of riparian buffer strips to create shade (leading to lower overall water temperatures), provide a source of detritus and large woody debris, and reduce sediment, organic material and nutrients in subsurface and shallow ground flow. The NRCS has adopted the concept of a buffer divided into three zones. Zone 1 is adjacent to the water body and has a minimum recommended width of 30 feet. Zone 1 contains permanent woody vegetation immediately adjacent to the active channel edge and extends through the zone of frequent flooding. Its main purpose is to maintain the channel bank and create and maintain a favorable habitat for aquatic organisms. Zone 2 is a managed forest and is up-slope of zone 1. Zone 3 is a herbaceous filter strip. Participation in riparian plantings is generally voluntary with the landowner contacting the NRCS for technical assistance and perhaps some cost share.

The East Lane Soil and Water Conservation District has developed riparian vegetation buffer guidelines for the purpose of stream bank stability, stream temperature reduction and enhancement of fish and wildlife habitat. Technical staff at the ELSWCD, suggest a buffer that extends a minimum of 50 feet from the top of the stream bank break in slope (measured perpendicular to the water body) with livestock exclusion or control as necessary (personal communication, Lorna Baldwin ELSWCD - May 1997). The program provides free technical assistance and in many instances provides free trees and labor if required (personal communication, Lorna Baldwin ELSWCD - June 1997). Participation in the program is voluntary.

All private forest landowners and non-federal public forest land managers engaged in timber production[18] must follow the Oregon Forest Practices Act. In 1994 changes were made to the Act resulting in the following requirements for buffer strip widths in riparian management areas (Table 2.1).

Table 2.1. Riparian Management Area Widths for Streams of Various Sizes and Beneficial Uses

Stream Size\Type	Type F[1]	Type D[2]	Type N[3]
Large	100 feet	70 feet	70 feet
Medium	70 feet	50 feet	50 feet
Small	50 feet	20 feet	Specified water quality protection measures

[1] Fish use or fish and domestic water use.
[2] Domestic water use with no fish use.
[3] Neither fish or domestic water use.
Source: Forest Practice Administrative Rules (1995).

Stream size is determined on the basis of the average annual stream flow. Large streams have an average annual flow greater than 10 cfs. Medium streams have an average annual flow between 2 and 10 cfs. Small streams have an average annual flow of less than 2 cfs.

[18] Any timber sold or bartered is subject to the Forest Practices Act, regardless of the size of sale (personal communication with Tom Bergland, Forester, Oregon Department of Forestry, East Lane District).

Type F streams have a fish use, or both fish use and domestic water use. Type D streams are used for domestic water but have no fish use. Type N streams have neither fish or domestic use. The majority of streams in the Mohawk watershed are type F and span all three size classifications.

2.6 Existing Tax Policies that Encourage Certain Land Uses

The State of Oregon has created tax incentives such as farm and forest deferrals and the riparian tax incentive program which encourage land uses such as forestry and agriculture within the state. Property taxes are a function of the tax rate per $1,000 of assessed property value. Each property owner in a tax district is taxed at the same rate. Some properties are eligible for a farm or forest deferral that lowers the assessed value of the property and reduces property taxes. The riparian tax incentive program is provided through the Oregon Department of Fish and Wildlife (ODFW). The program offers a complete property tax exemption on riparian lands up to 100-feet from the stream. To qualify for the program property owners must have a *bona fide* riparian management plan agreed upon with the ODFW. Incentive programs similar to the farm or forest deferral and the riparian tax incentive program could be used to change the distribution of costs associated with planting a riparian buffer in the Mohawk watershed.

3.0 CONCEPTUAL FRAMEWORK AND THEORY

This chapter presents a comparative static approach that can be used to estimate economic and environmental trade-offs at a watershed scale. An appropriate measure of welfare change is described followed by a discussion of its role within a cost effectiveness frontier. Similarly, a method is described which can be used to estimate changes in stream temperature in response to a variety of riparian buffer widths. A cost effectiveness frontier is one way of combining economic and physical data in a manner convenient for decision making.

Land use in the Mohawk watershed can be broken into two broad classifications namely, land used in production and land used for its amenity value. Some residents use the land base to maximize their welfare from production activities such as forestry and agriculture. These individuals are classified as producers. Other residents use the land base to maximize their utility from residential, aesthetic or other non-market amenities such as rural lifestyle and environmental attributes. These individuals are classified as consumers.

The adoption of wider or narrower riparian buffer strips will change the total welfare generated by the land base in the Mohawk watershed, both for producers and consumers. The following sections propose a framework that can be used to estimate the change in the economic welfare of producers and consumers as a result of adopting these practices.

3.1 Changes in Economic Welfare: Compensating and Equivalent Variation

The welfare of an agent is reflected by the utility that agent receives from making a set of choices given existing constraints. A change in resource availability or constraints allows (or forces) the agent to make a new set of choices that can result in either an increase or decrease in their utility. A change in utility is a direct indication of welfare change. However, utility is not measurable for an empirical analysis.

Hicks (1943) suggested the measures of compensating and equivalent variation as an observable alternative to measuring the intensities of individual preferences. These measures are based on the premise that a money measure of welfare change for an individual is the amount of money the individual is willing to pay or accept to move from one situation to another (Just, Hueth and Schmitz 1982).

The measure of compensating variation is based on the notion that the agent has the rights to the original situation and is the amount of money that, when taken away from (given to) an individual after an economic change, leaves the person just as well off as they were before the change. The measure of equivalent variation is based on the notion that the agent has the rights to the new situation and is the amount of money that, when taken away from (given to) an individual, would induce the person to forego the new situation.

The following discussion uses the concept of compensating variation as a measure of welfare change. That is, welfare change is measured by the amount of money that would be taken from/given to consumers and producers in the watershed to leave them as well off after the proposed changes as they were before.

3.2 Change in Producer Welfare

A change in producer welfare can be analyzed in the context of the neoclassical model of profit maximization. Profit is a directly observable money measure of welfare. Welfare changes can be calculated as the change in producer profit in response to some technological, political or market change.[19] CV will be negative for a change that increases profits and positive for a change that decreases profits.

In the following discussion, assume that the firm is a price taker in both input and output markets. The economic problem faced by the producer is to maximize profits (Π), subject to technological and market constraints as shown in equations (3.1) and (3.2). Where $\mathbf{p}$ and $\mathbf{w}$ are vectors of given output and input prices respectively. $\mathbf{y}$ is a vector of output quantities determined by the firm, $\mathbf{x}$ is a vector of input quantities determined by the firm and $\mathbf{b}$ is a vector of environmental inputs used in the production process. Equation (3.2) represents the technology facing the firm.

$$\text{Max } \Pi = \mathbf{py} - \mathbf{wx} \tag{3.1}$$

$$\text{s.t. } F(\mathbf{y},\mathbf{x},\mathbf{b}) = 0 \tag{3.2}$$

Substituting (3.2) into (3.1), solving for $\mathbf{x}^*$ (the optimal vector of inputs) and substituting back into (3.1), yields the firm's profit function, $\pi(\mathbf{p},\mathbf{w},\mathbf{b})$.

[19] In the event that the price change is so large that the firm decides not to produce, the correct measure of compensating variation is $-(\Pi_0 + TFC_1)$. Where Π_0 is profit obtained before the change and TFC_1 is total fixed cost after the change.

3.3 Change in Producer Welfare as a Result of a Change in Prices or Resource Endowment

Using Hotelling's lemma it can be shown that the first derivative of $\pi(\mathbf{p},\mathbf{w},\mathbf{b})$ with respect to p_i yields the output supply function $y_i(p_i,\mathbf{w},\mathbf{b})$ and the first derivative with respect to w_i yields the input demand function $x_i(\mathbf{p},w_i,\mathbf{b})$. For a firm k, producing one output using one market input and one environmental input, the welfare change (ΔW_k) associated with a price increase from p_0 to p_1 can be measured using the concept of compensating variation shown in equation (3.3).

$$\Delta W_k = \int_{p_0}^{p_1} y(p,w,b)\partial p = \pi(p_1,w,b) - \pi(p_0,w,b) \tag{3.3}$$

If we assume that the producer attaches a certain level of welfare to attaining profit level $\pi(p_0,w,b)$, then the compensating variation or welfare change is measured as the difference in the profits achieved before and after the change (as shown in equation (3.3)). In the case of a price increase, CV will be negative. Similarly, a welfare change resulting from a change in input prices or the availability of environmental inputs can be measured as the difference in profits before and after the change.

The discussion above illustrates how producer profit can be used to calculate changes in economic welfare as a result of a change in the parameters $\mathbf{p}$, $\mathbf{x}$, or $\mathbf{b}$. Total welfare change (ΔW_k^T) over all producers, equation (3.4) is simply the sum of all individual money measures of welfare change.

$$\Delta W_k^T = \sum_k \Delta W_k \tag{3.4}$$

3.4 Change in Consumer Welfare

A riparian buffer strip is a non-market good and as such does not have an explicit observable price. Although many environmental attributes are not explicitly sold in the market place, consumers often take into account these attributes when making a purchasing decision. Changes to the riparian buffer strip are a change in the characteristics of the living environment selected by consumers and can influence the value of land used for its non-consumptive or amenity value

If the housing market is in equilibrium and buyers are free to choose a property anywhere in the market, then buyers have optimized their property choice based on the cost of and utility provided by alternative locations (Freeman 1993). In addition to a property market in equilibrium, it is assumed that there are a wide variety of properties available, each property buyer purchases only one house and the area examined can be treated as a single market for housing services (Freeman 1993).

The price of property i (P_i) can be expressed as a function of a set of characteristics such as a vector representing the characteristics of the lot ($\mathbf{L}_i$), a vector of attributes of the residence standing on the lot ($\mathbf{R}_i$), a vector of neighborhood characteristics ($\mathbf{N}_i$) and a vector of environmental characteristics ($\mathbf{E}_i$) as shown in equation (3.5).[20]

$$P_i = P(\mathbf{L}_i, \mathbf{R}_i, \mathbf{N}_i, \mathbf{E}_i) \tag{3.5}$$

[20] For a more detailed explanation of the following theory, see Freeman (1993).

The vector of environmental characteristics can be further subdivided into the characteristic of a riparian buffer strip (RB_i) and a vector of all other environmental characteristics ($\mathbf{AOE}_i$). The hedonic price function can be written as shown in equation (3.6).

$$P_i = P(\mathbf{L}_i, \mathbf{R}_i, \mathbf{N}_i, RB_i, \mathbf{AOE}_i) \tag{3.6}$$

A property buyer is assumed to maximize utility[21] from purchasing a property and all other goods subject to their budget constraint as shown by equations (3.7) and (3.8). X is a numeraire good and its price is normalized to one. M represents the consumer's income.

$$\text{Max } U = U(X, \mathbf{L}_i, \mathbf{R}_i, \mathbf{N}_i, RB_i, \mathbf{AOE}_i) \tag{3.7}$$

$$\text{s.t } M - P_i - X = 0 \tag{3.8}$$

Forming a lagrangian and maximizing over X and RB_i results in the first order condition shown in equation (3.9).

$$\frac{MU_{RB_i}}{\frac{\partial P_i}{\partial RB_i}} = MU_x \tag{3.9}$$

Equation (3.9) shows that the property buyer maximizes utility at the point where the marginal utility per dollar spent on the numeraire good is equal to the marginal utility per dollar spent on the riparian buffer. From equation (3.9) it is clear that the partial derivative of the hedonic price function (equation (3.6)) with respect to the riparian buffer attribute yields the marginal implicit price of a small change in the quantity/quality of that attribute.[22]

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[21] It is generally assumed that utility is weakly separable in property and its characteristics. This assumption implies that the demand for property characteristics is independent of the prices of other goods (Freeman 1993).

[22] The partial derivative of the hedonic price function with respect to any attribute yields the marginal implicit price of that attribute.

That is $\frac{\partial P_i}{\partial RB_i}$ is the additional expenditure required to purchase a property with a marginally larger riparian buffer characteristic, *ceteris paribus*.

A utility maximizing consumer will select additional units of RB_i up to the point where their marginal willingness to pay, $b_j = b_j(\mathbf{L}_i^*, \mathbf{R}_i^*, \mathbf{N}_i^*, RB_i, \mathbf{AOE}_i^*, U^*)$, for RB_i is equal to the marginal cost of purchasing RB_i (that is, $\frac{\partial P_i}{\partial RB_i}$) as shown in figure 3.1. The marginal willingness to pay function, b_j, shows individual j's marginal willingness to pay for changes in an environmental characteristic (in this case a riparian buffer) on property *i*, holding utility constant.

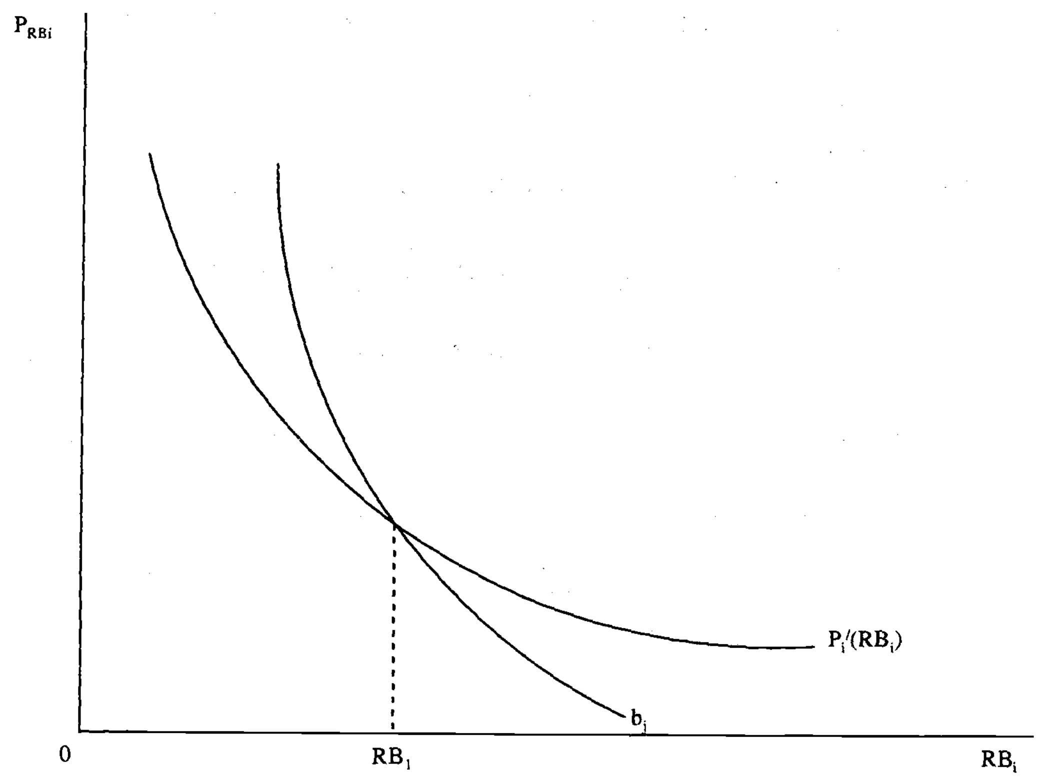

Figure 3.1. Marginal Willingness to Pay and Marginal Implicit Price Functions

3.5 Change in Consumer Welfare as a Result of Changing the Riparian Buffer Width

If b_j is known then the welfare change for individual j, associated with a change in RB_i can be found by integrating b_j over the relevant range of change in RB_i as shown in equation (3.10).

$$\Delta W_j = \int_{RB_0}^{RB_1} b_j(\mathbf{L}_i^*, \mathbf{R}_i^*, \mathbf{N}_i^*, RB_i, \mathbf{AOE}_i^*, U^*)\partial RB \tag{3.10}$$

The total welfare change over all consumers is the sum of their individual welfare changes. In some cases, it is not necessary to identify the marginal willingness to pay functions associated with each consumer to obtain a measure of welfare change. If the marginal willingness to pay function is constant, welfare changes can be calculated from the product of the marginal implicit price of RB_i at the original utility maximizing level and the quantity change in the amenity level of RB_i as shown in figure 3.2 and equation (3.11).

The curves b_{jA} and b_{jB} in figure 3.2 are two possible willingness to pay curves. If b_{jA} is horizontal, the welfare change associated with a change in the quantity of RB from RB_1 to RB_2 is measured by area X+Y+Z. If the marginal implicit price of the attribute at the initial point RB_1, is known, this can also be used to calculate the welfare change as in equilibrium, the marginal willingness to pay for RB_i equals its marginal implicit price. The welfare change can be calculated as shown in equation (3.11).

$$\Delta W_j = \frac{\partial P_i}{\partial RB_i}\left(RB_2 - RB_1\right) \tag{3.11}$$

If the marginal willingness to pay function is not constant but downward sloping (consistent with additional units of RB_i being considered beneficial) this measure will result in an overestimate of welfare change as the true welfare change in this instance is area Z. If RB_i is an undesirable attribute the willingness to pay function will be upward sloping and the assumption of constant marginal willingness to pay will result in an underestimate of welfare changes.

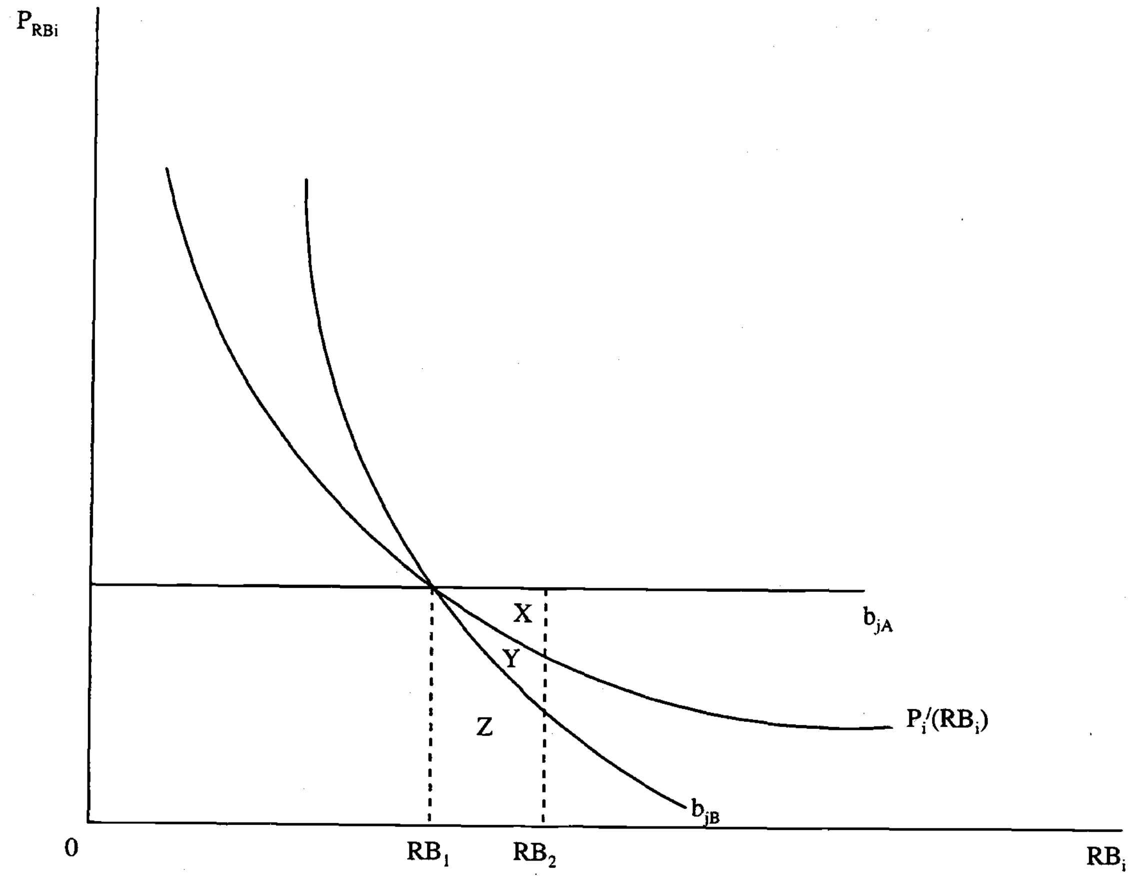

Figure 3.2. Special Case for Measuring Welfare Changes

The framework presented above can be used to impute a value for the riparian buffer as an environmental amenity for residents in the watershed that have purchased property for its amenity value. The total welfare change (ΔW_j^T) over all consumers (equation (3.12))is the sum of all individual welfare money measures of welfare change.

$$\Delta W_j^T = \sum_{j=1}^{J} \Delta W_j \qquad (3.12)$$

3.6 Change in Total Welfare: Sum of Consumer and Producer Welfare Change

The welfare measure, compensating variation, allows welfare changes to be expressed in observable dollar terms. The total welfare change, ΔTW , across producers and consumers in the watershed can be measured by summing the total producer welfare change and the total consumer welfare change as shown in equation (3.13).

$$\Delta TW = \Delta W_k^T + \Delta W_j^T \qquad (3.13)$$

3.7 Cost Effectiveness Analysis and Cost Effectiveness Frontier

A cost-effectiveness analysis can be used to identify the least cost alternative that achieves a given environmental improvement. The most efficient alternatives can be examined by constructing a cost effectiveness frontier that is the least cost envelope of plans that achieve a given outcome. A cost-effectiveness frontier, representing the least cost alternatives for reducing water temperature, can be developed for the Mohawk watershed. Estimates of total welfare change and stream temperature response to alternative buffer prescriptions are required to construct the frontier. Each riparian buffer prescription and tax policy alternative will have an associated pair of estimates of stream temperature reduction and economic welfare change which can be plotted to identify the cost effectiveness frontier (figure 3.3).

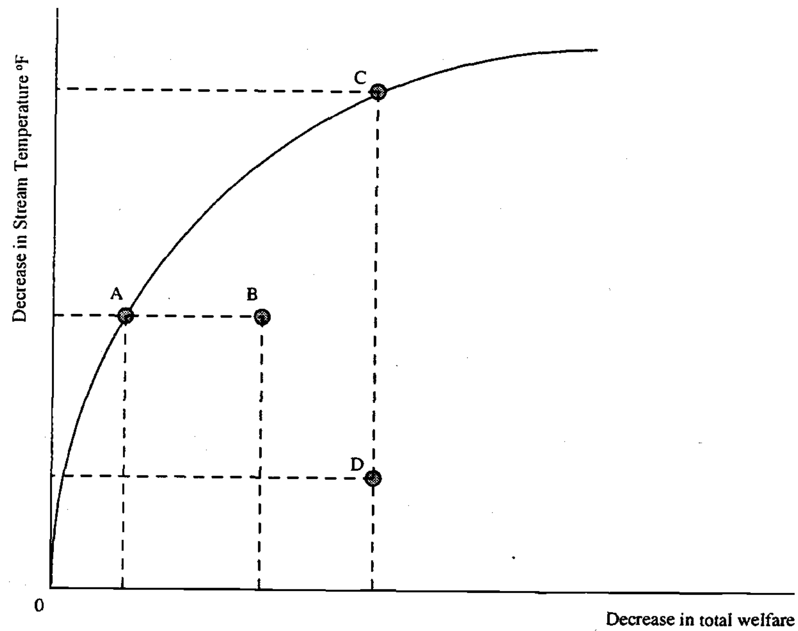

Figure 3.3. A Theoretical Cost Effectiveness Frontier

The frontier is depicts the cost of decreasing stream temperatures as increasing at an increasing rate, consistent with the theoretical expectation of diminishing marginal returns. Empirically generated frontiers may not be as smooth and will not necessarily exhibit this shape. Many functional forms for the frontier are possible. Points A, B, C and D represent welfare change and corresponding reductions in stream temperature under four different management scenarios. For example, A could represent the temperature reduction/cost pair corresponding to a 50 foot wide riparian buffer strip over 50 percent of the total stream length whilst D might represent an 80 foot buffer over 75 percent of the total stream length.

Only the least cost points are represented on the frontier. Points A and B achieve the same reduction in stream temperature; however, A achieves it at least cost. Comparing points C and D it is apparent that the two programs have equal cost. However, C achieves the greatest decrease in stream temperature and thus is more cost effective in comparison to D.

The frontier in figure 3.3 shows the case of a decrease in stream temperature achieved at progressively higher welfare costs to watershed residents. However, it is possible that temperature reductions could be achieved for no cost or increase the welfare of residents in the watershed. In addition, as technology or other factors change, the frontier could shift or change shape.

It is important to note that a cost effectiveness frontier represents the least cost envelope of points only over the range of alternatives considered. If a wider set of alternatives is considered then the frontier could change.

4.0 EMPIRICAL MODEL

This chapter describes the mathematical programming model used to estimate the economic cost and corresponding stream temperature outcome in response to management or policy changes aimed at reducing stream temperature in the Mohawk watershed.

4.1 The Mathematical Programming Model - Demonstrating Consistency with the Theoretical Framework

A mathematical programming optimization model can be developed to generate an explicit numerical solution to the theoretical problem of constrained welfare maximization presented in Chapter 3. Mathematical programming allows the researcher to formulate an algebraic representation of the theoretical problem. Well developed algorithms can then be used to select the combination of activities that maximize welfare subject to the given constraints.

The general problem faced by producers and consumers in the Mohawk watershed is one of maximizing welfare subject to technological, institutional, market, legal and other constraints such as the availability of productive land, buffer strip requirements, or restrictions on logging and grazing. Welfare changes associated with the adoption of a new management alternative, a change in the available resource base or cost structure can be estimated by comparing the absolute value of welfare generated under the new restrictions to the absolute value of welfare under the original scenario. If welfare is larger in the original scenario, then producers or consumers (or both) suffer a welfare loss as a result of the policy change. If welfare is smaller in the original scenario compared to the subsequent scenario, then producers or consumers (or both) experience an improvement in welfare.

A linear programming[23] formulation of the welfare maximization problem is shown in equations (4.1) to (4.3). Equation (4.1) is the objective function, and represents the goals of the economic agent (Koutsoyiannis 1979). Z is a scalar representing the dollar amount of welfare generated by the solution to the model, i.e., the maximum welfare from a given combination of activities $\mathbf{Y}_{(i*1)}$ given technological and other constraints.[24] $\mathbf{C}_{(1*i)}$ is a vector representing the dollar value of welfare generated by each unit of activity. Equation (4.2) represents feasible production technologies ($\mathbf{A}_{(j*i)}$) and resource endowments ($\mathbf{B}_{(j*1)}$). These constraints are determined by the state of technology and the availability of factors of production. Constraints express the fact that factors used in production, consumption and conservation activities cannot exceed the quantities available. Equation (4.3) constrains activities to be positive or zero.[25] $\mathbf{0}_{(i*1)}$ is a null vector.

$$\text{Max } Z = \mathbf{C}_{(1*i)}\mathbf{Y}_{(i*1)} \tag{4.1}$$

Subject to:

$$\mathbf{A}_{(j*i)}\mathbf{Y}_{(i*1)} \leq \mathbf{B}_{(j*1)} \tag{4.2}$$

$$\mathbf{Y}_{(i*1)} \geq \mathbf{0}_{(i*1)} \tag{4.3}$$

[23] Linear programming is one distinct mathematical programming technique. For a discussion of other mathematical programming techniques see Hazel and Norton (1984).
[24] The subscripts in brackets refer to the dimension of the matrix or vector, e.g. i*1 = I rows by 1 column.
[25] This set of constraints rule out the possibility of negative production.

A solution to the linear programming problem is generated using an iterative algorithm that searches for the combination of activities that maximize the value of the objective function while not violating the constraints to the problem.

4.1.1 Calculating Welfare Change in Response to a Change in Input or Output Price

Change in welfare as a result of a change in the prices of inputs or outputs, resource constraints or technology, can be calculated by comparing the solution generated by the linear programming model under the initial situation (base scenario), to the solution generated with the new conditions. The following example considers the case of a price change.

If the initial situation is expressed by equations (4.1) to (4.3), the maximum welfare generated as a solution to this problem is Z. Now, consider a situation in which the technology and resource availability are identical to those depicted in equations (4.2) and (4.3) but that the welfare generated by output $\mathbf{Y}$ has changed by m percent and is represented by the vector $\mathbf{C}'$. The maximum welfare generated under this scenario is Z'.

Welfare change as a result of this price change can be estimated by calculating the amount of money that when given to (taken away from) the individual or firm will make the individual or firm as well-off under the new situation as they were in the old (i.e. compensating variation), as shown in equation (4.4).

$$\Delta W = -CV = Z - Z' \tag{4.4}$$

4.1.2 Change in Welfare in Response to a Change in Resource Availability

Using equations (4.1) and (4.2) it can be shown that $Z = \mathbf{CF(B)}$. If all fixed resources, $\mathbf{B}$, are changed by a factor of proportionality, *k*, then the value of the objective function Z, will also change by *k* as shown in equation 4.5.

$$\mathbf{CF}(k\mathbf{B}) = \mathbf{C}k\mathbf{F}(\mathbf{B}) = kZ = Z'' \tag{4.5}$$

Welfare changes as a result of a change in resource availability can be calculated by comparing the maximum profit, Z, generated under the initial resource endowment, $\mathbf{B}$, and the maximum profit Z'' generated under the subsequent resource endowment, $k\mathbf{B}$, as shown in equation (4.6).

$$\Delta W = -CV = Z - Z'' \tag{4.6}$$

4.1.3 Assumptions of the Modeling Technique and their Applicability to the Mohawk Watershed

There are several underlying assumptions about production technology, resources and activities that are implicitly incorporated into a linear programming model. These assumptions are identified in this section and discussed in light of their applicability to the Mohawk watershed.

The linear programming technique requires that some objective be maximized or minimized. This is consistent with the activities in the Mohawk watershed if producers and consumers are rational economic agents.

The second assumption is fixedness that requires at least one constraint to have a non-zero right hand side coefficient. This assumption requires that activities be produced from a positive amount of resource. This is consistent with the situation in the Mohawk in as much as there is no activity that can be produced with zero resources.

The third assumption is finiteness that requires a finite number of activities and constraints to be specified for the model. This is consistent with real world decision making as generally decision makers choose between a limited number of options, not an infinite number.

The fourth assumption is determinism that requires the c_j, a_{ij} and b_i coefficients be known constants. For the c_j coefficients within the vector **C** to be known constants, firms within the area must be price takers in both input and output markets and must have perfect information. The producers in the Mohawk watershed are minor producers of agricultural commodities and timber in the Pacific Northwest. It is quite likely that producers in the area are price takers in both input and output markets however, it is unlikely that producers have perfect information and as such there is an element of risk associated with decisions that they make. It is not unreasonable to assume that producers are aware of their resource endowments (b_i's) and consider a range of technologies for which production practices and input requirements (a_{ij}'s) are known. The assumption of determinism does have a drawback in that it does not account for risks inherent with business practices in the real world. Despite this, the model can highlight the effects of important economic influences on production in the area even if it does not perfectly capture producer behavior.

The fifth assumption, continuity, allows resources and activities to be produced in fractional units. Many real world resources and activities can only be used or produced in "lumpy" units; for example it is not possible to produce beef cows in fractional units. The assumption expands the production possibilities available to producers in the area but will allow an approximation of production decisions. The sixth assumption is homogeneity which constrains the units of a given resource to be identical. This is not realistic in the real world as productivity and quality vary from unit to unit. This assumption is not very problematic if "average" resource productivity is assumed in the model.

Perhaps the two most important assumptions are additivity and proportionality that together define the linearity of the activities. Additivity means that there is no interaction effect between the production of different activities. Proportionality means that the resources required and gross margins generated remain constant for every unit of a similar activity. These two assumptions define linear isoquants in factor use between pairs of activities. Proportionality by itself suggests a leontief production function with L-shaped isoquants. The aggregate firm production function relating the value of the objective function Z to the fixed resources **B** exhibits constant returns to scale. These assumptions are restrictive and do not represent many real world production processes. However, it is possible to relax these assumptions by constructing models that include linear approximations to non-linear functions and activities that have joint, complementary or substitution effects in production.

4.2 Unique Features of the Model

While mathematical programming models have been used extensively, both for the type of problem addressed in this dissertation as well as numerous other applications, the empirical model developed for analysis of the Mohawk watershed has two unique features that call for further elaboration. These two features are the treatment of non-market goods and the estimation of the effect of alternative riparian management scenarios upon stream temperature. Each feature is discussed below.

4.2.1 Incorporating the Value of Non-Market Goods

The Mohawk watershed contains many residential dwellings with small acreages that are used for their yield of non-market goods rather than market production. The optimization problem faced by these residents is presented in section 3.4 (Change in Consumer Welfare) of the theoretical model.

Hedonic pricing is used to provide an empirical estimate of the relationship between residential property values and an increase or decrease in riparian buffer width. The estimate generated from the hedonic pricing technique is used in the linear programming model to change the price of residential properties adjacent to a stream in response to a change in riparian buffer width. The quantity of residential housing selected by the model remains constant between alternative buffer width scenarios. This constraint ensures that the model calculates directly the dollar value of consumer welfare generated by a different bundle of environmental attributes on existing properties in relation to the previous utility maximizing choice. The hedonic pricing analysis is described below in sections 4.2.1.1 and 4.2.1.2.

4.2.1.1 Estimating the value of non-market goods

The hedonic pricing technique uses information about real market transactions to impute a value for goods and services for which there is no formal market. A behavioral relationship between the observable choice variables and the environmental amenity of interest can be estimated using econometric techniques and used to identify an implicit price for the amenity of interest.

There is no *a priori* functional form suggested for the relationship $P_i = P(\mathbf{L}_i, \mathbf{R}_i, \mathbf{N}_i, RB_i, \mathbf{AOE}_i)$ expressed in equation (3.6). However, economic theory suggests that the sign on the first derivatives will be positive for desirable characteristics and negative for undesirable characteristics. Many studies have used a Box-Cox transformation (Box and Cox 1964) to let the data determine the most appropriate functional form (Lansford and Jones 1995, Streiner and Loomis 1995).[26, 27] Other studies (Mahan 1996, Kulshreshtha and Gillies 1993) have used functional forms such as linear, semi-log and log-log. If the relationship is linear in the parameters and other assumptions are upheld, the theoretical model can be expressed in terms of the classical linear regression model (equation (4.7)) that shows $\mathbf{Y}$ as a linear combination of the sample

[26] Second stage estimations are sensitive to the functional form selected in the first stage of analysis.
[27] See Freeman (1993) or Mahan (1996) for a discussion of second stage estimation.

observations on the explanatory $\mathbf{X}$ variables, plus a disturbance vector, $\mathbf{e}$ (Johnston 1984).

$$\mathbf{Y} = \mathbf{Xb} + \mathbf{e} \tag{4.7}$$

$$\text{where } \mathbf{Y} = \begin{bmatrix} P_1 \\ P_2 \\ \cdot \\ \cdot \\ P_n \end{bmatrix}_{(n*1)}$$

$$\mathbf{X} = \begin{bmatrix} \mathbf{X}_{\mathbf{0}(n*a)} & \mathbf{L}_{(n*b)} & \mathbf{R}_{(n*c)} & \mathbf{N}_{(n*d)} & \mathbf{RB}_{(n*1)} & \mathbf{AOE}_{(n*f)} \end{bmatrix}_{(n*(a+b+c+d+1+f))}$$

$$\mathbf{b} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \cdot \\ \cdot \\ \beta_{a+b+c+d+1+f} \end{bmatrix}_{((a+b+c+d+1+f)*1)} \qquad \mathbf{e} = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdot \\ \cdot \\ \varepsilon_n \end{bmatrix}_{(n*1)}$$

It is further assumed that $E(\mathbf{e}) = \mathbf{0}$, $E(\mathbf{ee}') = \sigma^2\mathbf{I}$, $\mathbf{X}$ is a non-stochastic matrix and $\mathbf{e} \sim N(\mathbf{0}, \sigma^2\mathbf{I})$. If the assumptions of the classical linear regression model hold then the ordinary least squares estimator ($\mathbf{b} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{y}$) can be used to estimate $\beta_4 = \frac{\partial P}{\partial RB}$, the marginal implicit price of a unit of riparian buffer, *ceteris paribus*.

4.2.1.2 Empirical representation of the hedonic pricing model

The general form of the model estimated in this study is represented in (4.8).

$$SALPRICE_i = \beta_0 + \beta_1 SALDAT_i + \beta_2 ATACRES_i + \beta_3 SQFT_i + \beta_4 YB_i + \beta_5 LOW_i + \beta_6 HIGH_i + \beta_7 MARCOLA_i + \beta_8 DIST + \beta_9 FRTLGTH_i + \beta_{10} AREATREE_i + \varepsilon_i \qquad (4.8)$$

Table 4.1 lists the variables used in the econometric estimation, and the expected signs of their coefficients. The dependent variable, SALPRICE, is the reported real market selling price of a property. The value of the lot and the residence are included in this dependent variable. Structural characteristics of the residence are controlled for in the variables SQFT, YB, LOW and HIGH (defined below).

An independent variable, SALDAT, is included to identify the date on which the property was sold. Sale price is expected to be positively related with the year of sale. The lot size (ATACRES) is expected to be positively related to the total sale price of the property.

Structural characteristics of the residence are incorporated in three separate variables. The size of the residence (SQFT) located on the lot is expected to be positively related to the total sale price of the property. The year the residence is built (YB) is also expected to be positively related to sale price reflecting the assumption that a newer home will bring a higher price, *ceteris paribus*. Residences are sorted into three groups LOW, medium and HIGH, according to the quality of their architecture and building materials. Intercept dummy variables are added to reflect low (LOW) and high (HIGH) quality housing. Medium quality housing is represented in the intercept term.

Table 4.1. Variable Definitions and Expected Signs

Symbol	Variable Definition	Units	Expected Sign
SALPRICE	Total sale price of the property (payment for land and improvements)	Dollars	Dependent Variable
SALDAT	Date of sale	Year/month/day	Positive
ATACRES	Size of lot	Acres	Positive
SQFT	Size of residence	Square feet	Positive
YB	Year residence was built	Year (1880 to 1996)	Positive
LOW	Dummy variable, reflecting lower quality housing[1]	1 if low quality housing, 0 otherwise	Negative
HIGH	Dummy variable, reflecting very high quality housing[1]	1 if high quality housing, 0 otherwise	Positive
MARCOLA	Dummy variable reflecting those properties within the Marcola school district[2]	1 if within the Marcola school district, 0 otherwise	---
DIST	Distance from the closest large town.	Feet	---
FRTLGTH	Length of water frontage	Feet	Positive
AREATREE	Total area of the lot, planted to trees along the water frontage	Square feet	---

[1]Medium quality housing is implicitly in the intercept. Housing quality was assessed by the Lane County Department of Assessment and Taxation and is based on factors such as the architectural design and the building materials used to construct the residence.
[2]The Springfield school district is implicitly in the intercept.

Locational characteristics of the property are also included. There is a difference of approximately 16 miles between properties closest to the major town and those furthest away.[28] This difference in distance translates into an increase in driving time to the closest major town of approximately 20 minutes. A dummy term reflecting school district is also included. MARCOLA is a dummy representing those properties within the

[28] The actual distance used in the regression analysis is the distance from each residence to the major highway that goes to the closest large town. This distance was calculated for every residence in the data set using ARCVIEW.

Marcola school district, the remaining properties are within the Springfield school district. School district and distance from the closest large town are correlated.[29,30]

Two environmental variables are included to describe the water front and riparian characteristics of properties that are sold. The length of water frontage (FRTLGTH) is measured for each property and is expected to be positively related to sale price.[31] For those properties with a water frontage the area of trees planted between the waterfront and the residence (AREATREE) is measured, for all non riparian properties this variable takes a value of zero.

4.2.2 Incorporating a Change in Stream Temperature

Riparian buffer widths for all land types in the Mohawk Watershed are included in the formulation of the mathematical model. Stream temperature response to a change in the riparian buffer is not calculated within the mathematical programming model.[32] Rather, the buffer widths specified within the mathematical programming model are used as input to a stream temperature estimator. A simplified conceptual model for stream

---

[29] Pearson's correlation coefficients (ρ) are generated between all potential model variables using SAS (Statistical Analysis Software). The value, $\rho \approx 0.74$, is found between the variable representing distance from the closest major town and the variable representing school district..

[30] They are both included in the model as the additional information may improve other parameter estimates.

[31] Based on the assumption that a river frontage is a good rather than a bad; supported by results in Kulshreshtha and Gillies (1993).

[32] It is possible to include stream temperature response directly within the mathematical programming model. This could be accomplished by re-programming the stream temperature estimator directly within the model.

heating is presented below, followed by a description of the stream temperature estimator used in this study.

4.2.2.1 Estimating stream temperature response

Stream temperature studies conducted by Brown in the late 1960's and early 1970's established a link between stream side vegetation and stream temperature. Brown's equation (Brown 1969) presented in equation (4.9), illustrates the fundamental concept underlying many stream temperature models.

$$\Delta T_{ab} = \frac{\phi A}{Q} \tag{4.9}$$

$$\phi = N_r + E + H + C \tag{4.10}$$

a = start of the reach[33]
b = end of the reach
ΔT_{ab} = change in temperature between a and b
ϕ = heat energy flux, i.e., net energy exchange over the reach
A = stream surface area
Q = stream flow
N_r = net radiation
E = evaporation
H = convection
C = conduction

Brown's equation (4.9) predicts a change in stream temperature over a reach as a function of the heat energy flux (ϕ), surface area (A) and stream flow (Q). Incoming (shortwave) radiation is the factor influenced the most in response to changes in the width, height and/or density of streambank vegetation (Beschta 1987). An increase in the

[33] A stream reach refers to a discrete section of the stream.

height of the trees within a riparian buffer will increase the period of time that the stream is shaded, thereby decreasing incoming radiation received by the stream.[34] An increase in the density or width of the riparian buffer will reduce the intensity of the solar radiation that penetrates the riparian buffer and strikes the stream, thereby reducing the net energy absorbed over the reach. Stream temperature change over a reach is not simply a function of the net energy exchange over that reach, but also a function of the initial water temperature (which is dependent upon heat exchanges in prior reaches).

4.2.2.2 Heat Source - A stream temperature estimator

Several factors were considered when reviewing stream temperature models for use within this study. The main ones were: (i) the model should be based on sound principles; (ii) the model should be capable of predicting changes in stream temperature in response to changes in riparian buffer prescriptions such as those described in section 2.5; (iii) the model should be suitable given the available data and (iv) the model should be sufficiently "user friendly."

An estimator that fulfilled all of the above criteria was chosen for use in this analysis. The estimator, Heat Source, was constructed as a Masters thesis project in the Department of Bioresource Engineering, Oregon State University.

Heat Source (Boyd 1996) is a reach based, stream temperature model that includes physically based mathematical descriptions of stream energy and hydrologic processes. The model provides stream temperature profiles and energy balance values in response to

[34] This might not be the case on streams that run north/south.

atmospheric parameters and canopy effects. A detailed description of model equations and the solution process can be found in Boyd (1996). A flow chart is presented in figure 4.1 that illustrates the main elements of the model and their linkages. Once the general and temperature inputs have been entered the user can select from a range of evaporation models and include general ground water effects if required. In addition, it is possible to select the time and distance steps that are used in calculating stream temperature. Large time and distance steps result in fewer calculations between the initial and terminal points for each model run. The model is then ready to simulate a downstream temperature profile. Model output can be displayed as text or graphics and includes stream temperature profiles for both the upstream and downstream reaches, energy balance values, atmospheric parameters and canopy effects.

The model has been used primarily for daily prediction of the diurnal energy flux[35] over a stream reach. The length of the defined reach is limited by the assumption that the upstream and downstream portions of the reach are relatively homogeneous and that no surface inflow from merging water bodies occurs within the defined reach (Boyd 1996). The height, density and width of the riparian buffer are some of the factors included in the model that influence stream temperature. Changes in these parameters will have an influence on the stream temperature results predicted by the model. This estimator can be used to analyze buffer prescriptions such as those described in section 2.5.

[35] Changes in the net energy absorbed by the stream reach over a twenty-four hour period.

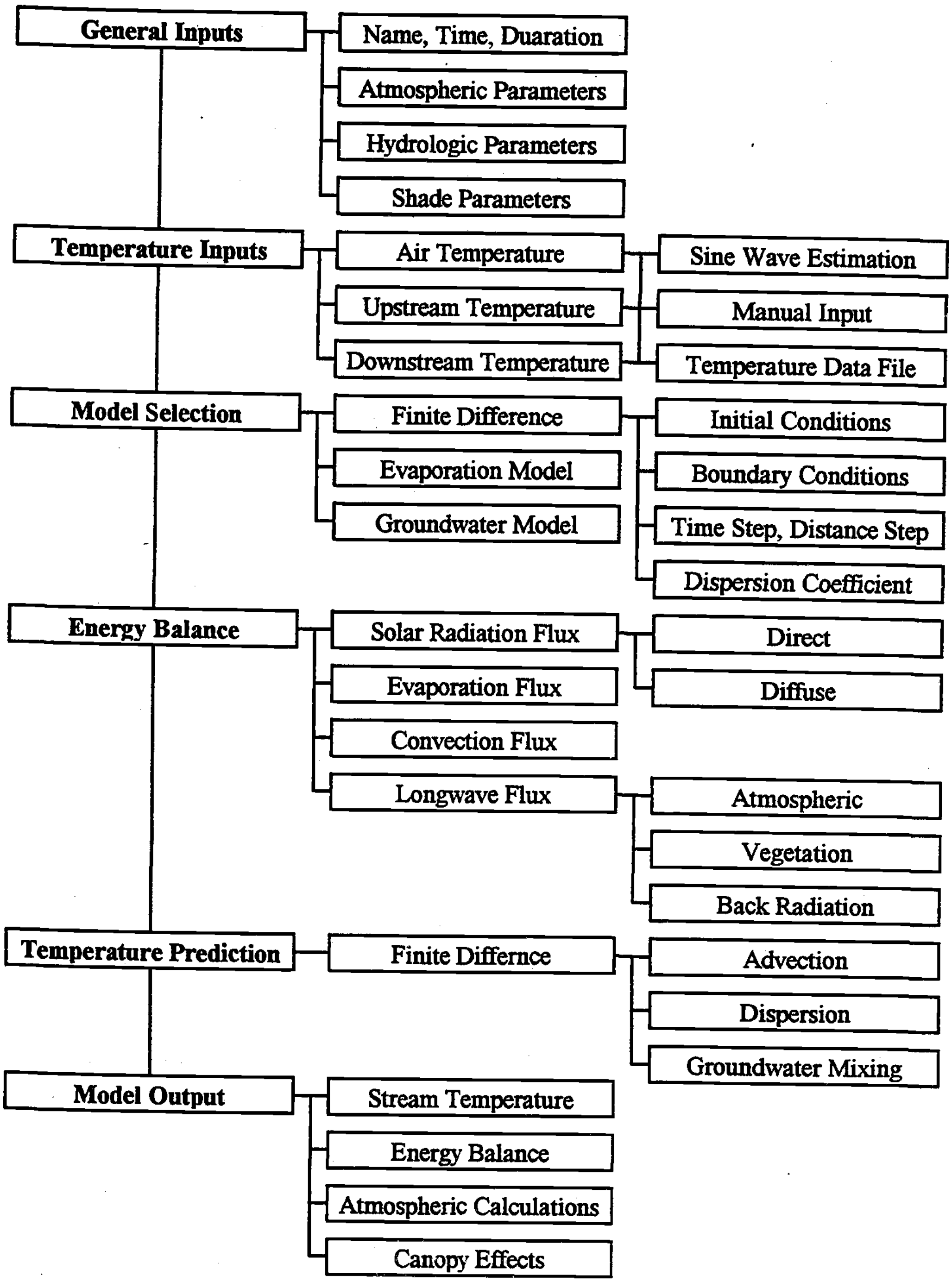

Figure 4.1 Heat Source Flow Chart

Source: Boyd (1996).

The Mohawk River and tributaries can be divided into many reaches. To accommodate the prediction of daily temperature changes over consecutive reaches the model is run multiple times, once for each reach.[36] Figure 4.2 depicts 2 consecutive stream reaches. Reach 1 lies between the points A and B and reach 2 lies between the points B and C.

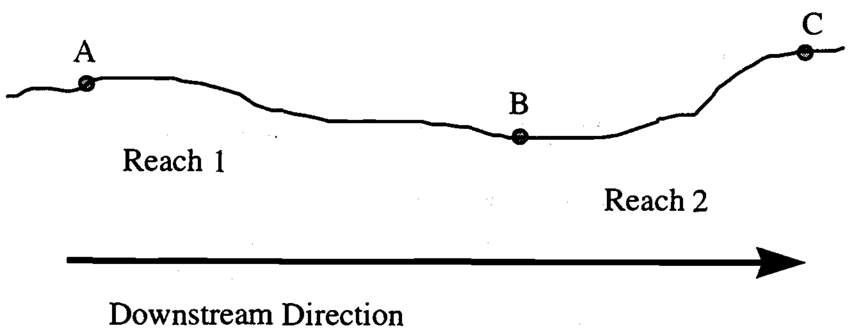

Figure 4.2. Multiple Stream Reaches

Heat Source is provided with an initial pattern of diurnal stream temperature at point A and is run for the first reach to calculate the change in stream temperature between A and B. Temperature change over the second reach is calculated by taking the diurnal stream temperature pattern predicted at B in the first model run as the initial starting temperature in the second model run and running the model between B and C to obtain the terminal pattern of diurnal stream temperatures at C. In this way, it is possible to calculate the change in stream temperature from the head waters of the Mohawk River to its confluence with the McKenzie River.

[36] Suggested in a personal communication with Matthew Boyd, developer of Heat Source.

4.3 Algebraic Representation of the Model

The algebraic representation of the mathematical programming model used in this study is constructed using GAMS (General Algebraic Modeling System (Brooke, Kendrick and Meeraus 1992)) Release 2.25. The GAMS model input file is presented in appendix C. The model is defined over a mixed use (agriculture, forestry and residential), multiple ownership (public and private) watershed and incorporates major land uses such as timber, hay and livestock production in addition to less common crops (such as blueberries and corn). The valley floor of the Mohawk watershed contains the majority of the agricultural and residential activity. Several visits to the area, discussions with local extension agents and a personal interview survey of residents (Appendix A) indicate that the area is largely underutilized[37] for agricultural production.

The property sales prices observed in the Mohawk are a directly observable solution to the consumer utility maximization problem. The model does not optimize over housing choices, rather it takes these as given. The model presented below represents the base case scenario described by the current residential, agricultural and forestry practices in the Mohawk watershed. The primary agricultural activities are hay and cattle production. The higher elevations are forested in either industrial or non-industrial timber production.

[37] Some areas are unutilized with pastures not grazed or hayed for 2 or 3 years (personal communication with Paul Day, County Agent, Oregon State University, Extension Service (retired).

Land area in the watershed is divided into river front property and non-river front property.[38] Land areas and activities that are adjacent to the river are identified by the extension *RP*. Land areas and activities that are not adjacent to the river are identified by the extension *NRP*. Within these two major classifications there are several subclasses of land and activities. Residential land adjacent to the river (denoted by set *LRP*) has three classifications; high, medium and low value per acre property areas. Residential land not adjacent to the river (denoted by set *LNRP*) is divided into the same three classifications. Land adjacent to the river that is used in agriculture or forestry is denoted by set *LPRODRP* while land not adjacent to the river that is used in production is denoted by set *LPRODNRP*. *LPRODRP* and *LPRODNRP* are further subdivided into seven land categories. In total, the model contains ten land types adjacent to the river (three residential land types and seven production land types) and ten land types not adjacent to a river. Table 4.2 lists the sets and their elements.

Activities are defined over these land types and are denoted by the sets *ACTRP* (production enterprises on river property), *ACTNRP* (production enterprises on non-river property), COWRP (livestock production on river property), COWNRP (livestock production on non-river property), RRP (residential property types on river property) and RNRP (residential property types on non-river property). Each of these sets are further subdivided into specific activities as listed in Table 4.3.

The algebraic model defined below sums the current 30 year annuity value of expenditure on residential property used for an amenity value in the area (which represents the dollar value of consumer welfare generated by the property each year) and

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[38] These classifications were identified and measured using a GIS.

Table 4.2. Land Types Included in the Mathematical Programming Model

Land Type Symbol[1]	Description
LRP	**Residential Land Adjacent to a River**
LLOWRIV	land area adjacent to the river, with low property values per acre
LMEDRIV	land area adjacent to the river, with medium property values per acre
LHIGHRIV	land area adjacent to the river, with high property values per acre
LNRP	**Residential Land Not Adjacent to a River**
LLOWNR	land area not adjacent to the river, with low property values per acre
LMEDNR	land area not adjacent to the river, with medium property values per acre
LHIGHNR	land area not adjacent to the river, with high property values per acre
LPRODRP	**Production Land Adjacent to a River**
F1PUBRP	public industrial forest land, adjacent to a river
F1PRIRP	private industrial forest land, adjacent to a river
F2RP	non-industrial forest land, adjacent to a river
RDEVRP	otherwise residential land with no residence, adjacent to a river
RRRP	rural residential land, adjacent to a river
OTHRP	"other" property, adjacent to a river
E40RP	agriculture zoned land, adjacent to a river
LPRODNRP	**Production Land Not Adjacent to a River**
F1PUBNRP	public industrial forest land, not adjacent to a river
F1PRINRP	private industrial forest land, not adjacent to a river
F2NRP	non-industrial forest land, not adjacent to a river
RDEVNRP	otherwise residential land with no residence, not adjacent to a river
RRNRP	rural residential land, not adjacent to a river
OTHNRP	"other" property, not adjacent to a river
E40NRP	agriculture zoned land, not adjacent to a river

[1] Sets are shown in bold type; their elements are listed below each set definition.

Table 4.3. Activities Defined for the Watershed

Activity Type Symbol[1]	Description
ACTRP	**Production Activities, on Land Types Adjacent to a River**
AHAHRP	alfalfa hay
BEANRP	green beans
BERRYRP	blueberries
CORNRP	corn
F2PLRP	non-industrial trees, area reforested and other prescriptions, age class 0-10
F2STRP	non-industrial remaining trees, all other age classes 10-40
F245RP	non-industrial tree production, age class 40 to 50
F2HVRP	non-industrial tree production, harvest
FPBPLRP	public industrial trees, area reforested and other prescriptions, age class 0-10
FPBSTRP	public industrial remaining trees, all other age classes 10-50
FPB56RP	public industrial tree production, age class 50 to 60
FPB67RP	public industrial tree production, age class 60 to 70
FPBHVRP	public industrial tree production, harvest
FPVPLRP	private industrial trees, area reforested and other prescriptions, age class 0-10
FPVSTRP	private industrial remaining trees, all other age classes 10-50
FPV56RP	private industrial tree production, age class 50 to 60
FPV67RP	private industrial tree production, age class 60 to 70
FPVHVRP	private industrial tree production, harvest
GHAYLRP	hay from non-improved pasture
GHAYHRP	hay from improved pasture
MINTRP	mint
NUTSRP	filberts
WHTRP	wheat
ACTNRP	**Production Activities, on Land Types Not Adjacent to a River**
AHAHNRP	alfalfa hay
BEANNRP	green beans
BERRYNRP	blueberries
CORNNRP	corn
F2PLNRP	non-industrial trees, area reforested and other prescriptions, age class 0-10
F2STNRP	non-industrial remaining trees, all other age classes 10-40
F245NRP	non-industrial tree production, age class 40 to 50
F2HVNRP	non-industrial tree production, harvest
FPBPLNRP	public industrial trees, area reforested and other prescriptions, age class 0-10
FPBSTNRP	public industrial remaining trees, all other age classes 10-50
FPB56NRP	public industrial tree production, age class 50 to 60
FPB67NRP	public industrial tree production, age class 60 to 70
FPBHVNRP	public industrial tree production, harvest
FPVPLNRP	private industrial trees, area reforested and other prescriptions, age class 0-10
FPVSTNRP	private industrial remaining trees, all other age classes 10-50
FPV56NRP	private industrial tree production, age class 50 to 60

Table 4.3. continued.

Activity Type Symbol[1]	Description
FPV67NRP	private industrial tree production, age class 60 to 70
FPVHVNRP	private industrial tree production, harvest
GHAYLNRP	hay from non-improved pasture
GHAYHNRP	hay from improved pasture
MINTNRP	mint
NUTSNRP	filberts
WHTNRP	wheat
COWRP	**Cattle Production on Land Types Adjacent to a River**
COW1RP	single cow produced
COWNRP	**Cattle Production on Land Types Not Adjacent to a River**
COW1NRP	single cow produced
RRP	**Residential Properties on Land Types Adjacent to a River**
LOWRIV	low value per acre property
MEDRIV	medium value per acre property
HIGHRIV	high value per acre property
RNRP	**Residential Properties on Land Types Not Adjacent to a River**
LOWNR	low value per acre property
MEDNR	medium value per acre property
HIGHNR	high value per acre property

[1] Sets are shown in bold type; their elements are listed below each set definition.

then maximizes the profit that can be generated from production activities. The model is designed to calculate the expenditures required to purchase the existing distribution of property types in the watershed. That is, the model does not select the combination of activities for land in residential property. Rather, it calculates the expenditure required to purchase the existing distribution of property given that its total value may change as the associated amenities change. On the production side, the model selects the combination of activities that maximize the returns to land that can be generated from the remaining area in the watershed.

4.3.1 The Objective Function

An algebraic expression of the objective function used in the model is presented in equation (4.11).

$$
\begin{aligned}
&\sum_{RP=1}^{3}(P^{A}_{RP} * ACRE_{RP}) + \sum_{NRP=1}^{3}(P^{A}_{NRP} * ACRE_{NRP}) \\
&- \sum_{RP=1}^{3}(TAX_{RP} * ACRE_{RP}) - \sum_{NRP=1}^{3}(TAX_{NRP} * ACRE_{NRP}) \\
&+ Max\Bigg\{ \sum_{LPRODRP=1}^{7} \sum_{ACTRP=1}^{23}((P_{ACTRP} * Y_{LPRODRP,ACTRP}) - C_{ACTRP}) * PRODRP_{LPRODRP,ACTRP} \\
&+ \sum_{LPRODNRP=1}^{7} \sum_{ACTNRP=1}^{23}((P_{ACTNRP} * Y_{LPRODNRP,ACTNRP}) - C_{ACTNRP}) * PRODNRP_{LPRODNRP,ACTNRP} \\
&+ \sum_{LPRODRP=1}^{7} \sum_{COWRP=1}^{1}((TR_{COWRP} - C_{COWRP}) * N_{LPRODRP,COWRP}) \\
&+ \sum_{PRODNRP=1}^{7} \sum_{COWNRP=1}^{1}((TR_{COWNRP} - C_{COWNRP}) * N_{LPRODNRP,COWNRP}) \\
&- \sum_{LPRODRP=1}^{7}(TAX_{LPRODRP} * ACRE_{LPRODRP}) - \sum_{LPRODNRP=1}^{7}(TAX_{LPRODNRP} * ACRE_{LPRODNRP})\Bigg\}
\end{aligned}
\tag{4.11}
$$

Where,

$ACRE$ = acres in each land type
C = per acre or per head production costs for cropping and livestock activities
N = number of animals selected by the model
P = prices (per acre of property[39] or per unit of crop yield)
PRODRP = number of acres of each production activity (excluding livestock) selected by the model on areas adjacent to a river
PRODNRP = is the number of acres of each production activity (excluding livestock) selected by the model on areas not adjacent to a river

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[39] P^{A} is a 30 year annuity, reflecting the yearly value of one acre of residential property.

TAX = per acre property taxes paid on land in the Mohawk watershed
TR = total revenue generated by one unit of the livestock enterprise
Y = per acre yield of each crop by land area

Property taxes are included in the model as these are one policy vehicle that can be used to redistribute the costs or benefits accruing to Mohawk residents as a result of changes in the riparian buffer width.

4.3.2 Representation of Consumer Welfare

Consumer welfare generated by a property purchase is calculated directly from the first two lines of the objective function (equation 4.11). Consumer welfare is the dollar value of all residential properties within the Mohawk. The total value of residential properties under varying riparian buffer widths are calculated using the coefficient generated from the hedonic pricing analysis[40], information on the sale price of the property and the change in area occupied by the riparian buffer as shown in equation (4.12).

$$P_{RP} = \frac{MEANV_{RP}}{MEANSZ_{RP}} - \frac{(MEANV_{RP} * BUFCOEF) * (LGTH_{RP} * (WDTH_{NEW} - WDTH_{ORIG}))}{MEANSZ_{RP}} \quad (4.12)$$

Where $MEANV_{RP}$ is the mean value of properties in each of the three classifications low, medium and high value properties . $MEANSZ_{RP}$ is the mean lot size of properties in each of the three property classifications. $BUFCOEF$ is the coefficient relating a change in

[40] Results of the analysis are presented in section 5.4.

the area of the property in a riparian buffer to the price of the property. $LGTH_{RP}$ is the average riparian frontage of a stream bank property in each property class. $WDTH_{NEW}$ is the altered riparian buffer width. $WDTH_{ORIG}$ is the current average riparian buffer width for a property in that class. The model calculates P_{RP} that is then converted to the annuity value per acre of property, P_{RP}^{A} , used in the objective function (4.11).

4.3.3 Incorporating Stream Temperature Response: Constraining Land Area

Several constraints are included in the model that limit the total area in production on each land type to be less than or equal to the available land area. Land area constraints for land types adjacent to a river provide a link between a change in the riparian buffer width on each land type and stream temperature response. The buffer width on each land type along with the linear feet of riparian frontage are used to calculate the total land area in a riparian buffer by land type. These areas are not available for production activities. The riparian buffer widths specified in the model are used in Heat Source (the stream temperature estimator) to relate stream temperature response to changes in riparian buffer width.

The land area constraint for production land types adjacent to a river is presented in equations (4.13) to (4.15).

$$\sum_{ACTRP=1}^{18} PRODRP_{LPRODRP,ACTRP} + \sum_{COWRP=1}^{1} N_{LPRODRP,COWRP} \leq ACREAVAIL_{LPRODRP} \quad (4.13)$$

$$\forall LPRODRP$$

Where,

$$ACREAVAIL_{LPRODRP} = ACRE_{LPRODRP} - ACMINUS_{LPRODRP} \quad (4.14)$$

and,

$$ACMINUS_{LPRODRP} = (FRNTLGTH_{LPRODRP} * BUFWIDTH_{LPRODRP}) / 43560 \quad (4.15)$$

$ACREAVAIL_{LPRODRP}$ is the acreage available for production activities. $ACMINUS_{LPRODRP}$ is the area in a riparian buffer strip. $FRNTLGTH_{LPRODRP}$ is total riparian frontage length, in feet, for each property class. $BUFWIDTH_{LPRODRP}$ is the riparian buffer width, in feet, on each land type.

4.3.4 Rotational and Other Production Area Constraints

Rotational constraints are included in the model for the corn, wheat and bean enterprises. These crops are used in a single rotation[41] and are constrained to be produced in equal quantities (reflecting the average returns from a 3 year rotation). The Mohawk has potential to be an agriculturally productive area based on soil type and crop yield estimates. However, the area is currently used for production at a level significantly below its potential. Personal visits to the area, discussion with extension agents and the results of a personal interview survey of local residents (Appendix A) indicate that the majority of the area is under or unutilized. Reasons that have been suggested for this situation are (i) a lack of interest in farming and or a lack of management expertise, (ii) an inability to purchase sufficient capital to increase productivity, (iii) speculative land

[41] Personal communication with Ross Penhalligon, County Agent, Oregon State University, Extension Service.

interest and (iv) a secondary supplemental source of family income that reduces the reliance on returns from land ownership and the availability of labor for farming activities. It is likely that a combination of these factors is responsible for the under-utilization of the land base for production activities.

Most crop acreage and livestock activities are limited to be no greater than the current acreage or numbers estimated for the area at present. Estimates of current production were obtained from local extension agents and aerial photograph interpretation and are described in Chapter 5.

4.4 Model Scenarios

4.4.1 Change in Riparian Buffer Width

The width and location of the riparian buffer strip in addition to vegetation height and canopy cover is thought to influence stream temperature (Beschta *et al.* 1987, Sullivan *et al.* 1990, Boyd 1996). This study only considers the effect of changes in riparian buffer width which has a direct economic effect by changing the available resource base within the Mohawk In all scenarios, tree height and canopy cover remain at current levels.

Five buffer strip scenarios are considered in this modeling effort and are summarized in Table 4.4. An identifier abbreviation for each scenario is listed in the first column of the table. Scenario 1 reflects the current situation of buffers consistent with the Oregon Forest Practice Act[42] prescriptions on industrial timber lands and observed buffer widths in other areas. In scenario 2, the Oregon Forest Practice Act rules are followed on large industrial forest and non-industrial timber lands. A 50-foot buffer is assumed on all agricultural land and existing observations of buffer widths are assumed on residential lands. Scenario 3 assumes that the Forest Practices Act is followed on large industrial timber lands and non-industrial lands. A 50-foot riparian buffer is assumed for all residential and agricultural lands. Scenario 4 assumes a 50-foot riparian buffer is used across the entire watershed regardless of stream size or adjacent landuse. In scenario 5, buffers consistent with the Forest Practices Act are used across the entire watershed regardless of land use.

4.4.2 Change in Costs of Implementation

A number of cost share, incentive and other government programs exist that are designed to encourage landowners to participate in conservation and restoration activities. Three alternative policy/cost redistribution schemes are considered in this study. The base policy (*B*) is the *status quo*, or base tax policy.[43] Property is taxed based on its current assessed value. The second policy (*D*) provides for a farm land or forest land deferral on all lands (except industrial timber land) that participate in the riparian planting scheme. The farm land/forest land deferral will apply to the entire tax lot not just the area

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[42] Forest practice rules are described in Chapter 2.

[43] The amount of tax paid per acre of land is a combination of the assessed value of that land and the tax rate per $1000 of assessed value. Every landowner is taxed at the same rate. However, landowners can receive a tax break by lowering the assessed value of their land. The policies described alter the assessed value of the land, not the tax rate.

planted in trees. This policy will reduce the assessed value of the entire tax lot upon which riparian plantings are made. The last policy (*TIP*), is modeled on the Oregon riparian tax incentive program. All land areas with a *bona-fide* riparian protection plan are totally removed from the owners tax base.[44] The remaining area of the land parcel is assessed at the regular value.

Table 4.4. Summary of Riparian Buffer Scenarios

	Large Industrial Forest Land[1]	Transitional Forest Land[2]	Agriculture[3]	Residential[4]
Scenario 1 (**B**) *Current Conditions*	forest practices act	current buffer widths	current buffer widths	current buffer widths
Scenario 2 (**AB**) *Agricultural Buffer*	forest practices act	forest practices act	50 foot buffer	current buffer widths
Scenario 3 (**ARB**) *Agricultural and Residential Buffer*	forest practices act	forest practices act	50 foot buffer	50 foot buffer
Scenario 4 (**50B**) *Complete 50 foot buffer*	50 foot buffer	50 foot buffer	50 foot buffer	50 foot buffer
Scenario 5 (**FPAB**) *Forest Practices Act*	forest practices act	forest practices act	forest practices act	forest practices act

[1] Lands in model classifications F1PUBRP, F1PUBNRP, F1PRIRP and F1PRINRP.
[2] Lands in model classifications F2RP and F2NRP.
[3] Lands in model classifications RRRP, RRNRP, E40RP, E40NRP, RDEVRP and RDEVNRP.
[4] Lands in model classifications LLOWRIV, LMEDRIV, LHIGHRIV, LLOWNR, LMEDNR and LHIGHNR.

[44] That is their assessed value is zero.

4.4.3 Summary of Riparian Buffer and Policy Alternatives Considered

Table 4.5 lists all riparian buffer and tax policy scenarios considered in this study. Thirteen scenarios are considered in total that represent the base situation and a combination of four alternative buffer prescriptions and 3 tax policies. An identifying abbreviation for each scenario is listed in the table. The first part of the abbreviation refers to the buffer prescription and is noted in bold type. The second part of the abbreviation represents the tax policy and is noted in italics. These abbreviations are used to identify scenario results in Chapter 6.

Table 4.5. Summary of Riparian Buffer and Tax Policy Scenarios

Tax Policies / **Buffer scenarios**	Policy 1 *Status quo*	Policy 2 *Farm or Forest Deferral*	Policy 3 *Riparian Tax Incentive Program*
Scenario 1 *Current Conditions*	**B***B*		
Scenario 2 *Agricultural Buffer*	**AB***B*	**AB***D*	**AB***TIP*
Scenario 3 *Agricultural and Residential Buffer*	**ARB***B*	**ARB***D*	**ARB***TIP*
Scenario 4 *Complete 50 foot buffer*	**50B***B*	**50B***D*	**50B***TIP*
Scenario 5 *Forest Practices Act*	**FPAB***B*	**FPAB***D*	**FPAB***TIP*

5.0 DATA COLLECTION AND SOURCES

In the following sections, data sources and collection methods are described for the mathematical programming model. Section 5.1 describes the information used to characterize economic activity in the watershed and the prices, costs and technologies faced by producers. Section 5.2 describes the residential land area, property prices, riparian frontage length and buffer width. Section 5.3 identifies the average assessed values per acre for all land types. Sections 5.4 and 5.5 describe the data and empirical regression results used to estimate the value of a riparian buffer planted in trees on residential property. The final section, 5.6, describes the atmospheric, hydrologic and shading parameters used to estimate changes in stream temperature in response to a change in the width of the adjacent riparian buffer. Summary data are presented in appendix B.

5.1 Production Activity in the Watershed

5.1.1 Land Use

The area spanned by the watershed, general land use and zoning are obtained from BLM (1995), Weyerhaeuser Company (1994) and GIS coverages supplied by Lane Council of Governments. The watershed analyses conducted by the BLM (1995) and Weyerhaeuser Company (1994) provided some information regarding the extent of forested area in the Mohawk. There exists little published information regarding the agricultural enterprises and practices adopted in the watershed.

The USDA Natural Resources Conservation Service has interpreted aerial photographs for 8,817 acres of the valley floor that approximates the agricultural area defined by the BLM (1995). The aerial photo interpretation was transferred to a mylar sheet and digitized using GIS software. The land use coverage was then refined and constructed in ArcView. Land use and vegetation identified through aerial photograph interpretation is presented in table 5.1. Figure 5.1 identifies the approximate spatial extent of this aerial photograph interpretation.

Table 5.1. Land Use and Vegetation in the Predominantly "Agricultural" Area of the Mohawk Watershed

Land Use/Vegetation	**Area - Acres**
Pasture	5913.96
Rural Residential	1358.06
Riparian - hardwood	543.52
Riparian - conifer	4.60
Riparian - mixed	138.74
Riparian - no cover	33.20
Golf Course	169.82
Forest land	378.72
Orchard	90.31
Industrial	7.40
Hay land	64.00
Oak woodland	59.51
Water (streams)	55.53
Total acres in the predominantly agricultural area	8817.37

Source: GIS coverage data provided by Craig Ziggler, USDA, NRCS.

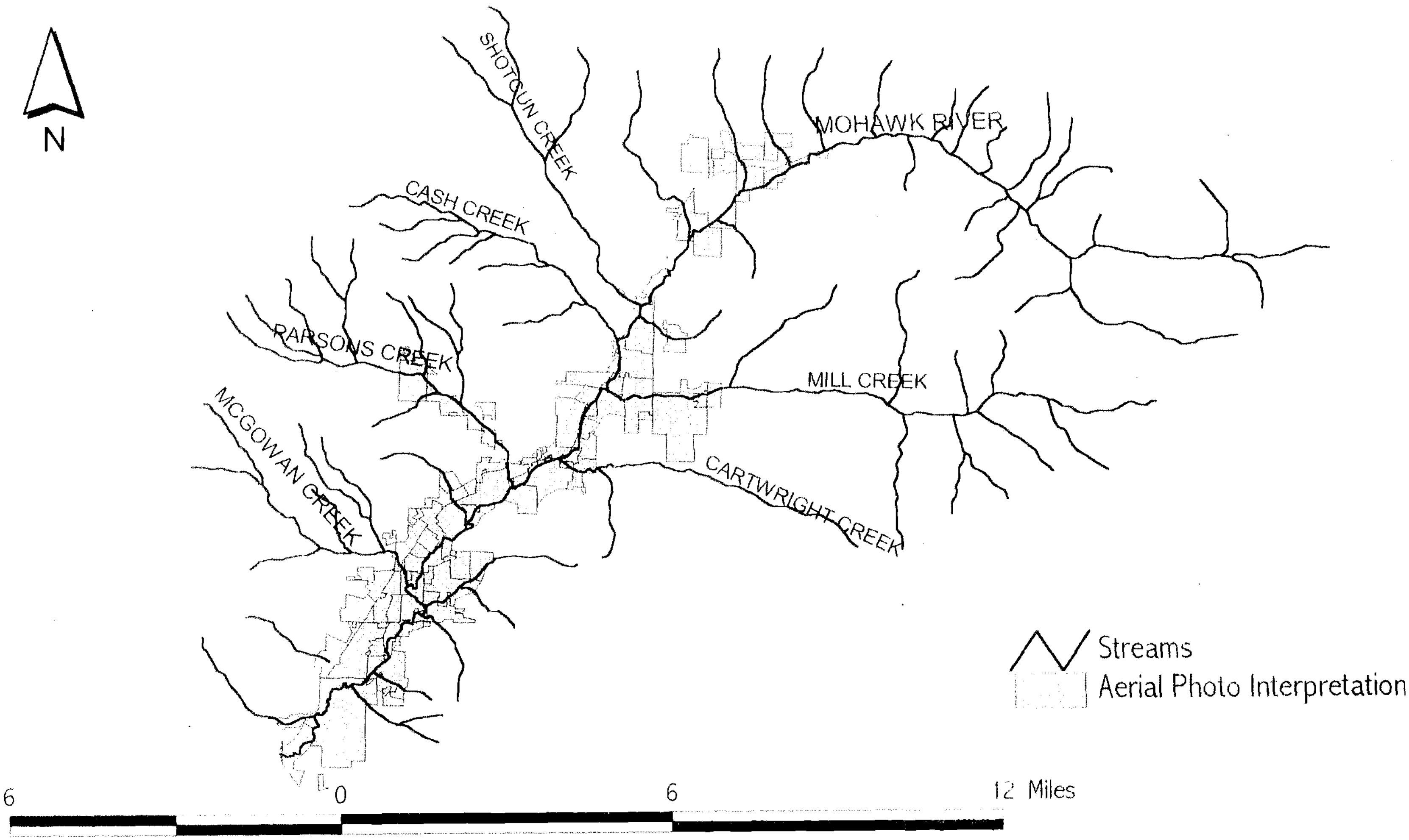

Figure 5.1 Approximate Extent of Aerial Photograph Interpretation

In an attempt to specify current agricultural land use, County Agents, Ross Penhalligon and Paul Day (retired) from the Oregon State University, Extension Service were contacted to obtain their specific recollections of agricultural enterprises and practices in the area. Their summary is presented in table 5.2. In addition, a personal interview survey of households in the Mohawk watershed was undertaken to verify and clarify land use and land use practices. A description of the sampling scheme, questionnaire and results are presented in Appendix A. Survey results verify that the primary enterprises (other than forestry) are livestock (mostly cattle) and hay production. The majority of enterprises are small scale with a few large scale commercial producers.[45]

Table 5.2. Agricultural Enterprises in the Mohawk Watershed

Type of enterprise	Number of units
Cattle production	1500 cows[1]
Blueberries	10 acres
Pumpkins	5 acres
Mint	50 acres
Vegetables (in rotation, corn, beans, wheat, sometimes peas and carrots)	50 acres
Native nursery	10 acres
Hazelnuts	60 acres

[1] This is an estimate of the number of resident cows in the watershed. This number is estimated through discussion with a local producer and the best judgment of a local county agent.
Source: Personal communication, Ross Penhalligon and Paul Day.

[45] Much of the agricultural area is underutilized (based on a personal communication with Paul Day and Ross Penhalligon, County Agents, OSU Extension Service, visits to the watershed and survey results (Appendix A)).

5.1.2 Land Area in Production and Length of Riparian Frontage

Taxlots greater than 25 acres with or without a residence and taxlots less than or equal to 25 acres without a residence are classed as land available for production activities.[46] Land used in production is subdivided into land adjacent to a river and land not adjacent to a river using a GIS. These two land classifications are further subdivided into another seven classes each on the basis of zone type and ownership. The seven classes are public industrial forest, private industrial forest, non-industrial forest, agricultural, rural residential, residential developed (but with no residence) and other. Land area covered by each class is estimated using a GIS. Land area is presented in table B.1, appendix B. The riparian frontage of each type of production land adjacent to the stream is estimated using a GIS. Riparian frontage lengths are presented in table B.1, appendix B.

5.1.3 Agricultural Production Technologies and Costs

Production costs and technologies are obtained from enterprise budgets developed for agricultural activities within the Mohawk. An enterprise budget includes all costs and returns associated with producing a given enterprise in a specific location in a particular manner. Enterprise budgets are generally constructed on a per unit basis (e.g., per acre or per head). Costs used in the model include all variable costs (including labor) and the fixed costs of machinery and equipment insurance, depreciation and interest. Land cost is

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[46] This classification was developed on the basis of survey results (appendix A).

not included in the optimization model therefore profits generated by each enterprise represent returns to land and management.

5.1.3.1 Crop budgets

Enterprise budgets for peppermint (establishment and production), sweet corn, green beans, hazelnuts, wheat and blueberries in the Willamette Valley are produced by Oregon State University Extension Service. The most recent budgets for crops produced in the Mohawk were published between 1990 and 1995. These budgets were taken to the Lane County horticultural extension agent and were examined on an operation by operation basis to characterize production practices in the Mohawk. MBMS (Microcomputer Budgeting Management System) was used to generate crop enterprise budgets specific to the Mohawk. Budgets are presented in exhibits B.1 to B.6, appendix B.

5.1.3.2 Livestock budget

An existing cow/calf budget produced in 1988 for the Willamette Valley was adjusted to reflect practices in the Mohawk region by Paul Day, County Agent, OSU Extension Service (retired). The original budget was for a 100 cow herd. MBMS was used to calculate depreciation of machinery and equipment. However, most of the calculations were completed using the spreadsheet package Microsoft Excel. The livestock budget is presented in exhibit B.7, appendix B.

5.1.3.3 Forage/hay production budget

Enterprise budgets developed for the Willamette valley are used as the basis for estimating alfalfa hay production. A budget for native pasture production was used to generate production costs for native hay. Harvest costs that were identified by the personal interview survey were added to the cost of pasture production to form an estimate of native hay production costs.

5.1.4 Commodity Prices

Crop prices are five year averages (1991-1995) of Lane County prices obtained from Stanley D. Miles, Extension Economist, Extension Economic Information Office, Oregon State University. In cases where county data are not available, an average of State wide prices obtained from Oregon Agricultural Statistics Service are used. The price data are presented in table B.2, appendix B.

Livestock prices and average market weights are also obtained from the Extension Economic Information Office, Oregon State University. An average of prices over the years 1991-1995 were used as a representative market price for the cattle enterprise budgets. The livestock price and weight data are presented in table B.3, appendix B.

5.1.5 Crop and Forage Yield

Crop and forage yields vary according to soil type and micro-climate. Crop and forage yield by soil type were obtained from the USDA Natural Resources Conservation

Service. In general, these yields represent a high level of management (Personal communication John Hagen, NRCS, Portland 1996). These yields are weighted by the soil type in each land classification and used in the programming model. The area of each soil type in each land classification is calculated using a GIS. Many of these yields were adjusted by Ross Penhalligon, County Agent, OSU Extension Service to reflect current production practices in the Mohawk watershed. Yield data, by land type, are presented in table B.4, appendix B.

5.1.6 Management Practices and Yields on Public Industrial Timber Lands

The following information on logging practices and yields on public industrial forest land was obtained from Art Emmons, BLM, Eugene District. Public industrial timber land is managed for multiple goals, not all of which are economic. Approximately 10,710 acres of BLM holdings within the watershed are considered suitable for timber harvest. The remaining area is reserved to support other management goals.

The area is on average a high site class 3. Trees are thinned between the ages of 50 and 60 years and thinned a second time between the ages of 60 to 70 years. Trees are harvested between 70 and 80 years of age. Approximate yields for existing trees within these age classes are presented in table B.5, appendix B. Equal area management was chosen as an approximation of general forest management.[47] Under equal area management, with a rotation of between 70 to 80 years, between $\frac{1}{70}^{th}$ and $\frac{1}{80}^{th}$ of the area

[47] Personal communication with Art Emmons.

is harvested and replanted each year. In the mathematical programming model $\frac{1}{75}$ th of the operable area is harvested each year.

5.1.7 Management Practices and Yields on Private Industrial Timber Lands

Yield and management data on private industrial forest lands are proprietary information. Private industrial timber owners in the Mohawk watershed were unwilling to supply data on yields or cultural practices. It is estimated that the land class is high site 3 similar to the BLM holdings. In general, private industrial forest lands are managed more intensively and more directly for economic goals than similar public lands (personal communications with Dr. Darius Adams and Dr. Douglas Brodie, Department of Forest Resources, Oregon State University and Norman Elwood, Forest Economist, Oregon State University Extension Service).

Yields on private lands are likely to be higher than those on public lands reflecting a more intensive management regime and greater emphasis upon economic goals. In the absence of available data for private lands, public land management techniques and yields are assumed. However, this will most likely result in an underestimate of the total and net costs or benefits generated by the model for private industrial forest lands.

5.1.8 Management Practices and Yields on Non-Industrial Timber Lands

On non-industrial timber lands there are likely to be many different management practices. One likely management scenario and corresponding yield estimates are suggested by Norman Elwood, Forest Economist, OSU Extension Service. It is assumed that non-industrial timber holders will thin stands between 40 and 50 years and harvest between 60 and 65 years. Yield estimates are presented in table B.6, appendix B.

5.1.9 Logging Costs

Logging costs are not estimated for this study. Stumpage price is used to calculate revenues from timber production. Stumpage price accounts for average logging costs. Logging costs can differ depending on the area of land harvested and logging practices. Costs of replanting were taken from estimates provided by Art Emmons (BLM) and are $929/acre on industrial lands and $636/acre on non-industrial lands.

5.1.10 Timber Prices

Stumpage prices between 1991 and 1995 for Douglas fir in western Oregon were obtained from Dr. Darius Adams, Department of Forest Resources, Oregon State University. Stumpage price reflects the difference between the average market price for timber and average logging costs. Recent stumpage prices for camp run Douglas fir in the Lane County area were obtained from Norman Elwood, Forest Economist, Oregon State University Extension Service. Camp run is an average of all timber grades. Prices are estimated at $650/mbf for mature timber and $525/mbf for timber harvested during thinning These prices are consistent with the Western Oregon prices and are used in the analysis as they more closely reflect prices in the local geographic area.

5.2 Residential Land Area, Land Description and Property Prices

Residential land is defined as any tax lot less than 25 acres in size that also contains a single family residence or mobile home. Using a GIS, 735 land parcels are identified that meet these criteria. These are further divided into parcels adjacent to a stream and parcels not adjacent to a stream. Residential land area is presented in table B.7, appendix B. Total river frontage for low, medium and high valued acreage adjacent to a river is measured using a GIS. Total stream frontage and average frontage per acre are presented in table B.7, appendix B. The sale price for every property is not available. Real market assessed values, provided by the Lane County Department of Assessment and Taxation, are used as a proxy for sale price.[48] These prices are converted to an annuity value representing the dollar value of utility generated by the property on a yearly basis and then divided by the property acreage to estimate an annual per acre property value. This allows a direct comparison with profits generated by production enterprises on a yearly basis. The annuity payment is calculated as in equation (5.1).

$$Annuity = \frac{PV}{\frac{1}{d}\left(1 - \frac{1}{(1+d)^n}\right)} \tag{5.1}$$

PV is the present value of the property. The discount rate (d =8.32%) is a 5 year (1991-1995) average of money market mortgage rates (US Department of Commerce 1996). The annuity is calculated over a time period (n) of 30 years. A period of 30 years is chosen as this is commonly defined as the time span of one generation (Simpson and

[48] A correlation of the data collected on true arms length sales against real market assessed values indicates that the two measures are highly correlated (ρ = 0.89).

Weiner 1989). Average property values, on a per acre basis, representing each property classification and mortgage interest rates are presented in table B.8, appendix B.

5.3 Tax Rate and Assessed Property Values for Agricultural, Residential and Timber Lands

The total tax paid on a property is a function of the tax rate per $1,000 of assessed value and the value of the property.[49] Each property owner in a tax district is taxed at the same rate. However, some properties can be assessed below their true market value to encourage certain land use activities (e.g., farming and forestry).

A tax rate of $10.03 per $1000 of assessed value is used in this study. This rate is an average of 1996-1997 rates for the levy codes[50] 1905, 7902 and 7903 that are in the Mohawk watershed (table 5.3).

Table 5.3. Estimate of Average Tax Rate for Properties in the Mohawk Watershed

Levy Code	Rate per $1000 Assessed Value
1905 - Springfield School District 19	10.0313
7902 - Marcola School District 79J	9.8323
7903 - Marcola School District 79J	10.2265
Average	**10.03**

Source: Lane County Department of Assessment and Taxation (1997).

[49] Which must reflect its real market value, i.e., the price that the property would sell for if it were on the market during the tax year (Oregon Department of Revenue 1993).
[50] Levy code denotes the tax district.

All residential properties are assessed at the market value previously defined. The average assessed value per acre for all other land types is presented in table 5.4. Average assessed value was calculated from tax records provided by the Lane Council of Governments.

Table 5.4. Assessed Value per Acre for Land Types in Production

Land Type	Average Assessed Value $/acre
F1PUBRP[1]	0
F1PUBNRP	0
F1PRIRP[2]	95
F1PRINRP	95
F2RP[3]	326
F2NRP	326
RDEVRP[4]	14,316
RDEVNRP	14,316
RRRP[5]	14,316
RRNRP	14,316
E40RP[6]	490
E40NRP	490

1 No tax is paid on public land.

2 60% of private industrial land holdings in the data set were in a forest deferral. This value reflects the average value of commercial timber land in a forest deferral.

3 64% of non-industrial timber land was in a forest deferral. This value reflects the average value of non-industrial timber land in a forest deferral.

4 This land type covered a very small land area, assessed values were similar to those on land zoned as rural residential 2. The average assessed value for Rural Residential land is used in these areas.

5 This value reflects a weighted average of assessed values in land zoned RR2, RR5 and RR10.

6 Approximately 60% of land in this area is zoned farm. This value reflects the average value of land in this area that is zoned as farm.

5.4 Coefficient Linking a Change in the Riparian Buffer Area to a Change in Residential Property Values

The coefficient used to generate changes in residential property values in response to a change in riparian buffer width is generated using a hedonic pricing analysis. The hedonic function specified in equation (4.8) requires data for ten variables. The variables are the actual sale price of the property, date of the sale, size of the land parcel, size of the house, year that the house was built, quality of construction materials and architecture, distance of the property from the closest major town, the length of riparian frontage that the property enjoys and the riparian area planted in trees. This section describes data sources and collection techniques that were used to generate data for the hedonic pricing model.

Data are obtained from actual sales records[51], a Geographical Information System and aerial photograph interpretation. Sales records of lots and property[52] in Lane County over the period 1987 to 1996 were provided by the Lane County Department of Assessment and Taxation. Records covering the geographical area of the Mohawk watershed are selected from the total using the township, range and section numbers that span the watershed. Of these records, only those that represented an arms length sale[53] of

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[51] Sales records include information on the sale price, structural and other characteristics of the property.

[52] The term "property" refers to a lot, upon which a residence is constructed. The term "lot" refers to the parcel of land contained within the property. The term "residence" refers to the residential structure contained within the property.

[53] An arms length sale is a true market transaction. Sales between family members, small changes to the property title, and other similar transactions, were excluded from the analysis. The manager of the property sales record database at the Lane County Department of Assessment and Taxation identified the sale codes that related to true market transactions.

property less than 25 acres with a residence are selected for the analysis. Properties greater than 25 acres in size are excluded on the basis that these properties are likely to be purchased for their productive agricultural or other characteristics rather than their amenity value and, as such, represent sales within a different market.[54] The sales records include information on the sale price, sale date, structural and other characteristics of the property.

Lots less than 25 acres with residences that are adjacent to a river or stream are identified using a Geographical Information System (GIS).[55] The length of each water frontage is calculated using a GIS.[56] Aerial photographs are used to calculate the riparian buffer width planted to trees on each residential lot that sold between 1987 and 1996.[57] Aerial photographs of the study region taken in 1995 were provided by the Oregon Department of Forestry, Springfield. A summary of data used in the econometric estimation is presented in table B.9, appendix B.

5.5 Estimating the Coefficient

Ordinary least squares (OLS) is used to examine several alternative functional forms. Only one is presented in this section. The variables defined in table 4.1 are used

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[54] A personal interview survey of residents in the Mohawk watershed identified a natural break between the intensity of production activities on lots less than 25 acres and those of 40 acres and above (Appendix A).

[55] Taxlot, stream and road coverages for the Mohawk Watershed were purchased from Lane Council of Governments.

[56] ARCVIEW is a commercial GIS software produced by Environmental Systems Research Institute, Inc. (ESRI).

[57] The width of the riparian buffer planted in trees was calculated using a stereoscope, a magnifying glass and a ruler divided into 100ths of an inch. Only properties adjacent to the

in each model with slightly different transformations; for example squared or logged terms. The adjusted R^2 obtained from all functional forms estimated ranges between 0.71 and 0.74. Estimates are extremely stable with respect to changes in functional form. Each model has a consistently high adjusted R^2 and F-statistic. Parameter signs on significant variables are consistent in all the forms evaluated. The results of the model with the highest adjusted R^2 are shown in table 5.5. The final model estimated is defined in equation 5.2.[58] Reported standard errors are adjusted by White's correction for heteroscedasticity.[59]

$$LN(SALPRICE)_i = \beta_0 + \beta_1 SALEDAT_i + \beta_2 LN(ATACRES)_i + \beta_3 LN(SQFT)_i + \beta_4 YB_i + \beta_5 LOW_i + \beta_6 HIGH_i$$
$$+ \beta_7 MARCOLA_i + \beta_8 DIST + \beta_9 DIST^2 + \beta_{10} FRTLGTH_i + \beta_{11} AREATREE_i + \varepsilon_i \qquad (5.2)$$

All significant coefficients have the expected signs. The primary variables of interest are the environmental characteristics of a property; that is, water frontage (FRTLGTH) and the total area of the property planted to a treed riparian buffer (AREATREE). Both FRTLGTH and AREATREE are significant at $\alpha = 0.01$. The total sale price of a property is positively related to the existence of a waterfront and negatively related to an increase in the riparian area planted in trees. This suggests that the existence of a treed riparian

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stream can have a riparian buffer planted in trees. Properties that are not adjacent to the stream have no riparian area. Calculated widths have not been ground truthed.

[58] FRTLGTH and AREATREE were also tried in a quadratic form in other models not reported. It was not possible to log these variables as a considerable number of observations have a value of zero.

[59] Breusch-Pagan (1979) tests indicated that heteroscedasticity was present in all models at the 1% level. White's (1980) correction mechanism was used to adjust the standard errors which are used with Ordinary Least Squares parameter estimates for hypothesis testing.

buffer strip is a "bad" and causes a decrease in the utility of the property purchaser.[60] One possible explanation is that trees obscure the river view.[61]

The marginal implicit prices of FRTLGTH and AREATREE (measured at their mean values) are shown in table 5.6. Results indicate that the mean marginal implicit price of an additional foot of river frontage is \$50.46/ft, while an additional square foot of trees in the riparian area comes at a cost of approximately \$1.42/ft^2. If we assume that each tree covers an area 15 ft by 15 ft (225ft^2), then an additional tree "obscuring" the river would decrease property values by approximately \$320.[62]

To illustrate the potential magnitude of decreases in property value consider the following example. A 50-foot riparian buffer strip on a lot with 60 feet of water frontage results in 3,000 square feet of riparian area planted in trees. If property owners' marginal willingness to pay is constant this would result in a decrease in property value of \$4,260.[63]

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[60] A treed riparian buffer strip is generally considered to be a measure for stream bank restoration and enhancement. The negative coefficient associated with this measure contradicts the results generated by Streiner and Loomis (1995). However, the stream bank enhancements discussed in their study did not include treed riparian buffers.

[61] There are several factors not accounted for in this study that could be included to determine which attributes of the riparian buffer were not desirable including the type, height and density of trees.

[62] This area is used only for illustration purposes. The actual area covered by a tree will be dependent on the size and type of the tree.

[63] It is unlikely that the marginal willingness to pay will remain constant. At present the shape of the marginal willingness to pay function is unknown.

5.6 Atmospheric, Hydrologic and Shading Parameters for Stream Temperature Response

Stream temperature response to a change in riparian buffer width is calculated for stylized representations of Shotgun Creek, Parsons Creek, Cash Creek, Mill Creek, McGowan Creek and the Mohawk River (figure 5.2). There is insufficient data to include

Table 5.5. Estimated Hedonic Regression for Properties within the Mohawk Watershed

Variable	Coefficient Estimates	White's Standard Error
SALEDAT	1.088E-5***	7.6309E-7
ATACRES		
LN(ATACRES)	0.1565***	0.0281
SQFT		
LN(SQFT)	0.4836***	0.1017
YB	0.0022	0.0013
LOW	-0.1905*	0.1048
HIGH	0.1993*	0.1197
MARCOLA	-0.3115***	0.0873
DIST	8.592E-6*	5.1531E-6
$DIST^2$	-5.37E-11	4.6441E-11
FRTLGTH	0.000417***	0.0001
AREATREE	-1.17E-5***	2.1346E-6
Intercept	-6.5809**	2.7266
N	152	
R^2	0.7649	
Adjusted R^2	0.7465	
F-statistic	41.69	

*** Coefficient significant at $\alpha = 0.01$

** Coefficient significant at $\alpha = 0.05$

* Coefficient significant at $\alpha = 0.10$

Table 5.6. Marginal Implicit Prices of Environmental Attributes at their Mean Market Values

Variable	Marginal Implicit Price
FRTLGTH marginal price $/foot of frontage	50.46
ACRETREE marginal price $/square foot riparian area in trees	-1.42

Cartwright Creek in the modeling effort. Temperature changes are calculated using Heat Source (Boyd 1996). There are four major data types required to run Heat Source: record keeping attributes; atmospheric; hydrologic and shading data (table 5.7). Many of these parameters have not been measured or are not well known for the Mohawk River and its tributaries and have been estimated using a variety of techniques. The data collected for Heat Source should be considered as representing a stylized river system loosely based on the Mohawk river and its tributaries. Parameter estimates have not been ground-truthed. Data sources and collection methods are discussed below by input type and presented in tables B.10 to B.15, appendix B.

5.6.1 Record Keeping and Atmospheric Parameters

Stream name is taken from the GIS. The atmospheric variables, cloud cover, relative humidity, minimum and maximum air temperatures, times of minimum and maximum air temperatures and wind speed are obtained from weather station records at the Eugene Airport and Foster Dam at Sweet Home which are south and north of the

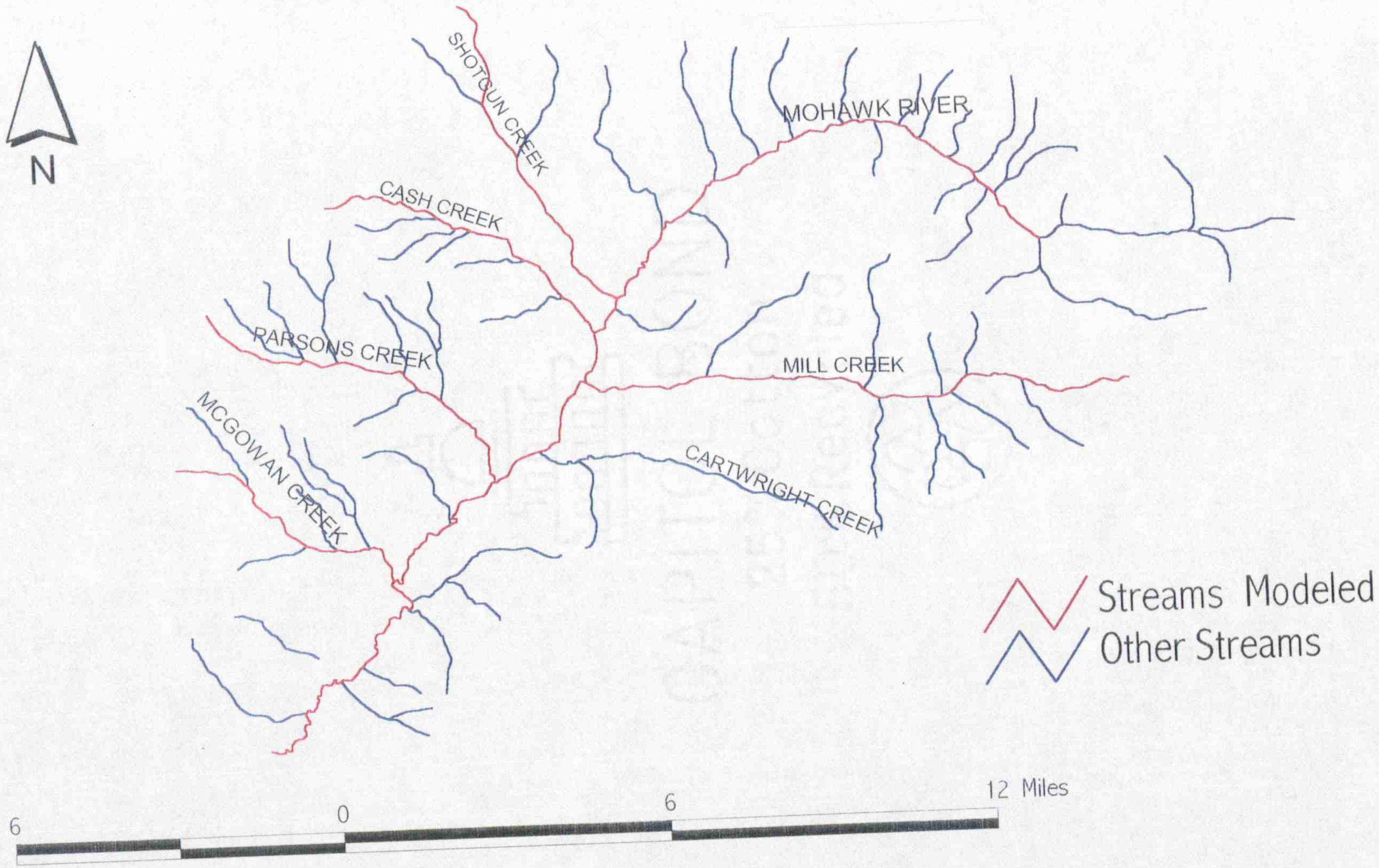

Figure 5.2. Streams Modeled Using Heat Source

Table 5.7. General Inputs Required for Heat Source

Record keeping	Stream/River Name Units Date of Simulation Duration of Simulation River/Stream Mile Elevation Latitude Longitude Time Zone Reach Length
Atmospheric	Cloud cover Relative humidity Minimum air temperature Maximum air temperature Time of minimum air temperature Time of maximum air temperature Wind speed
Hydrologic	Stream flow Flow velocity Average width Stream bed slope Percent bedrock Stream aspect Stream bank slope Topographic shade angle
Shading	Vegetation shade angle Vegetation height Vegetation width Canopy Coefficient

Source: Boyd (1996).

study area, respectively. Weather station records are provided by James Marron of the USDA, NRCS, Water and Climate Center, Portland, Oregon.

Data that reflects a fairly typical warm day in early August was used to create atmospheric variables for the model runs. Parameters for this day were chosen on the basis of historical temperature records at the weather stations. The maximum daily air temperature is taken to be 86 °F with wind at 5 mph and relative humidity at 55 percent. Stream elevation was determined from contour lines contained within the Oregon Atlas and Gazetteer (1991). Latitude and longitude were determined from the Oregon Atlas and Gazetteer (1991) and rounded to the nearest degree.[64] The time zone specified is the Pacific time zone. Reach length varies across model runs[65] and is the difference (in feet) between the upstream and downstream reaches.

5.6.2 Hydrologic Parameters

The stream parameters, flow, flow velocity, stream width, stream bed slope, percent bedrock, aspect, stream bank slope and topographic shade angle are obtained from several different sources. In all cases, stream aspect is determined from Oregon Atlas and Gazeteer (1991). Topographic shade angle is calculated as shown in equation (5.3) using measurements taken from the Oregon Atlas and Gazeteer (1991).

$$\arctan\left\{\frac{H}{D}\right\} \tag{5.3}$$

H = height above stream of highest contour line perpendicular to the stream bank
D = distance of highest contour line from the stream bank

Stream bank slope is unknown and is assumed to be 8 percent. Sensitivity analyses conducted with Heat Source indicate that model results are not very sensitive to changes

[64] Heat source does not deal with coordinates in units smaller than a degree.

in stream bank slope (Boyd 1996). Flow velocity is calculated using equation (5.4). Data sources and any additional calculations are presented below by tributary.

$$Velocity = \frac{Flow}{Depth * Width} \tag{5.4}$$

5.6.2.1 Stylized representation of Shotgun Creek

Stream flow, average wetted width, percent bedrock and depth are obtained from stream surveys conducted by the BLM between June 21st and July 20th 1983. These surveys represent the only detailed inventory of stream characteristics available for this tributary. Data from these surveys are provided by Karen Dodge, BLM, Eugene. Stream flow at 2,000 ft, 4,000 ft and 6,000 ft from the confluence with the Mohawk River is estimated using a regression of flow against distance from watershed divide using the data available for the remainder of the stream (Sullivan *et al.* 1990). Bedrock from 1,000 to 6,000 ft is assumed to be 12.6 percent which is the average for the stream reported in BLM (1995). Stream bed slope is obtained from the BLM (1995).

5.6.2.2 Stylized representation of Parsons Creek

Average wetted width, percent bedrock, depth and stream bed slope are obtained for 4,288 feet of Parsons Creek, starting at 20,259 feet from the headwaters. These data are provided by an aquatic inventory pilot project conducted on July 19th and 20th 1993 conducted by A.G. Crook Company (1993). Channel width from 0-10,000 feet is

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[65] Most reaches cover 2000 ft.

estimated from aerial photographs. Width from 10,000 to 20,000 is a linear function of width at 10,000 feet and 20,000 feet. Width at the headwaters (36,408 feet) is estimated to be 9 feet. Width between 26,000-36,408 feet is a linear function of the width at these two points. Depth at 0 feet is an average of the depth measured in the lower half of Shotgun creek. Depth between 0-20,000 feet is a linear function of depth at these two points. Depth at the headwaters is an average of the measured depth at the headwaters of Shotgun creek. Depth between 26,000 feet and the headwaters is a linear function of depth at these two points. In the absence of flow data, flow estimates are generated using the regression coefficients developed from Shotgun Creek. Actual flow in Parsons Creek may differ from that at Shotgun Creek. Percentage bedrock for all areas not sampled by A.G. Crook Company (1993) is assumed to be 12.6 percent, the average for the stream (BLM 1995).

5.6.2.3 Stylized representation of Mill Creek

Average wetted width, percent bedrock, depth and stream bed slope are obtained for 40,797 feet of the main channel from an ODFW aquatic inventory project stream report conducted on September 29th and 30th 1993 and between June 27th and July 11th 1994 (ODFW 1994a). Wetted width between 42,000 feet and the headwaters is assumed to be a linear function of the previous 40,000 feet. Depth from 42,000 to the headwaters is assumed to equal that at 40,000 feet. Flow estimates are generated from a regression equation estimated using data from Shotgun Creek. Actual flow may differ from that in

Shotgun Creek. Percent bedrock from 40,000 to the headwaters is assumed to be equal to that measured at 40,000 feet.

5.6.2.4 Stylized representation of Cash Creek

Stream flow, average wetted width, percent bedrock and depth are obtained from stream surveys conducted by the BLM over the period August 16th to August 21st 1984. Data are available for 8,750 feet of the main channel, which lies within BLM holdings. Width between 13,500 feet and the headwaters is a linear function of width between 12,500 feet and the confluence with the Mohawk. Depth from 13,500 feet to confluence is a linear function of depth between 12,500 feet and the confluence with the Mohawk. Stream flow between 0 to 6,500 feet and 13,500 feet from the headwaters is estimated using a regression equation generated from data for Shotgun Creek. Actual flow may differ from these estimates. Bedrock between 12,500 feet and the headwaters is an estimate of average bedrock for the river developed by BLM (1995).

5.5.2.5 Stylized representation of McGowan Creek

Stream flow, average wetted width, percent bedrock, and depth are obtained from stream surveys conducted by the BLM over the period June 25th to July 11th, 1985. Data are available for 5,000 feet of the main channel, which lies primarily within BLM holdings. Width from 0-12,000 feet is estimated from aerial photographs. Width from 18,000 to the headwaters (27,000 feet) is assumed to be 9 feet. Depth at 0 feet is estimated at 1 foot. Depth between 14,000 feet and 0 feet is a linear function of depth at these two points. Stream flow at 2,000 feet is a measurement taken July 10th, 1951 at the road crossing near Mohawk by the Oregon Water Resources Department. Stream flow at approximately 14,000 feet is a measurement taken August 21st, 1991 by USGS Water Resources Division. Flow at the headwaters is assumed to be 0.5 cfs (similar to Shotgun creek at this distance from the watershed divide). All other flows are linear functions of the 3 flows presented above. Average percentage bedrock for the stream is 4 percent (BLM 1995).

5.6.2.6 Stylized representation of the Mohawk River

Average wetted width, percent bedrock, depth and stream bed slope are obtained for 41,768 feet of the main channel from an ODFW aquatic inventory project stream report conducted from July 12th to July 21st, 1994 (ODFW 1994b). Stream flow at 0 feet is the August average (between 1986 and 1993) from the USGS gauging station, number 14165000. Stream flow at 34,000, 57,000, 69,000 and 95,000 are estimated using the relationship flow/basin area (suggested by Sullivan *et al.* 1990) using the flow at the gauging station. Flow at the headwaters (125,000 feet) is estimated to be 5 cfs. No empirical data are available for flow at the headwaters. All other flows are a linear function of the points above. Width at 0 feet is obtained from the USGS summary of discharge measurement data taken on September 17th, 1993 (on this day flow was equal to the yearly August average between 1986 and 1993). Width at other points is estimated from aerial photographs. Flow velocity from 1,000 to 87,000 feet is a linear function of the average velocity over the reaches 87,000 to 125,000 feet and velocity at 0 feet. Sullivan *et al.* (1990) indicated that flow velocity tends to increase as the river gets wider. Depth at 0 feet is obtained from the USGS summary of discharge data. Depth from 1,000-87,000 feet is calculated using equation 5.2. The percent bedrock from 0-87,000 feet is an average of the percent bedrock measured between 87,000 feet and the headwaters.

5.6.3 Shading

Riparian vegetation type is obtained from the Mohawk/McGowan Watershed Analysis (1995), Aquatic Inventory Projects (ODFW 1994a and 1994b) and The A.G. Crook Company (1993). An estimate of vegetation height given the tree age and type is made in consultation with BLM employees, Forestry Extension Agents, OSU, Extension Service and Oregon Department of Forestry, Springfield. Vegetation shade angle is calculated according to equation (5.5).

$$ARCTAN \quad \frac{(vegetation\ height)}{(0.5 * channel\ width)} \qquad (5.5)$$

Canopy coefficients are obtained from BLM (1995), ODFW (1994a and 1994b) and The A.G. Crook Company (1993). In areas for which there are no available data, the canopy coefficient is estimated using aerial photograph interpretation following WFPB (1994). Riparian buffer width is estimated using aerial photo interpretation. The buffer in industrial and some non-industrial forest lands is assumed to be at least equal to that required by the Oregon Forest Practices Act. Many buffers on public industrial forest land far exceed those required by the Forest Practices Act (personal communication with Art Emmons, Eugene BLM and Tom Bergland, Oregon Department of Forestry, East Lane District).

6.0 RESULTS

In this chapter results from the model scenarios are presented in terms of the change in welfare associated with adopting a given scenario in comparison the base scenario.[66] Scenario **B***B* is an estimate of the economic returns and production patterns in the watershed at present, given current riparian plantings. In most instances summary results are presented. Full model results for the base case scenario are presented in appendix C. Estimated stream temperature responses to the buffer width scenarios are discussed in section 6.3. Economic welfare change and stream temperature responses are used to construct a cost-effectiveness frontier that is presented in section 6.4.

6.1 Welfare Changes and Production Patterns Estimated by the Model

6.1.1 Scenario **B***B* - Base Case Scenario

Scenario **B***B* represents the current conditions in the watershed. This scenario is used for model validation and as a reference point against which other scenarios are compared. The activities selected in the solution to scenario **B***B* are presented in table 6.1. All activities are presented in acres except for the beef cow enterprise that is expressed in number of head of cattle. Production of each activity is aggregated over river and non-river properties in each land type.

[66] Unless otherwise indicated.

Table 6.1. Model Run Outcomes for Scenario **B***B*

Row Number	Activity Type	Residential amenity land (Acres)	Public Forest - Industrial (Acres)	Private Forest - Industrial (Acres)	Private Forest - Non-industrial (Acres)	[1]Residential - no residence (Acres)	[1]Zoned Rural residential (Acres)	[1]Zoned Agricultural (Acres or Head)	Total (Acres or Head)
(1)	Low value/acre property	2,677							2,677
(2)	Medium value/acre property	943							943
(3)	High value/acre property	253							253
(4)	Reforest, ages 0-10 years		143	983	110				1,236
(5)	Age classes 10-50 years industrial lands		10,139	69,793					79,932
(6)	Thin between 50-60 years		143	983					1,126
(7)	Thin between 60-70 years		143	983					1,126
(8)	Harvest between 70-80 years		143	983					1,126
(9)	Age classes 10-40 years non-industrial lands				6,812				6,812
(10)	Thin between 40-50 years				110				110
(11)	Harvest 65 years				110				110
(12)	Grass Hay Low yield					314	2,373	4,254	6,941
(13)	Mint						50		50
(14)	Beans						17		17
(15)	Sweet Corn							17	17
(16)	Wheat						17		17
(17)	Nuts						60		60
(18)	Cows							1,500	1,500

[1] Classified as agricultural lands.

Table 6.1 indicates that 1,236 acres of timber are harvested on industrial and non-industrial forest lands (sum rows (8) and (11)), a corresponding area of 1,236 acres is reforested (row (4)) and 2,362 acres are thinned (the sum of rows (6) and (7) and (10)). The remaining forested land area is 86,744 acres, (the sum of rows (5) and (9)) and is in other standing timber or a riparian buffer. Hay is the second largest activity in the solution, in terms of area, with production on 6,941 acres (row (12)) followed by 3,873 acres in residential homes (the sum of rows (1), (2) and (3)) and then 161 acres in other crops (sum rows (13), (14), (15), (16) and (17)). One thousand and five hundred beef cows are produced in the watershed. The total pasture grazed by these livestock is 1,289 acres. This figure is calculated by multiplying the area of pasture required to support one cow on each land type by the total feed requirement of the cows on each land type.[67]

Hay, cattle and other crops are produced on RDEV, RR and E40 land types that are collectively referred to as agricultural lands. Timber production, harvest and replanting occurs on industrial and non-industrial forest lands. These results are consistent with the land use patterns discussed in Chapter 5 with three exceptions. The area in residential housing is approximately 3 times greater in the model than identified by aerial photograph interpretation. This is because the aerial photograph interpretation only classed residences within the town of Marcola as residential land, whereas the definition was expanded in this study to include all residences on a lot less than 25 acres. The model's estimate of the area in hay production is 24 times greater than estimated by aerial photograph interpretation.[68] The base model scenario estimates that 6,941 acres are

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[67] This information is contained within table B.4 and exhibit B.7 in Appendix B.
[68] Conducted by Craig Ziggler of the USDA,NRCS.

in hay production, whereas aerial photograph interpretation indicates that 64 acres are used in this activity. Similarly the area in pasture is 4.5 times smaller than estimated using aerial photograph interpretation. The potential overestimation of hay production and underestimation of pasture production by the model in comparison to estimates generated by aerial photograph interpretation are very likely to be related. Survey results (Appendix A) suggest that hay is often cut from native pasture. If hay had not been recently cut before the photographs were taken it would be hard to distinguish pasture from hay and thus determine the relative proportions of each enterprise (personal communication, Dr. Charles Rosenfeld, Oregon State University). Given an estimate of 1,500 cattle in the watershed, if actual pasture was 5,913 acres this would result in an extremely low stocking density of almost 3.9 acres per cow. Survey results suggest that this stocking density is low for the area and leads to two considerations. Firstly, the area of pasture identified using aerial photograph interpretation is too high and, in fact, some of this pasture area is hay land. Secondly, the estimate of the number of grazing animals in the watershed is too low. Only cattle were considered in the model. Survey results indicate that other livestock for example horses, also graze the area. However, these other livestock numbers are small in comparison to cattle numbers. Even if actual hay production is much greater than estimated by aerial photograph interpretation it is still possible that the model overestimates hay production in a given year as some areas are not grazed or hayed every year (personal communication with Paul Day, OSU Extension Service). There are no estimates available that identify the extent of the watershed that could be idle in an average year.

If hay production is overestimated (and more land remains idle), the total welfare predicted by the model will be greater than the true welfare generated from production activities in the watershed resulting in an overestimate of welfare changes as a result of planting a wider riparian buffer strip. However, the contribution of one acre of hay production to the overall welfare of the watershed is so small ($1.23/acre) that even a significant over or underestimate of production area will not change the general welfare results by a large amount.

The total net annual value of production, residential and selected environmental amenities under scenario **B***B* is estimated at $49,661,000 (table 6.2). This reflects the sum of returns generated from forestry and agricultural enterprises plus the 30 year annuity value of residential properties minus the sum of all property taxes. Forestry activities on F1PUB, F1PRI and F2 lands together generate $41,461,000 which is 83.5 percent of the net annual value of production. Residential and amenity activities generate $8,572,000, or 17 percent of net annual production value. The agricultural lands RR, RDEV and E40, collectively generate a loss of approximately $374,000 or 0.8 percent of annual production value.[69] Hay, wheat and mint are not sufficiently profitable to cover production costs (excluding land charges) and property taxes on RR and RDEV lands. Beans and nuts are sufficiently profitable to cover production costs and property taxes. However, these crops make up such a small part of production acreage that they cannot offset the losses generated by other crops resulting in a loss of $388,000 on RDEV and RR lands. Although property taxes are lower on E40 lands, hay still generates a loss.

[69] Percentages do not add up to 100 percent due to rounding.

Table 6.2. Value Generated by Production, Residential and Amenity Enterprises in the Mohawk Watershed, by Land Area: All Model Runs

Land Type	Scenario **B**_B_ ($ '000)	Scenario **AB**_B_ ($ '000)	Scenario **AB**_D_ ($ '000)	Scenario **AB**_TIP_ ($ '000)	Scenario **ARB**_B_ ($ '000)	Scenario **ARB**_D_ ($ '000)	Scenario **ARB**_TIP_ ($ '000)
Residential	8,572	8,572	8,610	8,573	8,462	8,500	8,463
F1PUB	4,855	4,855	4,855	4,855	4,855	4,855	4,855
F1PRI	33,354	33,346	33,346	33,346	33,346	33,346	33,346
F2	3,252	3,250	3,254	3,250	3,250	3,254	3,250
RR	-343	-343	-258	-335	-343	-258	-335
RDEV	-45	-45	-43	-44	-45	-43	-44
E40	14	14	24	15	14	24	15
Total Value	49,661	49,651	49,789	49,660	49,541	49,679	49,551

Table 6.2 continued

Land Type	Scenario **50B**_B_ ($ '000)	Scenario **50B**_D_ ($ '000)	Scenario **50B**_TIP_ ($ '000)	Scenario **FPAB**_B_ ($ '000)	Scenario **FPAB**_D_ ($ '000)	Scenario **FPAB**_TIP_ ($ '000)
Residential	8,462	8,500	8,463	8,031	8,068	8,032
F1PUB	4,855	4,855	4,855	4,855	4,855	4,855
F1PRI	33,429	33,429	33,430	33,346	33,346	33,346
F2	3,252	3,256	3,252	3,250	3,254	3,250
RR	-343	-258	-335	-343	-258	-327
RDEV	-45	-43	-44	-45	-43	-43
E40	14	24	15	14	24	15
Total Value	49,626	49,764	49,636	49,109	49,247	49,128

However, that is offset by the positive returns from the cattle enterprise resulting in a production value of $14,000. Economic theory suggests that these losses would not persist in practice as a landowner consistently making a loss would not remain in business. However, in the case of the Mohawk watershed, the existence of these losses can be explained, in some part, by the following factors. It is apparent from the survey (Appendix A) that many residents are not fully utilizing the productive capacity of their land. It is likely that some residents engage in agricultural practices for lifestyle reasons and do not rely on income generated from agriculture as their main income source. Residents engaging in agriculture for lifestyle reasons may be willing to experience some financial losses from their agricultural activities in return for the amenity benefit generated by that lifestyle. For some residents, agriculture is a consumptive rather than a productive activity. Anecdotal evidence suggests that even the larger producers in the area have one or more family members bringing in income or engaging in periodic timber harvesting that could offset these losses. Residents that generate income from other sources may not be able to supply sufficient labor to produce higher valued crops and instead opt to produce crops (such as low yielding hay) that require less labor and management attention.

6.1.2 Results for Buffer Scenario **AB**

6.1.2.1 Scenario **AB***B*

Production patterns under buffer scenario **AB** are presented in table 6.3. Production is very similar to scenario **B***B* with a total of 1,236 acres of timber harvested on industrial and non-industrial forest land (sum rows (8) and (11)), 1,126 acres reforested (row (4)) and 2,362 acres thinned (rows (6), (7) and (10)) and 86,723 acres in standing timber or riparian buffer. The areas of timber harvested, replanted and thinned are slightly less than the base scenario although this is not reflected by the figures presented in table 6.3 due to rounding. Timber production declines slightly due to an increase in riparian buffer widths on non-industrial forest lands. Hay production is the first activity to be reduced from the agricultural areas as it is the least profitable enterprise (contributing only $1.23/acre to total welfare). Mint, beans, sweet corn, wheat, nut acreage and cattle production do not change from scenario **B***B*. Table 6.2 indicates that the total net annual value of production activities, residential and environmental amenities generated by scenario **AB***B* is $49,651,000. Absolute welfare changes by land type in comparison to scenario **B***B* are presented in table 6.4. The adoption of the Forest Practices Act on all F2 lands and a 50-foot riparian buffer on agricultural lands (RR, RDEV and E40) results in a total welfare loss of $10,553. A comparison of figures for scenario AB*B* in table 6.4 indicates that a reduction in the activities on private industrial and non-industrial forest lands account for 99.5 percent of this loss which represents a loss of 0.03 percent of sectoral welfare in comparison to the base level.

Table 6.3. Model Run Outcomes for Scenarios **AB*B***, **AB*D*** and **AB*TIP***

Row Number	Activity Type	Residential amenity land (Acres)	Public Forest - Industrial (Acres)	Private Forest - Industrial (Acres)	Private Forest - Non-industrial (Acres)	[1]Residential - no residence (Acres)	[1]Zoned Rural residential (Acres)	[1]Zoned Agricultural (Acres or Head)	Total (Acres or Head)
(1)	Low value/acre property	2,677							2,677
(2)	Medium value/acre property	943							943
(3)	High value/acre property	253							253
(4)	Reforest, ages 0-10 years		143	983	110				1,236
(5)	Age classes 10-50 years industrial lands		10,139	69,777					79,916
(6)	Thin between 50-60 years		143	983					1,126
(7)	Thin between 60-70 years		143	983					1,126
(8)	Harvest between 70-80 years		143	983					1,126
(9)	Age classes 10-40 years non-industrial lands				6,807				6,807
(10)	Thin between 40-50 years				110				110
(11)	Harvest 65 years				110				110
(12)	Grass Hay Low yield					313	2,377	4,222	6,912
(13)	Mint						50		50
(14)	Beans						17		17
(15)	Sweet Corn							17	17
(16)	Wheat						17		17
(17)	Nuts						60		60
(18)	Cows							1,500	1,500

[1] Classified as agricultural lands.

Table 6.4. Absolute Welfare Changes by Land Type, in Comparison to Scenario B*B*

Land Type	Scenario **B***B*	Scenario **AB***B*	Scenario **AB***D*	Scenario **AB***TIP*	Scenario **ARB***B*	Scenario **ARB***D*	Scenario **ARB***TIP*
Residential	0	0	37,362	324	-110,075	-72,713	-109,640
F1PUB	0	0	0	0	0	0	0
F1PRI	0	-7,696	-7,696	-7,266	-7,696	-7,696	-7,266
F2	0	-2,822	1,427	-2,789	-2,822	1,427	-2,789
RR	0	4	84,389	7,751	4	84,389	7,751
RDEV	0	-1	1,689	658	-1	1,689	658
E40	0	-39	10,038	396	-39	10,038	396
Difference from Value Generated in Scenario BB	0	-10,553	127,209	-926	-120,628	17,134	-110,890

Table 6.4 continued

Land Type	Scenario **50B***B*	Scenario **50B***D*	Scenario **50B***TIP*	Scenario **FPAB***B*	Scenario **FPAB***D*	Scenario **FPAB***TIP*
Residential	-110,075	-72,713	-109,640	-541,403	-504,041	-540,533
F1PUB	0	0	0	0	0	0
F1PRI	75,670	75,670	75,920	-7,696	-7,696	-7,266
F2	-506	3,743	-489	-2,822	1,427	-2,789
RR	4	84,389	7,751	-61	84,324	15,433
RDEV	-1	1,689	658	-7	1,683	1,312
E40	-39	10,038	396	-145	9,931	723
Difference from Value Generated in Scenario BB	-34,946	102,816	-25,404	-552,133	-414,371	-533,121

6.1.2.2 Scenario **AB***D*

Under the tax deferral policy scenario, taxlots with a riparian buffer planted in trees are assessed at a lower value than those with no buffer. On land areas E40, RR and RDEV, taxlots with a riparian buffer in trees are granted a timber deferral.[70] Riparian taxlots are assessed at $92/acre, $2,280/acre and $2,280/acre on E40, RR and RDEV lands respectively. F2 lands are assessed at $92/acre.[71] The market price of residential property within a riparian buffer is reduced by 20 percent.[72] No additional deferral was calculated for industrial timber lands. Production patterns are presented in table 6.3 and are identical to those described in section 6.1.2.1 for scenario **AB***B*. Total net annual value of production, residential and selected environmental amenities is $49,782,000 (table 6.2) a welfare increase of $127,209 in comparison to the base scenario (table 6.4). This increase is entirely due to the reduction in property taxes paid on river front areas which offset production losses on all eligible land areas.

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[70] In the case of properties in area E40, riparian tax lots are classed as zoned farm with a timber deferral.

[71] Original assessed values per acre are presented in table 5.4.

[72] No tax assessment records could be found in the data set that provide for a timber deferral on residential property. A 20 percent reduction in value is an arbitrary value reduction for the purposes of this study. A larger reduction in property value will result in larger welfare gains to residential property owners than those calculated. A smaller reduction in property value will result in greater welfare losses than calculated.

6.1.2.3 Scenario **AB***TIP*

Under the riparian tax incentive policy, the land area occupied by a riparian buffer strip is completely removed from the taxable land base of the property owner.[73] Production patterns are identical to scenarios **AB***B* and **AB***D* and are shown in table 6.3. The total net annual value is $49,660,000 (table 6.2), a decline in welfare of $926 across the entire watershed in comparison to the base scenario (table 6.4). The riparian tax incentive program is not sufficient to offset lost revenues from timber production on non-industrial forest lands, indicating that production revenues are greater than the property taxes paid on a per acre basis. The net value of production on all agricultural lands has risen in comparison to the base scenario (table 6.4). The tax savings on each acre of riparian buffer in RR and RDEV lands are $144/acre each, whereas tax savings on E40 lands are $4.91/acre. Tax savings are greater than the value of hay production in these acres therefore taking hay land out of production and accepting a riparian tax incentive for these areas increases the sectoral welfare. Despite the increase in welfare generated by the tax incentive, production activities on RR and RDEV lands continue to make a loss (table 6.2) as the revenue generated by reducing tax payments on riparian lands is not sufficient to cover the production losses on the remaining lands.

[73] Unlike the previous policy scenario, only that part of the property planted in trees is removed from the taxable base, not the entire tax lot.

6.1.3 Results for Buffer Scenario **ARB**

6.1.3.1 Scenario **ARB***B*

Production patterns generated by the mathematical programming model under buffer scenario **ARB** are presented in table 6.5. Production patterns are identical to those already described for scenario **AB***B*. The activities do not change from scenario **AB***B* because the buffer scenarios are identical on production lands. Scenario **ARB***B* differs from **AB***B* in that there is a 50-foot riparian buffer requirement on residential lands. The addition of a wider riparian buffer width on residential land does not reduce the number of residences or amount of residential area; rather, the values of the properties are adjusted to account for the decline in property value associated with planting a wide treed riparian buffer.[74] The total net annual value generated by this scenario is $49,541,000 (table 6.2) a welfare loss of $120,628 compared to the base level (table 6.4). Approximately 91 percent of this decline is accounted for by a reduction in property values associated with planting a wider riparian buffer that represents a welfare reduction for the sector of 1.28 percent in comparison to scenario **B***B*. All other welfare changes are as described for scenario **ARB**.

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[74] See section 5.4 for further explanation.

Table 6.5. Model Run Outcomes for Scenarios **ARB*B***, **ARB*D*** and **ARB*TIP***

Row Number	Activity Type	Residential amenity land (Acres)	Public Forest - Industrial (Acres)	Private Forest - Industrial (Acres)	Private Forest - Non-industrial (Acres)	[1]Residential - no residence (Acres)	[1]Zoned Rural residential (Acres)	[1]Zoned Agricultural (Acres or Head)	Total (Acres or Head)
(1)	Low value/acre property	2,677							2,677
(2)	Medium value/acre property	943							943
(3)	High value/acre property	253							253
(4)	Reforest, ages 0-10 years		143	983	110				1,236
(5)	Age classes 10-50 years industrial lands		10,139	69,777					79,916
(6)	Thin between 50-60 years		143	983					1,126
(7)	Thin between 60-70 years		143	983					1,126
(8)	Harvest between 70-80 years		143	983					1,126
(9)	Age classes 10-40 years non-industrial lands				6,807				6,807
(10)	Thin between 40-50 years				110				110
(11)	Harvest 65 years				110				110
(12)	Grass Hay Low yield					313	2,377	4,222	6,912
(13)	Mint						50		50
(14)	Beans						17		17
(15)	Sweet Corn							17	17
(16)	Wheat						17		17
(17)	Nuts						60		60
(18)	Cows							1,500	1,500

[1] Classified as agricultural lands.

6.1.3.2 Scenario **ARB***D*

Table 6.5 displays the production patterns generated by scenario **ARB***D* which are identical to scenario **ARB***B*. A tax deferral policy results in a total net annual value of production, residential and selected environmental amenities of $49,679,000 (table 6.2). This is a welfare increase across the watershed of $17,134 (table 6.4). Welfare changes on agricultural and forest lands are the same as those described for scenario **AB***D* in section 6.1.2.2. Despite a 20 percent reduction in assessed values on riparian tax lots, residential property owners experience a decline in welfare of $72,713 (table 6.4). These results indicate that the tax incentive does not sufficiently cover the perceived reduction in environmental amenities on residential properties as a result of planting a wider riparian buffer strip.

6.1.3.3 Scenario **ARB***TIP*

Production patterns generated under scenario **ARB***TIP* are identical to those generated under scenario **ARB***B* and are presented in table 6.5. The total net value of production, residential and selected environmental amenities is $49,551,000 (table 6.2) which is an overall welfare decline of $110,890 (table 6.4) despite the adoption of a riparian tax incentive program. Welfare changes on agricultural and forest lands are the same as those described for scenario **AB***TIP* in section 6.1.2.3. The largest welfare reduction ($109,640) occurs on residential land (table 6.4) again reflecting that the tax incentive is not sufficient to offset the perceived amenity losses on residential properties as a result of planting a wider riparian buffer.

6.1.4 Results for Buffer Scenario **50B**

6.1.4.1 Scenario **50B***B*

Production patterns generated under this scenario are presented in table 6.6. In comparison to the base scenario, hay production decreases by 29 acres and timber harvest increases by 2 acres as does reforesting and thinning. Production patterns on agricultural lands and welfare changes on agricultural and residential lands are identical to those described for scenario **ARB***B*, as the buffer prescriptions on these lands are the same in both scenarios. A 50-foot buffer on all forest lands strip increases the area available for timber harvesting. This is reflected in table 6.4 by a corresponding increase in production and net revenues generated by these areas. Under scenario **50B***B*, the total net annual value generated by activities in the watershed is $49,626,000 (table 6.2). This is a welfare loss of $34,946 in comparison to the scenario **B***B* (table 6.4). Table 6.4 shows that private industrial timber lands experience an increase in welfare of $75,670 while non-industrial lands suffer a loss of $506. Total sectoral welfare in the forestry sector increases by 0.18 percent in comparison to the base scenario.

6.1.4.2 Scenario **50B***D*

Production patterns generated under scenario **50B***D* are presented in table 6.6 and are the same as those described for scenario **50B***B*. The total net annual value generated under this scenario is $49,764,000 (table 6.2), a welfare increase of $102,816 (table 6.4).

Table 6.6. Model Run Outcomes for Scenarios **50B***B*, **50B***D* and **50B***TIP*

Row Number	Activity Type	Residential amenity land (Acres)	Public Forest - Industrial (Acres)	Private Forest - Industrial (Acres)	Private Forest - Non-industrial (Acres)	[1]Residential - no residence (Acres)	[1]Zoned Rural residential (Acres)	[1]Zoned Agricultural (Acres or Head)	Total (Acres or Head)
(1)	Low value/acre property	2,677							2,677
(2)	Medium value/acre property	943							943
(3)	High value/acre property	253							253
(4)	Reforest, ages 0-10 years		143	985	110				1,238
(5)	Age classes 10-50 years industrial lands		10,139	69,951					80,090
(6)	Thin between 50-60 years		143	985					1,128
(7)	Thin between 60-70 years		143	985					1,128
(8)	Harvest between 70-80 years		143	985					1,128
(9)	Age classes 10-40 years non-industrial lands				6,811				6,811
(10)	Thin between 40-50 years				110				110
(11)	Harvest 65 years				110				110
(12)	Grass Hay Low yield					313	2,377	4,222	6,912
(13)	Mint						50		50
(14)	Beans						17		17
(15)	Sweet Corn							17	17
(16)	Wheat						17		17
(17)	Nuts						60		60
(18)	Cows							1,500	1,500

[1] Classified as agricultural lands.

The distribution of welfare changes on agricultural and residential lands are the same as those described in scenario **ARB***D*. Figures in table 6.4 indicate that the forestry sector experiences a welfare increase of $79,413 in comparison to the base scenario (table 6.4) as a result of an increase in the area available for timber harvest as well as a reduction in the cost of leaving a riparian buffer on non-industrial forest land as a result of the tax deferral.

6.1.4.3 Scenario **50B***TIP*

Production patterns under this scenario are the same as those described for scenario **50B***B* and presented in table 6.6. Total net annual value generated under this scenario is $49,636,000 (table 6.2). This is an overall welfare decline of $25,404 for the watershed as a whole (table 6.4) in comparison to scenario BB. The welfare changes on agricultural and residential lands are the same as those described in scenario **ARB***TIP*. The welfare of the forestry sector has increased by $75,431 in comparison to the base scenario.

6.1.5 Results for Buffer Scenario **FPAB**

6.1.5.1 Scenario **FPAB***B*

A buffer strip scenario based on the Forest Practices Act does not have a significant effect on production activities on industrial forest lands as they are subject to these guidelines in scenario **B***B*. A comparison of production patterns presented in table

6.7 with base production in table 6.1 shows that timber production remains at base levels. Agricultural lands produce 6,766 acres of hay, 46 fewer acres than in the base scenario (table 6.7 compared to table 6.1). Production of all other crops remains the same as in scenario **B***B*. The total net annual value generated under this scenario is $49,109,000 (table 6.2). This results in a welfare loss of $552,133 (table 6.4). The residential sector experiences approximately 98 percent of this welfare decline (table 6.4) which represents a 6.32 percent decline in sectoral welfare in comparison to scenario **B***B*. The large welfare decline in the residential sector in comparison to the other sectors indicates that the amenity value of the riparian area to residential property owners is much higher than its value in most current agricultural production.

6.1.5.2 Scenario **FPAB***D*

Production patterns for scenario **FPAB***D* are presented in table 6.7 and are identical to scenario **FPAB***B*. Under a tax deferral program, total net annual value generated is $49,247,000 (table 6.2), a decline in welfare of $414,371 (table 6.4). Welfare increases (in comparison to scenario **B***B*) on agricultural and non-industrial forest lands as a result of lower property tax payments. A 20 percent reduction in the assessed values of residential properties does reduce their welfare loses in comparison to scenario **FPAB***B*, although this reduction is not sufficient to wholly offset the predicted decline in property values in response to a wider riparian buffer.

Table 6.7. Model Run Outcomes for Scenarios **FPAB*B***, **FPAB*D*** and **FPAB*TIP***

Row Number	Activity Type	Residential amenity land (Acres)	Public Forest - Industrial (Acres)	Private Forest - Industrial (Acres)	Private Forest - Non-industrial (Acres)	[1]Residential - no residence (Acres)	[1]Zoned Rural residential (Acres)	[1]Zoned Agricultural (Acres or Head)	Total (Acres or Head)
(1)	Low value/acre property	2,677							2,677
(2)	Medium value/acre property	943							943
(3)	High value/acre property	253							253
(4)	Reforest, ages 0-10 years		143	983	110				1,236
(5)	Age classes 10-50 years industrial lands		10,139	69,777					79,916
(6)	Thin between 50-60 years		143	983					1,126
(7)	Thin between 60-70 years		143	983					1,126
(8)	Harvest between 70-80 years		143	983					1,126
(9)	Age classes 10-40 years non-industrial lands				6,807				6,807
(10)	Thin between 40-50 years				110				110
(11)	Harvest 65 years				110				110
(12)	Grass Hay Low yield					309	2,323	4,134	6,766
(13)	Mint						50		50
(14)	Beans						17		17
(15)	Sweet Corn							17	17
(16)	Wheat						17		17
(17)	Nuts						60		60
(18)	Cows							1,500	1,500

[1] Classified as agricultural lands

6.1.5.3 Scenario **FPAB***TIP*

The change in production patterns for **FPAB***TIP* in comparison to the base scenario are identical to those generated for scenarios **FPAB***B* and **FPAB***D* (compare table 6.7 with table 6.1). The total annual value generated is $49,128,000 (table 6.2). The overall welfare decline in comparison to the base scenario is $533,121 (table 6.4). Agricultural lands experience a positive welfare change from this program. Again the largest welfare losses are experienced in the residential sector. These losses account for 101 percent of welfare loss in the scenario (table 6.4). The loses are greater than the total welfare loss for the scenario as welfare gains in the agricultural sector serve to offset the total losses in the residential and forestry sectors.

6.1.6 Discussion of Total Welfare Change and Distribution of Change between Sectors

Table 6.8 presents sectoral welfare changes in terms of dollar changes, sectoral welfare change as a percentage of sectoral welfare generated by the base scenario and as a percentage of total welfare generated under the base scenario. In every scenario the sectoral welfare change is less than 1.1 percent of the total welfare estimated under the base scenario. The solutions to each of the model scenarios were very stable which resulted in very small changes in the production activities selected in each solution. This stability is partially a result of the few substitution opportunities available on agricultural and timber lands. In addition, the change in total productive land area in response to wider riparian buffers is very small. In all cases a reduction in agricultural land area was accounted for by reducing the area of hay, which is a low valued crop.

Table 6.8 Welfare Changes by Sector in Comparison to Scenario B*B*

	B*B* welfare$_\Delta$ ($)	AB*B* welfare$_\Delta$ ($)	AB*B* % Δ sectoral welfare	AB*B* % Δ total welfare	AB*D* welfare$_\Delta$ ($)	AB*D* % Δ sectoral welfare	AB*D* % Δ total welfare	AB*TIP* welfare$_\Delta$ ($)	AB*TIP* % Δ sectoral welfare	AB*TIP* % Δ total welfare	ARB*B* welfare$_\Delta$ ($)
Forestry	0	-10,518	-0.03	-0.02	-6,269	-0.02	-0.01	-10,055	-0.02	-0.02	-10,518
Agriculture	0	-35	-0.01	0.00	96,116	25.72	0.19	8,805	2.36	0.02	-35
Residential	0	0	0.00	0.00	37,362	0.44	0.08	324	0.00	0.00	-110,075

	ARB*B* % Δ sectoral welfare	ARB*B* % Δ total welfare	ARB*D* welfare$_\Delta$ ($)	ARB*D* % Δ sectoral welfare	ARB*D* % Δ total welfare	ARB*TIP* welfare$_\Delta$ ($)	ARB*TIP* % Δ sectoral welfare	ARB*TIP* % Δ total welfare	50B*B* welfare$_\Delta$ ($)	50B*B* % Δ sectoral welfare	50B*B* % Δ total welfare
Forestry	-0.03	-0.02	-6,269	-0.02	-0.01	-10,055	-0.02	-0.02	75,164	0.18	0.15
Agriculture	-0.01	0.00	96,116	25.72	0.19	8,805	2.36	0.02	-35	-0.01	0.00
Residential	-1.28	-0.22	-72,713	-0.85	-0.15	-109,640	-1.28	-0.22	-110,075	-1.28	-0.22

	50B*D* welfare$_\Delta$ ($)	50B*D* % Δ sectoral welfare	50B*D* % Δ total welfare	50B*TIP* welfare$_\Delta$ ($)	50B*TIP* % Δ sectoral welfare	50B*TIP* % Δ total welfare	FPAB*B* welfare$_\Delta$ ($)	FPAB*B* % Δ sectoral welfare	FPAB*B* % Δ total welfare	FPAB*D* welfare$_\Delta$ ($)	FPAB*D* % Δ sectoral welfare
Forestry	79,413	0.19	0.16	75,431	0.18	0.15	-10,518	-0.03	-0.02	-6,269	-0.02
Agriculture	96,116	25.72	0.19	8,805	2.36	0.02	-212	-0.06	0.00	95,938	25.67
Residential	-72,713	-0.85	-0.15	-109,640	-1.28	-0.22	-541,403	-6.32	-1.09	-504,041	-5.88

	FPAB*D* % Δ total welfare	FPAB*TIP* welfare$_\Delta$ ($)	FPAB*TIP* % Δ sectoral welfare	FPAB*TIP* % Δ total welfare
Forestry	-0.01	-10,055	-0.02	-0.02
Agriculture	0.19	17,467	4.67	0.04
Residential	-1.01	-540,533	-6.31	-1.09

Notes: Dollar Δ sectoral welfare = sectoral welfare in comparison scenario - sectoral welfare scenario B*B*.

% Δ sectoral welfare = (((sectoral welfare in comparison scenario)/(sectoral welfare in scenario B*B*))*100) -100.
Signs on agricultural sector welfare change have been reversed to improve clarity and reflect the direction of welfare change, e.g. 25.72 should read -25.72 which is a 25.72 percent decrease in losses.

% Δ total welfare = (((sectoral welfare in comparison scenario)/(total welfare in scenario B*B*))*100) -100.

Δ = change.

The distribution of costs and benefits resulting from the proposed changes in buffer width and tax policy differs between scenarios. Under each scenario, the forestry and agricultural sectors experience a welfare change of less than 0.2 percent relative to the total base welfare in response the buffer prescriptions and tax policies examined in this study. A similar pattern is exhibited by the residential sector which experiences a welfare change of 0.22 percent or less in comparison to the total base welfare except in scenarios **FPAB**, in which the welfare decline ranges between 1.01 to 1.09 percent (table 6.8).

Welfare change by sector in comparison to the initial sectoral welfare generated under the base scenario provides some interesting results. The welfare change experienced in the forestry sector in comparison to the base sectoral welfare is less than 0.2 percent for every scenario. The maximum welfare change experienced by the residential sector as a percentage of the base welfare generated by that sector is a loss of 6.32 percent under scenario **FPAB*B***. The tax incentive programs examined in this study are not sufficient to offset the perceived amenity losses that result from planting a riparian buffer on residential properties.

In all buffer scenarios with the base tax policy the agricultural sector experiences a decline in sectoral welfare of 0.06 percent or less. Policy scenarios that include a tax deferral result in an increase in welfare on agricultural lands. It is interesting to note that the tax deferral scenarios result in a welfare increase of almost 26 percent in comparison to the base case. This occurs as a result of significant tax savings on land used in low valued crops (such as hay). A reduction in the taxes payable on the land area reduces production costs to such a degree that low valued enterprises can almost cover the sum of production costs plus taxes. In addition, the tax savings from land areas taken out of production can help to offset losses created by low valued crops. However, many agricultural activities do not contribute a positive sum to the value of production from the watershed even with favorable tax policies. Reasons for the persistence of these losses are presented in section 6.1.1.

This analysis clearly indicates that the welfare implications of planting a riparian buffer in trees differs in magnitude between sectors. Total welfare change for the watershed as a whole in comparison to scenario **B***B* is less than 0.30 percent for all scenarios except **FPAB** in which total watershed welfare losses range between 0.83 and 1.11 percent (calculated from figures in table 6.2). It has been demonstrated that the agricultural sector in the Mohawk watershed could receive considerable benefits as a result of riparian plantings associated with a tax deferral program. However, it is important to recognize that there could be individual landowners in the watershed that may experience much larger welfare gains or losses as a result of riparian plantings. Landowners that might experience losses are those with efficient management practices producing high valued commodities on riparian lands. These losses will be exacerbated if the landowner has a large riparian frontage. Landowners that might benefit considerably are those with inefficient management practices producing low valued commodities on riparian lands. These benefits will be increased by a long riparian frontage.

6.2 Estimates of Stream Temperature Response to Buffer Width Scenarios

Heat Source, is used to estimate daily stream temperature patterns in response to alternative riparian buffer scenarios for stylized representations of the Mohawk River and five tributaries (Mill Creek, Cash Creek, Parsons Creek, McGowan Creek, Shotgun Creek). One hundred and sixty-four model runs are required to complete each scenario. Each run calculates stream temperature change over one reach. Heat Source generates hourly estimates of stream temperature at the downstream point of the reach from which a daily maximum[75] and a daily minimum temperature can be taken. The output stream temperature profile for the upstream reach is used as the input stream temperature profile for the next downstream reach. In this way, the model accounts for water as it is transported from the headwaters of the river system to the confluence of the Mohawk River with the McKenzie River. The average buffer widths for each buffer scenario by land type are shown in table 6.9.

Table 6.9. Average Riparian Buffer Widths by Land Type by Scenario

Land Type	Scenario **B** (feet)	Scenario **AB** (feet)	Scenario **ARB** (feet)	Scenario **50B** (feet)	Scenario **FPAB** (feet)
F1PUB	80	80	80	50	80
F1PRI	82	85	85	50	85
F2	39	100	100	50	100
RR	53	50	50	50	100
E40	31	50	50	50	100
RDEV	40	50	50	50	100
Res.	37	37	50	50	100

Figures 6.1. to 6.6. present the maximum daily stream temperatures estimated for each reach under each buffer scenario. The ODEQ water temperature standard is represented on each figure as a horizontal line at 64 °F. Points on or below the line meet or exceed the standard whereas points above the line do not. Figure 6.1 presents the

[75] The maximum daily temperature for a reach is taken to be the highest temperature predicted during the day for the reach.

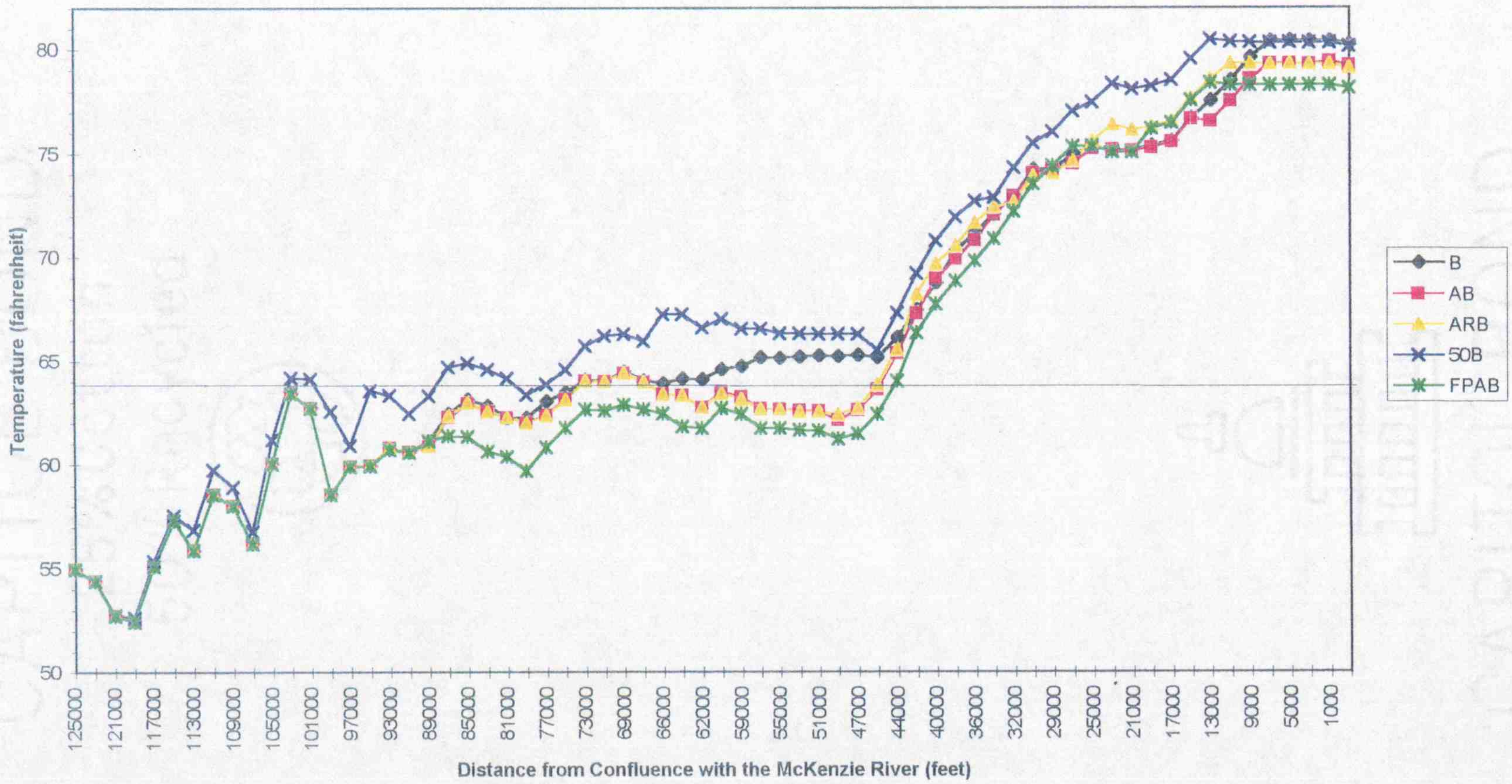
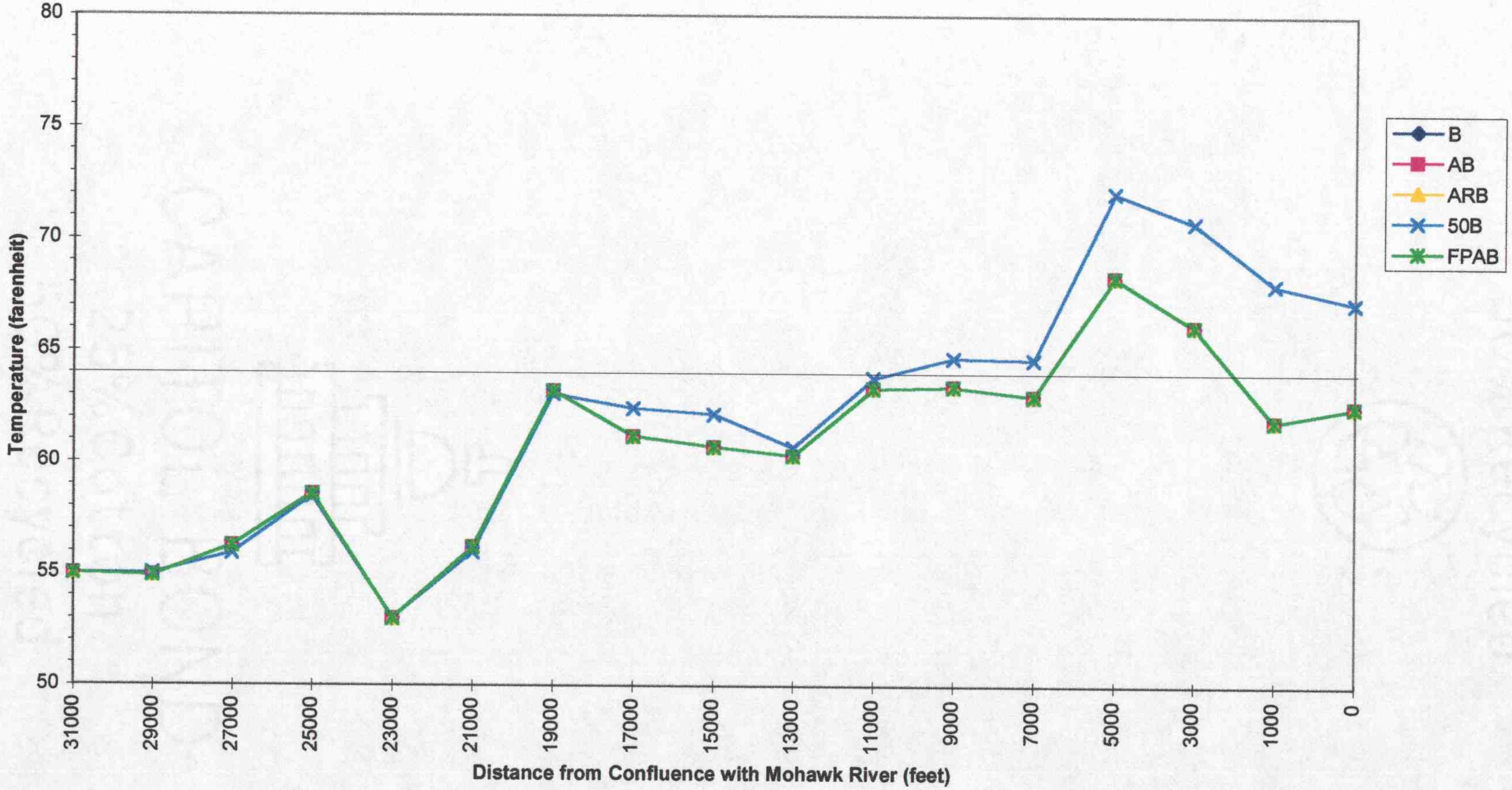
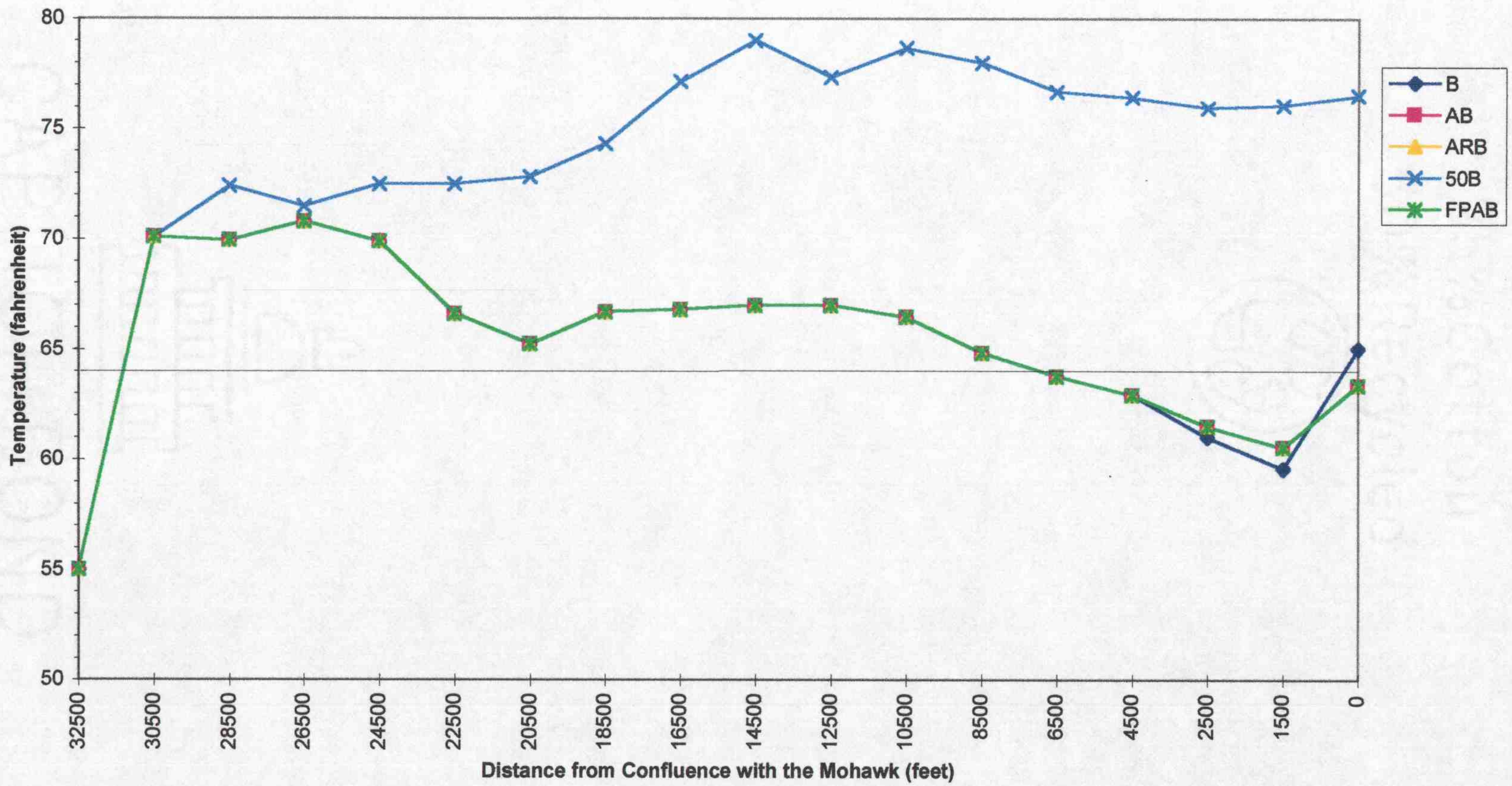


Figure 6.1 Maximum Stream Temperature Predicted for a Stylized Representation of the Mohawk River



Note: Buffer scenarios B, AB ARB and FPAB have the same stream temperature profile and as a result the identifying symbols overlay each other.

Figure 6.2. Maximum Stream Temperature Predicted for a Stylized Representation of Shotgun Creek



Note: Buffer scenario AB, ARB and FPAB have the same temperature profile and as a result the identifying symbols overlay each other.

Figure 6.3 Maximum Stream Temperature Predicted for a Stylized Representation of Cash Creek

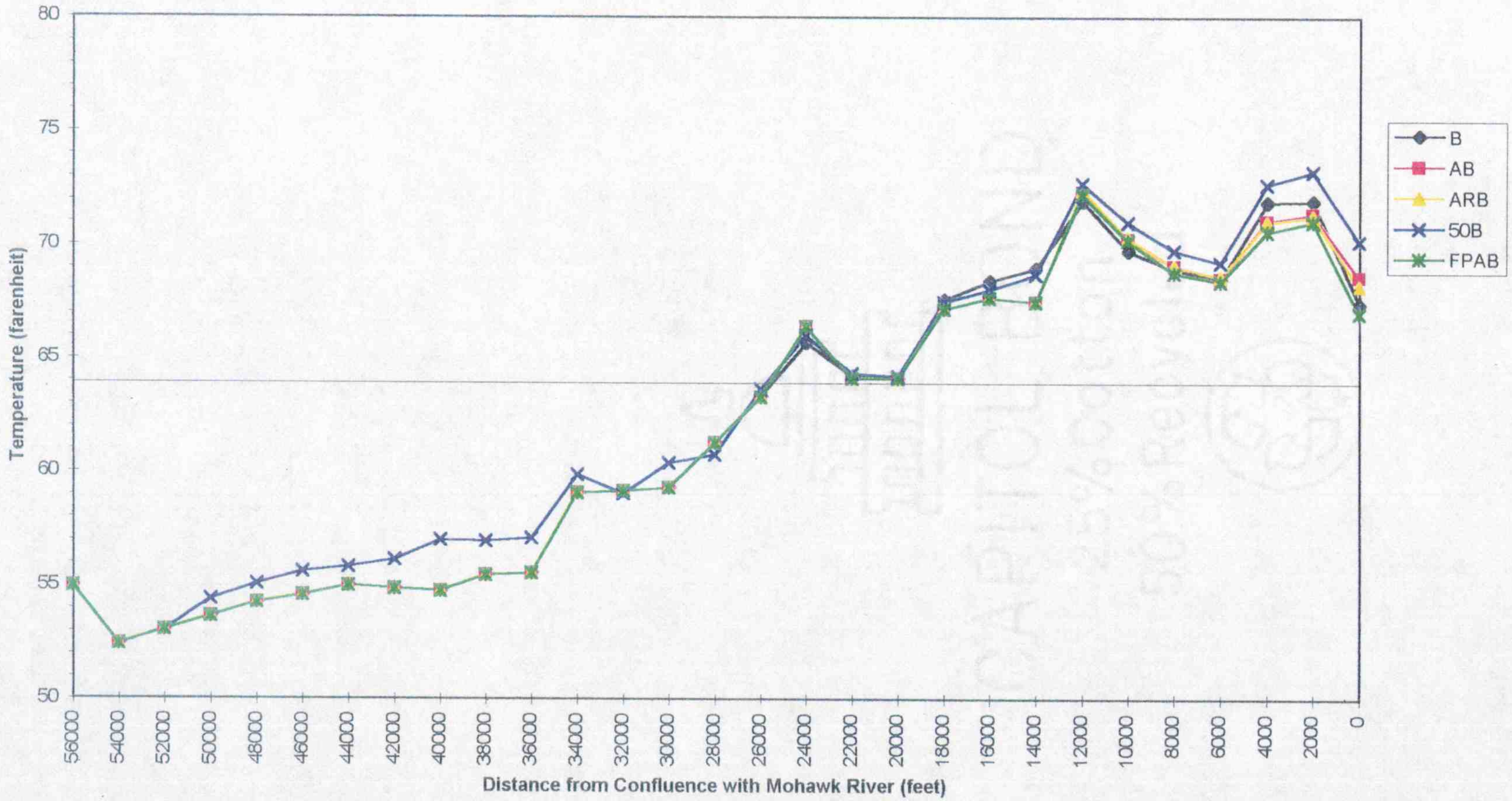


Figure 6.4 Maximum Stream Temperature Predicted for a Stylized Representation of Mill Creek

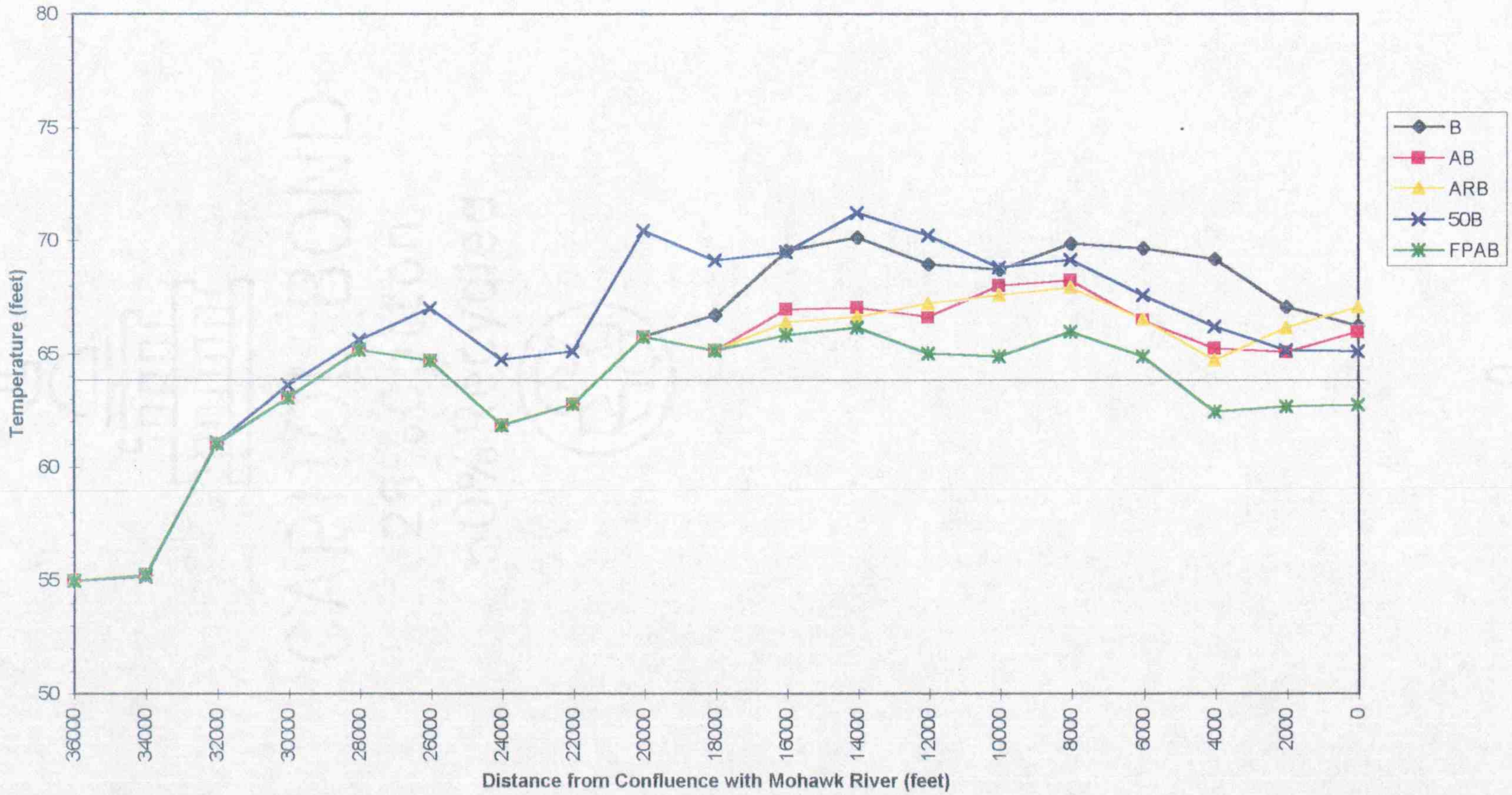


Figure 6.5 Maximum Stream Temperature Predicted for a Stylized Representation of Parsons Creek

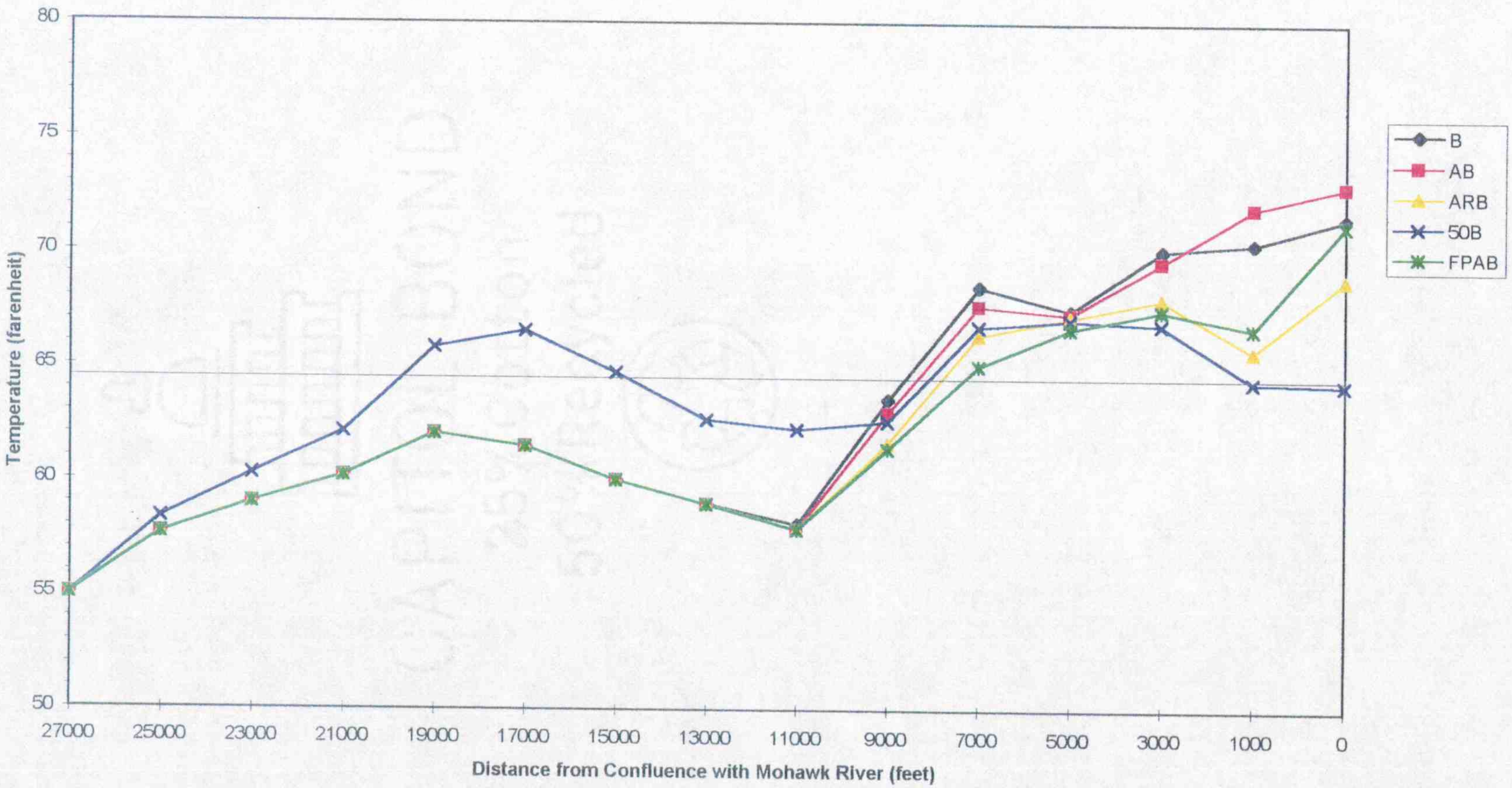


Figure 6.6 Maximum Stream Temperature Predicted for a Stylized Representation of McGowan Creek

maximum stream temperatures predicted for a stylized representation of the Mohawk River. Each of the buffer scenarios follow a similar stream temperature profile from the headwaters to the confluence. Temperatures rise between 125,000 and 95,000 feet from the confluence, then remain fairly stable between 95,000 and 47,000 feet and then start to rise rapidly between 47,000 and 13,000 feet after which they reach an equilibrium. The sharp increase in temperatures at approximately 47,000 feet from the confluence is probably a result of a wide stream channel (approximately 50-feet wide) and poor canopy cover (between 10 to 30 percent) in comparison to the previous stream reaches.

Stream, channel and riparian vegetation characteristics for the stylized Mohawk River are presented in table B.15, appendix B. With so many consecutive model runs it is possible that errors within the model could become compounded during the modeling process. The results from the base model run, scenario **B**, are compared against empirical data in sections 6.2.1 and 6.2.2 to examine whether model estimates are similar to empirical measurements.

6.2.1 Comparison of Scenario **B** Temperature Estimates with Field Measurements - Stylized Mohawk River

There are few field temperature measurements available for the Mohawk River. Measured temperatures will be a function of the weather conditions, shading and flow (among other factors) at the time when the measurements were taken. Conditions during the day on which field measurements were made may be quite different from the conditions used as input into Heat Source. Table 6.10 contains a summary of empirical temperature measurements taken during summer months on the Mohawk River. The data

Table 6.10. Comparison of Base Temperature Estimates with Empirical Measurements - Stylized Mohawk River

Description of location - empirical measurement	Measured Temperature °F	Closest Modeled Stream Reaches (feet from confluence)	Estimated Max Temperature °F
[1]Mohawk 15S-1E-18	55.6 to 65	103,000 101,000	63.45 62.74
[2]Mohawk above Log Creek	68	89,000 87,000	61.19 62.47
[3]Mohawk Lat: 4414562 Long: 12246378	59.9	89,000 87,000	61.19 62.47
[1]Mohawk at shade change above confluence with Shotgun Creek 15S-1W-33	57.56 to 67.35	77,000 75,000 73,000	63.05 63.49 64.08
[2]Mohawk above Marcola	72	64,000 62,000	64.11 64.13
[1]Mohawk just above Mill Creek 16S-1W-08	60.14 to 70.58	64,000 62,000	64.11 64.13
[2]Mohawk at McGowan	76	32,000 30,000	72.95 74.23
[4]Mohawk at Hill Rd. Lat: 4405323 Long: 12257336	69.8 and 78.62	32,000 30,000	72.95 74.23
[5]Mohawk Nr. Springfield	67 to 74	0,000	80.26
[2]Mohawk Nr. mouth	77	0,000	80.26

[1] Figures obtained from Weyerhaeuser Company. Range of measured daily maximum temperatures, August 1995.
[2] Recorded maximum summer temperatures 1986 presented in BLM (1995), no source was cited.
[3] EPA, STORET data base, station number 404024. Measurement taken at 10.00 a.m. on August 20th., 1996. Note, this might not be the maximum temperature achieved over the day.
[4] EPA, STORET data base, station number 402340. Measurements taken at 2.55 p.m. on August 26th., 1996 and 3.11 p.m. on July 30th., 1996 respectively. Note, these might not be the maximum temperatures achieved over these days.
[5] USGS Gauging station 14165000. Range of measured daily maximum temperatures, August 1st., to 21st., 1984.

presented are not an exhaustive list of temperature measurements for the Mohawk, they represent the most recent measurements at each location. In some cases the temperature records are for periods greater than 10 years from the current date. Vegetation cover and land use could have undergone considerable changes during this time. In many cases the exact point at which the sample was taken is not identified by its longitude and latitude. Stream reaches thought to be close to the sample points are selected to compare the estimates of maximum daily temperature with measured values.

Table 6.10 indicates that the maximum daily stream temperatures estimated using Heat Source are similar to measurements taken in the field. In most cases where a range of maximum field measurements is available, temperature estimates from Heat Source fall within the range. Temperature measurements taken close to the mouth of the Mohawk (Mohawk Nr. Springfield and Mohawk Nr. mouth) are lower than those estimated using Heat Source. Possible explanations are described below.

Inputs used in Heat Source are generated with data reflecting recent vegetation and land use practices which could be quite different from those present at the time when the field measurements were taken (1986 and 1984). It is possible that stream temperatures are higher today than those measured approximately a decade ago. Another potential explanation for the differences between measured and estimated temperature values is that Heat Source may overestimate temperature increases at higher levels (this has not been tested) or that the data used in the model is not a good representation of conditions in the lower reaches of the Mohawk.

6.2.2 Comparison of Scenario **B** Temperature Estimates with Field Measurements - Stylized Mohawk Tributaries

Table 6.11 contains a summary of empirical temperature measurements taken on tributaries to the Mohawk River. Only those measurements taken during the summer months are used for comparison against the model estimates. Again, it is important to note that weather conditions during the day on which empirical measurements were made may be quite different from the weather conditions used as input into Heat Source.

Table 6.11. Comparison of Base Temperature Estimates with Empirical Measurements - Stylized Mohawk Tributaries

Description of location - empirical measurement	Measured Temperature °F	Closest Modeled Stream Reaches (feet from confluence)	Estimated Max Temperature °F
[1]Shotgun Creek at Park	64	13,000 11,000	60.31 60.33
[2]Mill Creek at mouth, just above confluence with Mohawk 16S-1W-08	59.01 to 73.29	2,000 0,000	71.94 67.41
[2]Mill Creek 16S-1W-11	57.9 to 69.1	18,000 16,000	67.59 68.41
[2]Mill Creek 16S-1W-12	58.12 to 71.76	24,000 22,000	65.68 64.21
[3]McGowan at Mohawk Lat: 4409081 Long: 22570101	65.12	0,000	71.53

[1] Recorded maximum summer temperatures 1986 presented in BLM (1995), no source was cited.
[2] Figures obtained from Weyerhaeuser Company. Range of measured daily maximum temperatures, August 1995.
[3] EPA, STORET data base, station number 404025 . Measurements taken on August 21st., 1996. Note, this might not be the maximum temperature achieved over the day.

Estimates are only available for three of the five modeled tributaries. Similar to the case with the stylized Mohawk River, the exact point at which the sample was taken is not identified in every case. Stream reaches thought to be close to the sample points are selected for a comparison of the estimated maximum temperatures with measured values. Estimated maximum daily temperatures for Mill Creek are within the range of daily maximums measured at three points on Mill Creek (table 6.11). There are insufficient empirical data available to draw any conclusions regarding the accuracy or otherwise of temperature estimates at the specific points identified on Shotgun and McGowan Creeks.

6.3 Measuring the Effectiveness of the Buffer Proposals

The effectiveness of buffer prescriptions considered in this study is expressed in terms of the percentage of model reaches[76] for which the maximum stream temperature predicted at the downstream point is at or below 64 °F. This temperature is chosen as the cut-off point as ODEQ classifies streams with temperatures above this level as water quality limited on the basis of temperature. The stream temperature standard is based on the average maximum daily water temperature for the stream's warmest consecutive seven day period during the year. A one time measurement above the standard is not considered to be a violation of the standard.[77] The approximate spatial location of reaches included in this calculation is shown in figure 6.7.

Table 6.12 represents the percentage of model runs in the selected area that have a daily maximum temperature less than or equal to 64 °F. Under the buffer scenario **B** (which represents current conditions in the watershed) 21 percent of the selected reaches have a maximum temperature less than or equal to 64 °F. Scenario **AB** increases the

[76] The headwaters of the tributaries and the Mohawk River run through industrial forest land that is subject to buffer prescriptions consistent with the Forest Practices Act. This prescription is maintained for all scenarios except buffer scenario **50B**. To get a clear picture of how the proposed buffer prescriptions influence water temperatures in the downstream reaches that pass through a mix of mostly agricultural and residential land only those reaches downstream of industrial forest lands are included in this calculation.

[77] ODEQ web page http://www.deq.state.or.us/wq/wqfact/solar.htm.

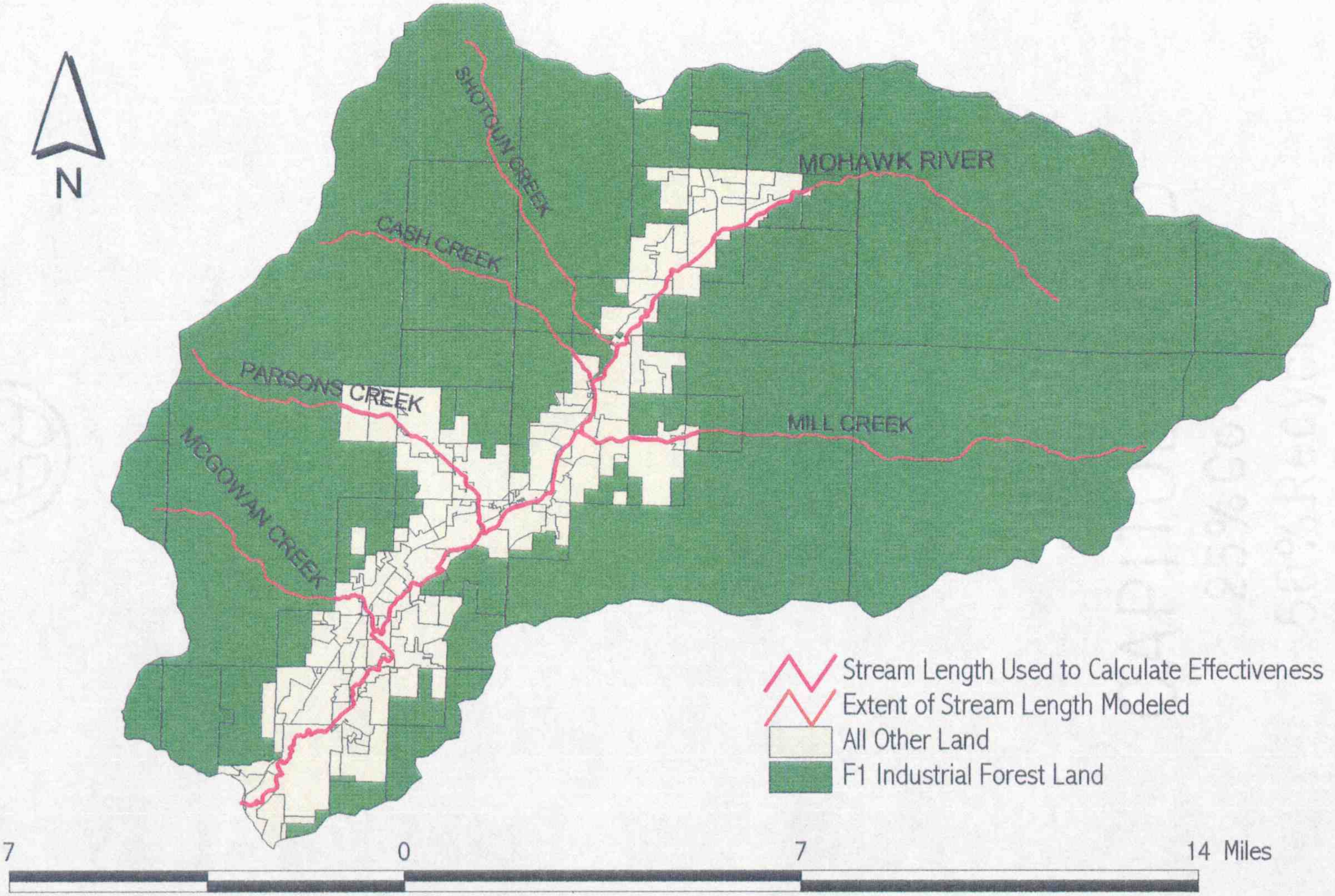


Figure 6.7 Location of Reaches Used in Effectiveness Calculations

buffer width on non-industrial private forest lands to match the Forest Practices Act guidelines and ensures a 50-foot buffer on all agricultural lands. This significantly increases the percentage of reaches at or below 64 °F to 36 percent. This is an increase of 71 percent over scenario **B**. The level of effectiveness remains at 36 percent in scenario **ARB** even with the addition of 50-foot buffer strips on residential land.

Table 6.12. Percent of Selected Reaches with a Maximum Temperature Less than or Equal to 64 °F

Scenario	Percent of Reaches Less than or Equal to 64 °F
Buffer Scenario **B**	21
Buffer Scenario **AB**	36
Buffer Scenario **ARB**	36
Buffer Scenario **50B**	10
Buffer Scenario **FPAB**	44

Interestingly, scenario **50B** results in a 50 percent decline in the number of reaches with temperatures less than or equal to 64 °F. In many respects this scenario is identical to scenario **ARB** except for the reduction in buffer width on forested lands. The dramatic reduction in effectiveness underscores the importance of keeping the headwaters of streams well shaded to reduce the rate of heating.

The most effective scenario is **FPAB**, which uses buffer widths suggested by the Forest Practices Act over the entire watershed. Under scenario **FPAB**, 44 percent of the selected reaches had temperatures less than or equal to 64 °F. This is an increase of approximately 110 percent over base levels. The buffer scenarios were unsuccessful in meeting the ODEQ water temperature standards on all reaches of the stylized Mohawk River and its tributaries.

6.4 Cost Effectiveness Frontier

Figure 6.8 displays thirteen points which represent the cost and corresponding effectiveness of all buffer and tax policy alternatives considered in this study. The cost of each scenario is measured on the x-axis as the total welfare change from the base scenario **B***B*. The effectiveness is measured on the y-axis as the percentage of selected reaches that meet or exceed the ODEQ 64 °F temperature standard. These points are used to construct a cost effectiveness frontier that depicts the least cost alternatives (of those considered) that can be used to increase the percentage of stream reaches with a daily maximum temperature below 64 °F.

Scenarios **AB***D* and **FPAB***D* are on the cost-effectiveness frontier. The adoption of wider riparian buffer strips in agricultural areas (buffer scenario **AB**) increases the percentage of reaches that have a maximum temperature below 64 °F to 36 percent. Scenario **AB***D* increases the welfare of watershed residents in comparison to the base case by $127,000. This indicates that an additional 15 percent of stream reaches can achieve the temperature standard while welfare is increased if accompanied by a policy that grants a tax deferral on all taxlots planted in a riparian buffer. However, this welfare gain results from a decline in tax revenues which could reduce the services provided in the area or alternatively increase the tax burden faced by residents in other areas to make up the shortfall. The tax deferral will reduce tax dollars generated in the watershed by approximately $138,000[78] in comparison to the case where no tax incentive is offered for the same buffer requirement (scenario **AB***B*). A tax deferral in this case overcompensates property owners for planting a riparian buffer in trees.

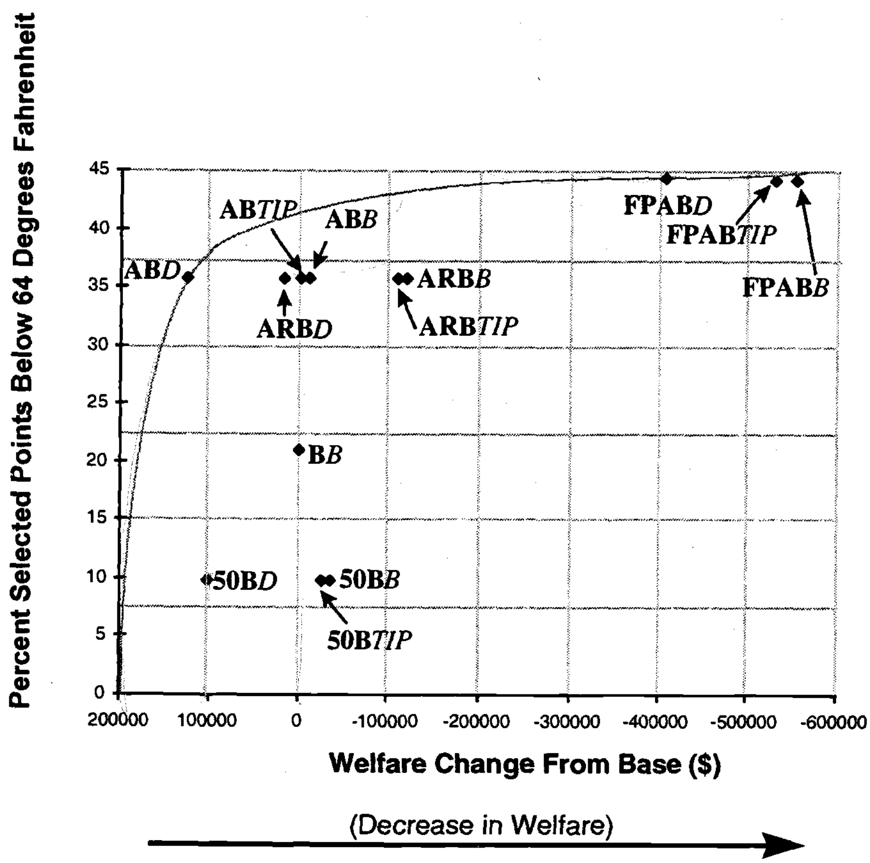


Figure 6.8. Cost and Effectiveness of Actions and Policies to Reduce Stream Temperature

Scenario **FPAB***D* provides for a riparian buffer strip consistent with the Forest Practices Act in addition to a tax deferral. An additional 23 percent of stream reaches

[78] Calculated from table 6.2 as the total change in value of scenario **AB***D* minus the total change in value of scenario **AB***B*.

meet or exceed the temperature standard under **FPAB***D* in comparison to the base scenario at a welfare loss of $414,371 (table 6.4). The reduction in tax revenues in comparison to the case where land in a riparian buffer would not receive a tax break (**FPAB***B*) is also approximately $138,000.[79] This tax deferral scheme increases the welfare of agricultural and non-industrial timber producers in relation to the base case scenario. This occurs as the Mohawk is considered to be an area producing low valued agricultural commodities under (generally), inefficient management practices. The majority of the welfare cost of this scenario is experiences by the residential sector. Their welfare losses are greater than the total welfare losses for the scenario as a whole.

Assuming that the tax incentives discussed are accepted in practice, the choice of which policy to select from those on the frontier in figure 6.8 is a choice to be made by the residents of the Mohawk watershed. Both policies increase the percentage of reaches that meet the 64 °F temperature standard. However, they differ in their effectiveness and the total costs and distribution of costs. From the perspective of a policy maker, both policies cost the same in terms of a reduction in tax revenues ($138,000). Scenario **FPAB***D* is more effective in reducing stream temperatures. Although the policy may appear to place a disproportionately heavy burden upon residential land owners in comparison the agricultural and forestry sectors, this cost is skewed as it does not take into account the losses in welfare already accepted by the forestry sector as a result of the Forest Practices Act (this was taken to be the *status quo*).

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[79] This figure is the same as the difference between scenarios **AB***D* and **AB***B*. The difference will be the same as no matter how much of the tax lot is planted in a riparian buffer the whole lot receives the same deferral and so the tax cost is the same under this policy whether the area is planted in buffers 10 feet wide or 100 feet wide.

7.0 CONCLUSIONS

The research conducted in this dissertation has focused on identifying cost effective actions to reduce stream temperature in the Mohawk watershed. Seven objectives and working hypotheses were outlined in Chapter 1. The following discussion examines these in light of the analysis performed in this dissertation and presents some of the major conclusions that can be drawn from this work.

7.1 General Conclusions and Discussion

In an attempt to identify the least cost ways to reduce stream temperature in the Mohawk watershed a conceptual framework and associated methods were developed that are suitable for assessing economic and environmental trade-offs at the watershed scale. An important consideration of the project was that the framework and methodology be transportable to other areas with similar characteristics.

The conceptual framework identifies a single dollar measure of welfare change, compensating variation, that can be used to calculate total welfare changes across consumers and producers in response to riparian plantings. The framework and methods are sufficiently general to be transferred to other areas with characteristics similar to the Mohawk watershed. The specific model formulations would have to be changed to represent production, residential and selected amenities present in any other area.

In chapter 2, several factors were identified that influence stream temperature; for example flow, channel surface area and vegetative shading. One component of vegetative shading, the riparian buffer width, was chosen as a practice that could be used to reduce stream temperature in the Mohawk watershed.

Stylized representations of the Mohawk river and its major tributaries were created using the stream temperature estimator Heat Source. Riparian buffers were demonstrated to be an effective means of reducing stream temperature to below the 64 °F standard set by ODEQ over part of the Mohawk watershed. However, the buffer scenarios considered could not reduce temperature in all reaches sufficiently to meet the temperature standard. The most effective scenario was a buffer width consistent with the Oregon Forest Practices Act that resulted in a uniform 100-foot wide buffer on the stylized Mohawk and its tributaries.[80] This buffer prescription increased the percentage of stream reaches that met or exceeded the temperature standard to 44 percent, an increase of more than 110 percent in comparison to the base scenario. Fifty six percent of the selected reaches remained above the 64 °F standard. It might be possible to reduce stream temperatures further by combining the riparian buffer prescriptions with additional practices such as augmenting flow. Stream heating is inversely proportional to flow (Boyd 1996, Beschta *et al.* 1987). Water in the Mohawk watershed is over-appropriated and in most years the low flow is close to 20 cfs, the minimum required flow (BLM 1995).

The economic model identified that, in the absence of mitigating tax programs, a reduction in stream temperature did decrease welfare in the watershed. An effectiveness measure of 44 percent results in the largest reduction of net annual welfare of $552,133 (scenario **FPAB***B*, table 6.4). In general, with no mitigating tax policy, an increased

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[80] The headwaters of some tributaries have smaller buffers associated with the FPA.

riparian buffer width reduces welfare in the agricultural sector by between 0.01 and 0.06 percent, residential welfare by between 0 to 6.32 percent and both increases by 0.18 percent and decreases by 0.03 percent the welfare in the forestry sector as a percentage of base sectoral welfare. Each sector bears some of the cost of reducing stream temperature when there are no mitigating tax policies.[81]

The two tax programs considered, i.e., a tax deferral and tax incentive, indicate that it is possible to alter the distribution of welfare changes between resource users and in some cases reverse the direction of welfare change in comparison to scenarios that do not consider incentive programs. This effect is particularly apparent on agricultural lands in the scenarios that consider a tax deferral. Agricultural welfare changes range between a loss in sectoral welfare of 0.06 percent without a tax deferral to a 26 percent welfare gain with the deferral. This indicates that an improvement in environmental quality need not come at any welfare loss to residents if the right incentive programs can be identified for different sectors. In fact it is probably possible to increase agricultural welfare without offering a tax incentive. For example, riparian plantings could be combined with education to increase production efficiency which could both increase the non-market amenities and agricultural welfare. At present, many producers are not engaged in efficient production practices. The tax programs also influence welfare changes in the residential sector, providing for an increase in welfare of 0.44 percent under scenario **AB***D*. However, in general the reduction in tax revenues is not sufficient to offset the perceived loss in environmental amenities that result in a reduction of residential property

[81] In scenario **50B***B* the forestry sector receives a welfare increase.

values. Residential property owners bear almost the entire welfare loss for the watershed under buffer scenario **FPAB**.

An interesting conclusion is that there does seem to be a trade off between the provision of different environmental amenities. Two considered in this study are increases in fish habitat (as a result of a reduction in stream temperature) and the amenity value of riparian lands. A riparian buffer planted in trees reduced the general amenity value of the property to individual property owners indicating that they would prefer a riparian area with few trees. However, reducing stream temperature (and correspondingly improving fish habitat) is considered to be an environmental amenity and was one of the goals identified as desirable for the overall watershed by the McKenzie Watershed Council.

The cost effectiveness frontier sketched in figure 6.8 suggests that as there is an increase in the percentage of stream reaches that have a temperature below 64 °F, welfare costs increase at an increasing rate. The welfare losses experienced by the residential sector (which have been discussed previously) are the main factor driving up costs. Welfare losses in the residential sector are based on the assumption that the marginal willingness to pay for an additional square foot of trees in the riparian area is constant (that is, the marginal willingness to pay function is horizontal). In fact, this could result in an underestimate of welfare changes as discussed in Chapter 3, section 3.5. The actual shape of the marginal willingness to pay function is not known at this time.

The distribution of welfare changes between sectors could influence the resident's policy choices among those on the frontier if riparian plantings are voluntary. Under scenario **AB*D*** the forestry sector experiences a decrease in sectoral welfare of 0.02

percent while the residential and agricultural sectors experience and increase in sectoral welfare in comparison to base sectoral welfare of 0.44 percent and 25.72 percent respectively. Under scenario **FPAB*D*** the forestry and agricultural sectors experience the similar welfare changes to scenario **AB*D***, however residential land owners experience a welfare decrease of 5.88 percent (table 6.8). Although this scenario results in the largest percentage of stream reaches that meet the standard it may meet with opposition from residential property owners if the riparian planting scheme is voluntary.

From a policy makers perspective each policy on the cost-effectiveness frontier results in the same decline in tax revenues. If the plantings were mandatory the choice of which policy to select will depend on whether a particular standard needed to be met or other political factors such as the will of policy makers to request property owners to bear the welfare loss.

This study indicates that the total welfare changes as a result of a riparian buffer planted in trees range between a welfare increase of 0.25 percent to a welfare decrease of 1.11 percent for the Mohawk watershed and are spread over many landowners and sectors. It is possible that a landowner with good management techniques, who is using his resources efficiently, would experience larger income losses than an inefficient producer that would deter him from participating in such a riparian planting program. Tax incentive programs might offset some of this loss.

The location of riparian planting is an important consideration when designing riparian buffer prescriptions on the watershed scale. A comparison of the buffer prescriptions **50B** and **ARB** demonstrate the importance of keeping a stream shaded from the headwaters on down, to maximize the effectiveness of buffer prescriptions. These two riparian buffer prescriptions are identical except for prescriptions on forested land. In scenario **ARB**, forested lands are buffered in accordance with FPA rules, under scenario **50B** they have a constant 50-foot buffer width. The effectiveness of shading under the buffer scenario **ARB** is approximately 300 percent greater than under scenario **50B**. The costs to agricultural and residential remain constant under each of these buffer prescriptions. However, the total effectiveness of scenario **50B** is much less than **ARB** as the temperature of the stream was much higher when it reached the agricultural lands. This suggests that policies based on land use might not be as effective as policies that target lands on the basis of spatial location.

A riparian planting program has been in operation in the Mohawk that offers free trees and free labor to local residents. Only a few property owners have participated in this program. If the results of this study are correct and there is little financial loss from planting a riparian buffer, then this suggests that there are other factors that affect the willingness of residents and producers to participate in such a program. Possible explanations are apathy (do not want to get involved, or do not have time to get involved), fear of government involvement on their property, protection of privacy, lack of education (do not realize that a riparian buffer will reduce stream temperature and why reducing stream temperature is an important goal) and a wish to maintain a way of life (for example, farming or rural non-farm activities). It is also possible that residential and small agricultural land owners have not been approached to participate in a riparian planting scheme. These landowners are not the traditional clientele of many agencies that provide advice and technical assistance.

7.2 Limitations of Study and Suggestions for Further Research

There are a number of limitations identified for this study. In this section they are considered as falling under two main categories. The first category is that of limitations associated with the model or data used in the study. The second category is that of limitations associated with the scope of the study. The identified limitations naturally lead to suggestions for further research.

7.2.1 Limitations and Suggestions for Further Research Associated with Data and Model Specification

Two distinct classes of individuals were considered in this study, producers and consumers. There is a third, important class of individuals which were not accounted for, namely those individuals that are engaged in both production and amenity activities. A considerable amount of further research could be conducted into ways to identify and characterize the welfare maximizing choices of these individuals and their welfare changes in response to environmental changes.

The assumption of a constant marginal willingness to pay for each additional square foot in trees in the riparian area on residential property is probably not realistic and could benefit from additional research to determine the losses associated with plantings which will influence the willingness of residential property owners to participate in planting schemes. The shape of the marginal willingness to pay function can be estimated by conducting the second stage of the hedonic price analysis. This will require additional data collection. It is likely that there are other characteristics of a riparian buffer that would influence the degree to which property values would change in response to planting trees in the riparian area; for example tree height, species and spacing.

Although a personal interview survey was conducted to elicit information about land use practices in the Mohawk watershed more detailed information is required. In particular more research could be conducted to identify the extent of idle and underutilized land in the Mohawk, what factors determine whether a land owner will underutilize land and the economic or other rationale that cause landowners to hold land and not use it in production. In addition, further research could determine with greater certainty the proportion of pasture, hay land and associated cattle numbers in the watershed. These and other data limitations constrained some of the features that could be included in the economic model. In particular, only one technology was considered for each production enterprise. Better information about land management practices would allow a richer economic model to be formulated that could consider multiple production technologies.

Other data limitations were faced in terms of collecting data for the stream temperature estimator Heat Source. In particular, far more research is needed to generate accurate measurements and records of stream flow, velocity, channel characteristics, shading characteristics and current stream temperatures along the Mohawk and its major tributaries.

Although perhaps not an area for further economic research, it would be of value to extend the stream temperature estimator, Heat Source into a network model. This would reduce the time commitment required to run alternative modeling scenarios and allow the researcher to consider a wider range of prescriptions within a reasonable period of time.

7.2.2 Limitations and Further Research Associated with the Scope of the Study

During the course of this study, many ideas were generated for further research and extensions to the current project. In particular, it would be useful to examine a wider range of more creative policy scenarios or alternative economic incentives in which riparian plantings could be used as a cash crop by some landowners; for example, growing poplars or alders along the stream bank and periodically harvesting some for economic gain. Alternatively it would be of value to consider a scheme in which a single manager is responsible for managing the entire riparian area of the watershed for timber, harvesting occasionally and sharing the harvest revenues with the participating landowners. A third possibility would be to consider a scheme of riparian easements.

Further research could be conducted into the economic and temperature effects associated with changing tree height and canopy cover in the watershed. Flow considerations could also be examined. At present the Mohawk is considered to be over-appropriated, more research could be conducted into examining ways to decrease withdrawals from the system.

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Appendices

Appendix A

Survey Design, Questionnaire and Summary of Results

A.1 Brief Overview of Study Design and Sampling Scheme

A stratified random sampling scheme was used to sample residents in the Mohawk watershed to elicit information about land management practices. The population of interest was defined as all private lands in the Mohawk watershed that are managed by persons that live in the watershed. The land area in the watershed was divided into five strata on the basis of zoning type. A Geographical Information System was used to identify the area of land within each zone, table A.1.

Table A.1. Total Land Area by Zone Type

Zone	Description	N_h =Size of Strata Acres
F2	Non-Industrial Forest Lands	8,433.19
E40	Exclusive Agriculture	6,597.07
RR10	Rural Residential 10	1,457.44
RR5	Rural Residential 5	4,350.91
RR2	Rural Residential 2	65.25

The sample size was selected with assistance from Breda Muñoz-Hernández, a consultant in the department of Statistics, Oregon State University. The total sample size was calculated at 110. Sample size was calculated in accordance with achieving estimates of cattle numbers with $\pm$ 10 percent error and a 95 percent level of confidence. Parameter estimates of the likely range of cattle numbers was required to calculate sample size. The estimates used are presented in table A.2.

Table A.2. Estimates of Livestock Numbers by Strata in the Mohawk Watershed

Strata	Estimate[1] of Cattle Numbers/household
F2	0 to 50
E40	0 to 70
RR10	0 to 40
RR5	0 to 30
RR2	0 to 25

[1] Initial estimates provided by personal communication with Lorna Baldwin, NRCS.

The total sample size was estimated using equation (A.1). The total sample size is allocated between strata using proportional allocation in accordance with equation (A.4).

$$n = \frac{N(Z_{1-\alpha})^2 \dfrac{\hat{\sigma}_w^2}{\hat{\bar{X}}^2}}{N(\varepsilon)^2 + (Z_{1-\alpha})^2 \dfrac{\hat{\sigma}_w^2}{\hat{\bar{X}}^2}} \tag{A.1}$$

Where:

n = total sample size
ε = level of error (0.1 in this case)
$Z_{1-\alpha}$ = 1.96 - desired level of confidence equal to 95 percent
N = total number of acres from which to draw the sample
$\hat{\sigma}_w^2$ = weighted estimate of variance
$\hat{\bar{X}}$ = weighted estimate of mean

and,

$$\hat{\sigma}_w^2 = \frac{\sum_{h=1}^{H} N_h \hat{\sigma}_h^2}{N} \tag{A.2}$$

N_h = acres of land in each strata h

$\hat{\sigma}_h^2$ = estimated variance for each strata h

and,

$$\hat{\bar{X}} = \frac{\sum_{h=1}^{H} N_h \hat{\bar{X}}_h}{N} \qquad \text{(A.3)}$$

where:

$\hat{\bar{X}}_h$ = estimated mean for each strata h

and,

$$n_h = n\left(\frac{N_h}{N}\right) \qquad \text{(A.4)}$$

n_h = number of residents sampled in strata h

The number of residents chosen to be sampled in each strata is presented in table A.3.

Table A.3. Number of Residents to be Sampled by Strata

Strata	Sample Size
F2	45
E40	37
RR10	8
RR5	24
RR2	1

A random sample of residents in each strata was picked using a random number table. A questionnaire was designed to collect information about land management practices in the watershed. A pre-test questionnaire was tried on a small number of residents. The questionnaire design was then reviewed by Pam Bodenroder of The Survey Research Center, Oregon State University. Each resident in the sample was sent a postcard (exhibit A.1) indicating that they had been selected for the survey. The postcard detailed the aims of the survey and indicated that the resident would be contacted and asked to participate. Questionnaire responses were collected by two enumerators during a personal interview survey. The survey questionnaire is presented in exhibit A.2. A summary of results is presented in section A.2.

Exhibit A.1 Pre-Visit Postcard sent to Mohawk Residents Selected for the Survey

Dept. Agricultural and Resource Economics
OREGON STATE UNIVERSITY

Ballard Extension Hall,
Corvallis, Oregon, 97331

Your household has been selected at random for a survey of residential, agricultural, forestry and other land uses in this area. Survey results will be used to examine conservation needs and to assist current projects (such as ongoing flood assistance) provided by agencies such as the Natural Resources Conservation Service (NRCS, formerly SCS) and East Lane Soil and Water Conservation District (ELSWCD). The study is conducted by the Department of Agricultural and Resource Economics, Oregon State University with assistance from NRCS and ELSWCD.

In the next few weeks you will receive a telephone call or visit from a surveyor who will request an appointment to visit with you.

All individual responses are voluntary and confidential. Summaries of the completed study will be available to interested participants. If you require more information, do not hesitate to contact me. Thank you for your assistance.

SIAN MOONEY
(1-541-737-1448)

Exhibit A.2. Questionnaire used to Elicit Additional Information about Landuse in the Mohawk Watershed

Mohawk Survey

Number ________________

Not all questions may be applicable to your situation.

Exhibit A.2 (continued)

1.	**ACRES**	**DK/NA**
a) Approx. how many acres of land do you own in the Mohawk Watershed?	______________	9999
b) Approx. how many acres do you rent from others?	______________	9999
c) Approx. how many acres do you rent to others?	______________	9999

2a) Are there any streams on or adjoining the land that you manage?

	YES	1
(GO TO 3a)	**NO**	2
(GO TO 3a)	**DK/NA**	9999

2b) Please could you name the/these stream(s)

	NAME	**DK/NA**
i	______________	9999
ii	______________	9999
iii	______________	9999
iv	______________	9999

(For each of the above mentioned streams, ask the following questions)

Exhibit A.2 (continued)

2c) Is the stream seasonal or all year?

	(c)		
NUMBER	**SNL**	**AY**	**DK/NA**
i)	1	2	9999
ii)	1	2	9999
iii)	1	2	9999
iv)	1	2	9999

3a) Are there any lakes or ponds within your property?

YES 1
(GO TO 4a) **NO** 2
(GO TO 4a) **DK/NA** 9999

3b) Beginning with the largest lake or pond, please answer the following:
i) Is the pond/lake seasonal or all year?
ii) What is the area of the pond/lake on square feet?

	(i)			(ii)
NAME/NUMBER	**SNL**	**AY**	**DK/NA**	**AREA (ft^2)**
____________	1	2	9999	________
____________	1	2	9999	________
____________	1	2	9999	________
____________	1	2	9999	________
____________	1	2	9999	________

Exhibit A.2 (continued)

4a) Do you raise any livestock on the land that you manage?

	YES	1
(GO TO 9 iv)	**NO**	2
(GO TO 9 iv)	**DK/NA**	9999

5a) How many cattle, if any, did you raise last year?

(IF > 0) NUMBER ________

DK/NA 9999

1. On average, how many hours per week do you spend on your cattle enterprise?

   NUMBER ________

   DK/NA 9999

2. Approximately how much protein supplement, if any, do you feed your cattle each year?

   LBS ________

   DK/NA 9999

3. Do you raise your own replacement heifers?

   YES 1

   NO 2

5b) How many horses, if any, did you raise last year?

NUMBER ________

DK/NA 9999

5c) How many sheep, if any, did you raise last year?

NUMBER ________

DK/NA 9999

Exhibit A.2 (continued)

5d) How many pigs, if any, did you raise last year?

NUMBER	______
DK/NA	9999

5e) Other ______________

NUMBER	______
DK/NA	9999

5f) Other ______________

NUMBER	______
DK/NA	9999

5g) Other ______________

NUMBER	______
DK/NA	9999

Exhibit A.2 (continued)

6) In what way do your livestock have access to water?

	Yes	No	DK/NA	J (A)	F (B)	M (C	A (D)	M (E)	J (F)	J (G)	A (H)	S (I)	O (J)	N (K)	D (L)
a) Full access to stream	1	2	9999		2	3	4	5	6	7	8	9	10	11	12
b) Confined access to stream	1	2	9999	1	2	3	4	5	6	7	8	9	10	11	12
c) Trough	1	2	9999	1	2	3	4	5	6	7	8	9	10	11	12
d) Lake or pond	1	2	9999	1	2	3	4	5	6	7	8	9	10	11	12
e) Other	1	2	9999	1	2	3	4	5	6	7	8	9	10	11	12

Exhibit A.2 (continued)

7) How many acres, in total, do your livestock graze?

ACRES ________

DK/NA 9999

8) How many separate acreages or management units do you have?

NUMBER ________

DK/NA 9999

Exhibit A.2 (continued)

9) Starting with your largest pasture or acreage, please answer the following questions.

i) How large is the pasture or management unit in acres?

ii) Is the pasture native or improved?

iii) If improved what species of grass was used?

iv) Is the pasture or unit also used for hay?

(if yes go to 9(v))
(if no go to 10)

v) What is the average hay yield?

UNIT		(i) SIZE (ACRES)	(ii) NATIVE OR IMP			(iii) SPECIES	(iv) ALSO HAY?			(v) HAY YIELD (TONS/ACRE)	DK/NA
			N	I	DK/NA		Y	N	DK/NA		
a)	1	________	1	2	9999	________	1	2	9999	________	9999
b)	2	________	1	2	9999	________	1	2	9999	________	9999
c)	3	________	1	2	9999	________	1	2	9999	________	9999
d)	4	________	1	2	9999	________	1	2	9999	________	9999
e)	5	________	1	2	9999	________	1	2	9999	________	9999
f)	6	________	1	2	9999	________	1	2	9999	________	9999
g)	7	________	1	2	9999	________	1	2	9999	________	9999

Exhibit A.2 (continued)

10) What proportion of your hay crop do you sell?

TONS ______________________________
DK/NA 9999

11) Approximately how much hay, if any, do you feed each year to your livestock?

i) **Grass hay (tons)** ______________
ii) **Alfalfa hay(tons)** ______________
iii) **Other (please specify) (tons)**________

12) Do you cut, rake and/or bale your own hay?
(IF NO TO ANY PRACTICE, REQUEST THE CUSTOM CHARGE)

Practice	Yes	No	DK/NA	(i) Custom charge if any, ($/acre) or ($/ton. Please specify
a) Cut	1	2	9999	
b) Rake	1	2	9999	
c) Bale	1	2	9999	

Exhibit A.2 (continued)

13) Do you engage in any cropping, berry or other non livestock enterprises?

	YES......... 1
(GO TO 15a)	**NO**.......... 2
(GO TO 15a)	**DK/NA** 9999

14a) How many acres of alfalfa hay, if any, do you produce?

ACRES __________
DK/NA 9999

14b) How many acres of commercial vegetables, if any, do you produce?

ACRES __________
DK/NA 9999

14c) How many acres of other crops such as what, mint etc., if any, do you produce?

ACRES __________
DK/NA 9999

14d) How many acres of berries, if any, do you produce?

ACRES __________
DK/NA 9999

14e) How many acres of nuts, if any, do you produce?

ACRES __________
DK/NA 9999

14f) How many acres of other ______________ do you produce?

ACRES __________
DK/NA 9999

14g) How many acres of other ______________ do you produce?

ACRES __________
DK/NA 9999

Exhibit A.2 (continued)

15a) Do you irrigate any of the land that you manage?

	YES	1
(GO TO 20a)	**NO**	2
(GO TO 20a)	**DK/NA**	9999

15b) What kind of irrigation system do you use, how many acres do you irrigate and which enterprise do you irrigate?

	(i) **Enterprise type**	(ii) **Approx. Area (acres)**
Side roll 1		
Solid set 2		
Big guns 3		
Hand lines 4		
Other 5		

16) What is the length of your irrigation season in months?

MONTHS ____________

DK/NA 9999

17) How many times per week do you irrigate?

NUMBER ____________

DK/NA 9999

Exhibit A.2 (continued)

18) What water source do you use?

RIVER (SURFACE WATER) 1
GROUND WATER 2
OTHER ______ 3
DK/NA 9999

19) How much water do you use?

ACRE/INCH or ACRE/FT ______
DK/NA 9999

20a) Do you manage any forest stands?

YES 1
NO .... 2 **(GO TO 22)**
DK/NA 9999 **(GO TO 22)**

20b) How many acres of trees are in the following age classes?

Age (years)	Acres	DK/NA
i) 0-5		9999
ii) 6-15		9999
iii) 16-45		9999
iv) 46-80		9999
v) 81-195		9999

21a) Do you plan to cut your trees?

YES 1
NO .... 2 **(GO TO 23)**
DK/NA 9999 **(GO TO 23)**

21b) At what age do you plan to cut your trees?

AGE (YEARS) ______
DK/NA 9999

Exhibit A.2 (continued)

22) Approximately what percentage of your household income is generated through the agricultural/forestry enterprises that you have described?

PERCENT ______________
DK/NA 9999

Thank you for time that you have taken in participating in the questionnaire, do you have any additional comments or questions?

A.2 Summary of Survey Results

A.2.1 Response Rates

A total of 90 households were selected to participate in the personal interview survey. 37 households from E40; 20 from F2[82]; 8 from RR10; 1 from RR2; 24 from RR5. The break down of responses is presented in figure A.1. 4% of respondents who asked to be re-contacted by phone were unavailable on subsequent phone attempts and were classified as "out".

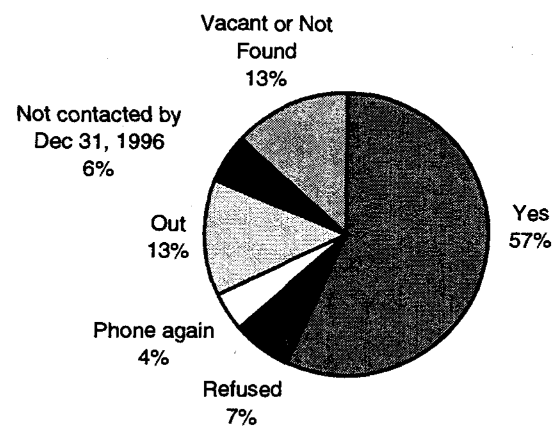

Figure A.1. Break Down of Sample by Participation

Of those households successfully contacted by the enumerators and who gave a definitive response i.e. refusal or acceptance, 89% agreed to participate in the study and

[82] A smaller sample size was chosen for this strata to reduce survey costs. The primary strata of interest are E40, RR10, RR5 and RR2.

11% refused. A total of 21 questionnaires were completed in the E40 zoning designation however, one was un-useable. In zone F2, 11 questionnaires were completed; in RR10, 3 questionnaires were completed and in the RR5 and RR2 zones there were 15 and 1 completed questionnaires respectively.

A.2.2 Land Use

A.2.2.1 Land Use by Zone

A break down of land use into the percentage grazed, forested, used as crop land or other is presented in figures A.2 to A.5 by zone type. The classification "other" is all land that is not used for raising livestock, crops or timber and includes land used for a home site and yard or land used for an unspecified purpose. Survey results indicate that a greater proportion of E40 and F2 zoned land is used for non-residential purposes. 100% of land surveyed in zone RR2 was classified as "other".

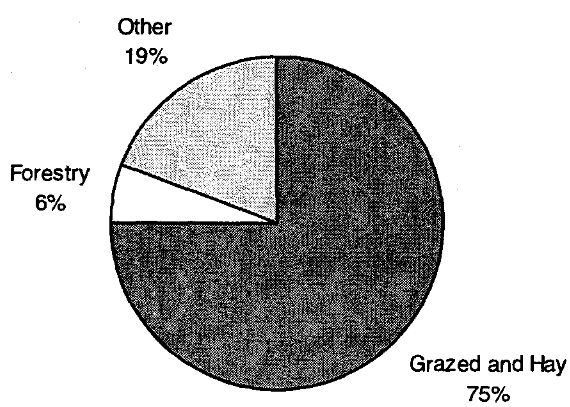

Figure A.2. Land Use in Zone E40

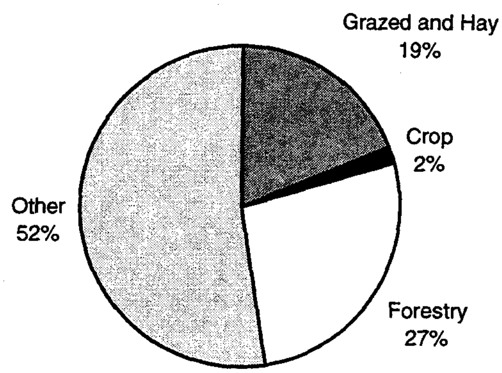

Figure A.3. Land Use in Zone F2

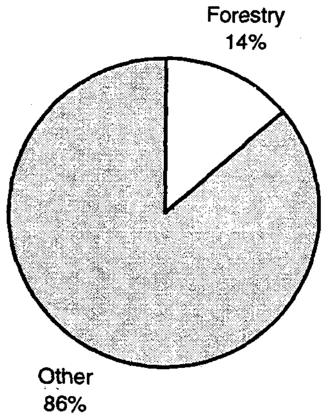

Figure A.4 Land Use in Zone RR10

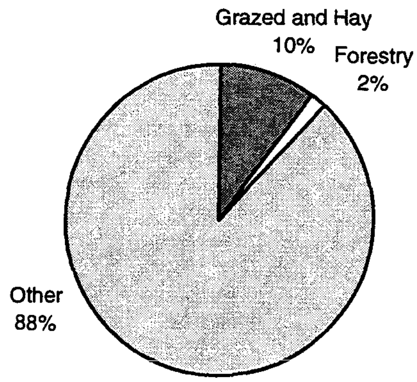

Figure A.5 Land Use in Zone RR5

A.2.2.2 Land Use by Size of Holding

A break down of land use into the percentage grazed, forested, used as crop land and other is presented in Table A.4 by size of holding. Two size classes of holdings less than 25 acres and holdings greater than 25 acres across all zone types are considered.

Table A.4. Land Use by Size of Holding

	Total land Acres	Grazed and Hayed Acres	Crop Acres	Forestry Acres	Other Acres
Holdings of less than 25 acres	242.76	51.00	2.00	67.00	122.76
Holdings of greater than 25 acres	733.50	526.00	0.00	9.00	198.50

Survey results indicate that a greater percentage of land holdings 25 acres or larger are devoted to timber or forestry activities (figure A.6) than is the case with land holdings less than 25 acres in size (figure A.7). There is a strong positive correlation of 0.76 between the total acres owned or managed by a household and the percentage of income generated from livestock, crops or timber that supports these results.

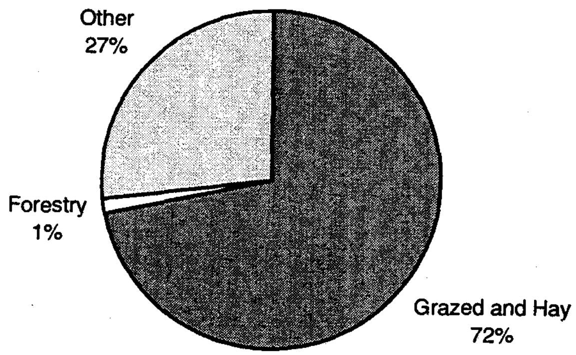

Figure A.6. Land Use of Holdings greater than 25 acres

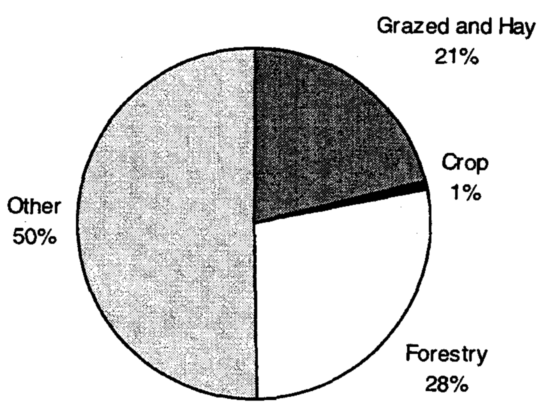

Figure A.7. Land Use of Holdings less than 25 acres

A.2.3 Livestock Production

47% of households surveyed raised livestock and 53% did not. A break-down of livestock holdings by households in each zone indicates that 65% of households surveyed have livestock in zone E40, 55% in zone F2, 0% in zone RR10, 29% in zone RR5 and 0% in zone RR2. A break-down of results by lot size indicates that 38% of lots less than 25 acres raise livestock and 80% of lots greater than 25 acres raise livestock. Overall, 13 households kept cattle, 13 kept horses, 4 kept pigs, 5 kept poultry, game or exotic birds, 6 kept goats and 1 bred dogs on a commercial basis.

The average herd size across the watershed was 15 head. The greatest frequency of cattle holdings occur between 0 to 5 head, table A.5 and figure A.8. It is possible that cattle holdings are bi-modal with a common herd size for smaller holdings and another for larger holdings. This result is suggested when holdings are analyzed according to size classification, figures A.9 and A.10. Holdings less than 25 acres had an average of 4 cows. Holdings greater than 25 acres had an average of 23 cows.

Table A.5. Frequency Distribution of Herd Size for all Holdings

Number of cattle	Frequency
5	7
10	1
20	3
30	0
40	0
50	0
60	2
>60	0

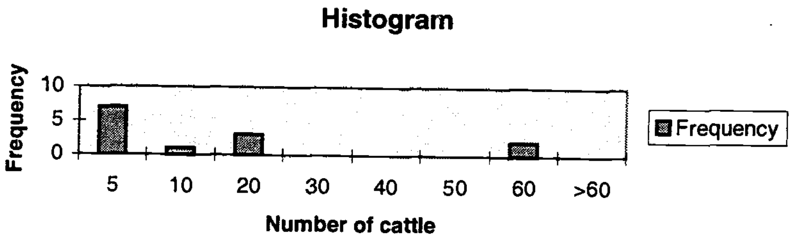

Figure A.8. Histogram of Herd Size - All Holdings

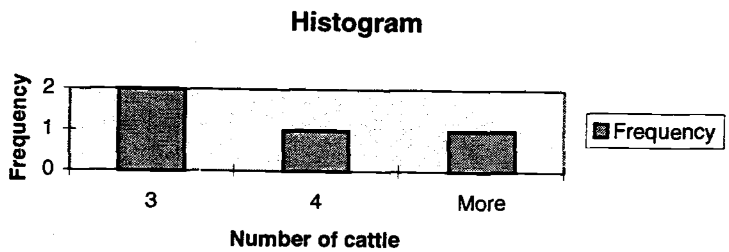

Figure A.9. Histogram of Herd Size for Holdings less than 25 acres

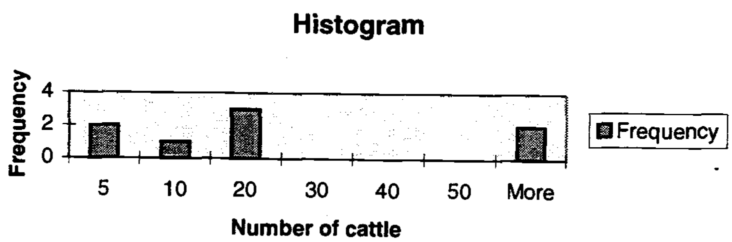

Figure A.10. Histogram of Herd Size for Holdings greater than 25 acres

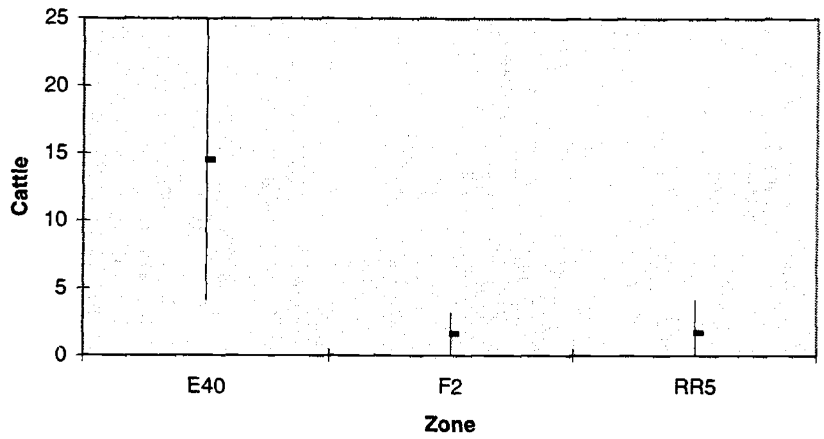

Figure A.11 90% Confidence Estimates for Mean Herd Size by Zone

A.2.3.1 Stocking Density

Stocking density in terms of animal unit months was calculated by zone type and by holding size. All grazing animals were converted into cow unit equivalents and divided by the grazed acreage to calculate stocking density. The average stocking density over all holdings was 0.94 cows/acre. Table A.6 and figure A.12 present the stocking densities expected on land holdings less than 25 acres. The mean stocking density on holdings less than 25 acres was 1.15 cows/acre. Table A.7 and figure A.13 present the stocking densities expected on land holdings greater than 25 acres. The mean stocking density on units greater than 25 acres was 0.65 cows/acre, figure A.14. The hypothesis that the stocking density on lots less than 25 acres was no different to the stocking density on lots greater than 25 acres could not be refuted. The Mean Stocking Density on E40 land was 0.77 cows/acre, figure A.15. The mean stocking density on F2 was 1.61

cows/acre, figure A.16. The mean stocking density on RR5 was 0.55 cows/acre, figure A.18.

Table A.6. Frequency Table of Stocking Density on Lots Less than 25 Acres

Cows/acre	Frequency
0.5	3
1.0	4
1.5	2
2.0	1
More	1

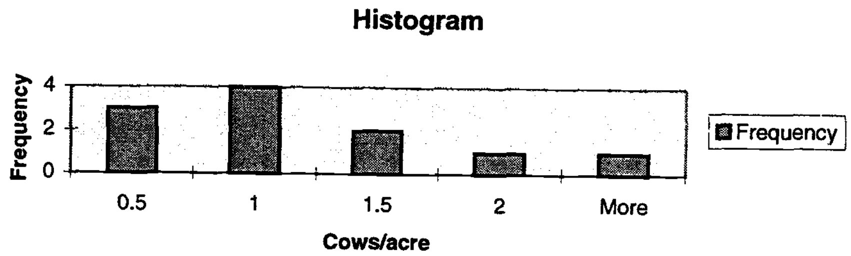

Figure A.12. Histogram of Stocking Density on Lots Less than 25 Acres

Table A.7. Frequency Table of Stocking Density on Lots Greater than 25 Acres

Cows/acre	Frequency
0.5	4
1.0	2
1.5	1
2.0	1
More	0

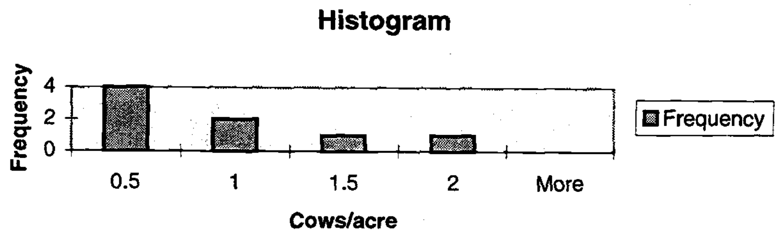

Figure A.13. Histogram of Stocking Density on Lots Greater than 25 Acres

Table A.8. Two Tailed t-test at 95% Confidence, to see if Stocking Density is Different between Holdings less than 25 acres and Holdings greater than 25 Acres that have Livestock

Ho: $\bar{x}_1 - \bar{x}_2 = 0$

Ha: $\bar{x}_1 - \bar{x}_2 \neq 0$

	Stocking density on holdings >25 acres	Stocking Density on Holdings < 25 acres
Mean	0.65	1.15
Variance	0.26	1.62
Observations	8.00	11.00
Hypothesized Mean Difference	0.00	
df	14.00	
t Stat	-1.16	
P(T<=t) one-tail	0.13	
t Critical one-tail	1.76	
P(T<=t) two-tail	0.26	
t Critical two-tail	2.14	

$t_{\alpha/2} = \pm 2.14$ and t-stat =-1.16; therefore we cannot reject Ho as $|\text{t-stat}| \leq |t_{\alpha/2}|$. This means that we cannot refute the hypothesis that there is no difference between the stocking density on holdings grater than 25 acres and holdings less than 25 acres.

Table A.9. Frequency Table of Stocking Density on E40 Lots

Cows/acre	Frequency
0.5	5
1.0	4
1.5	2
2.0	2
More	0

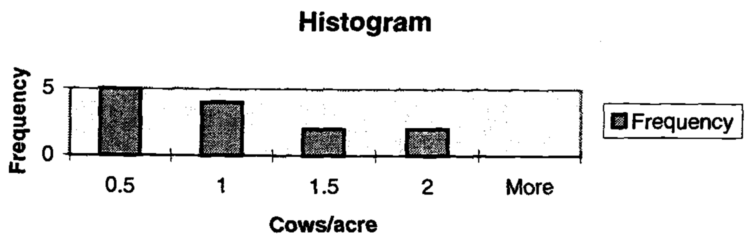

Figure A.14. Histogram of Stocking Density on E40 Lots

The percentage of grazing area in zone E40 within each stocking density is displayed in figure A.15.

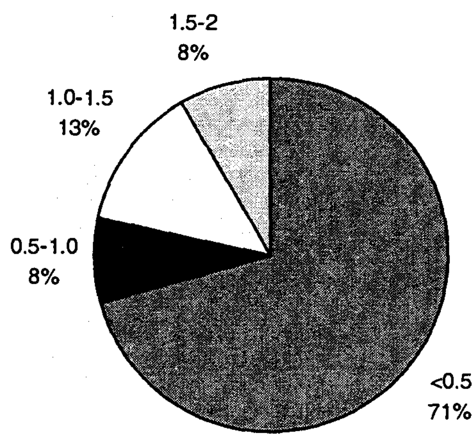

Figure A.15. Percentage of Grazing Area in Zone E40 by Stocking Density

Table A.10. Frequency Table of Stocking Density on F2 Lots

Cows/acre	Frequency
0.5	1
1.0	2
1.5	0
2.0	0
More	1

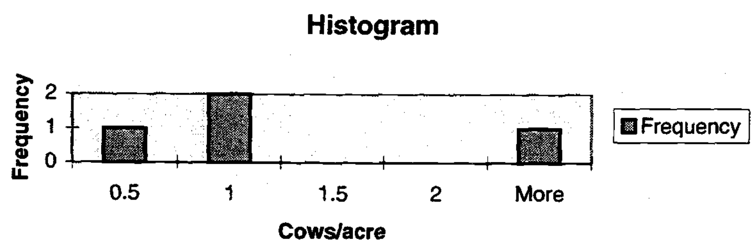

Figure A.16. Histogram of Stocking Density on F2 Lots

The percentage of grazing area in zone F2 within each stocking density is displayed in Figure A.17.

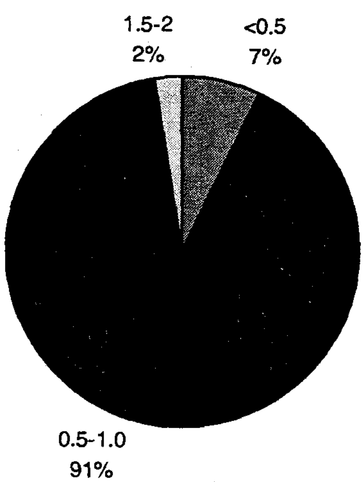

Figure A.17. Percentage of Grazing Area in Zone F2 by Stocking Density

Table A.11. Frequency Table of Stocking Density on RR5 Lots

Cows/acre	Frequency
0.5	1
1.0	1
1.5	1
2.0	0
More	0

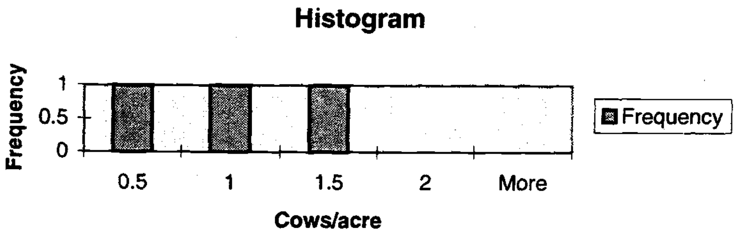

Figure A.18 Histogram of Stocking Density on RR5 Lots

The percentage of grazing area in zone RR5 within each stocking density is displayed in figure A.19.

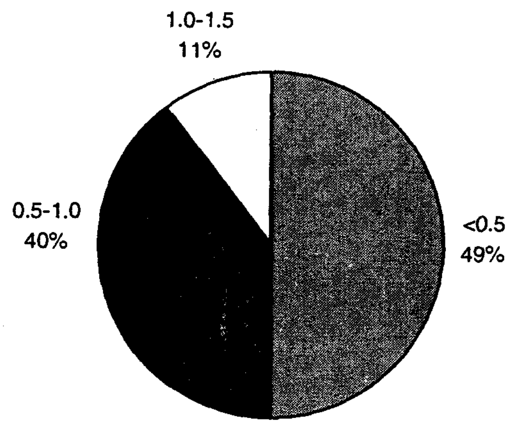

Figure A.19. Percentage of Grazing Area in Zone RR5 by Stocking Density

A.2.4 Forage Production

Approximately 25% of respondents produced hay. In every case, households producing hay also produced livestock. Seventy five percent of the producers were in the E40 zone and 25% in F2. 18% of the total land area surveyed was hayed. 32% of the total acreage used to raise livestock was also used in hay production. 33% of respondents cut raked and baled their own hay, table A.12. 33% paid an average of $32.50/ton for a local contractor to harvest the hay. The remaining producers negotiated payment in kind; for example cattle grazing or a percentage of the hay crop. One producer did not recollect the price that was customarily charged for harvesting hay.

Table A.12 Payment for Harvesting Hay

Payment for Harvesting
75% hay
$35/ton
Unknown
Relative
For cattle grazing
$30/ton
$35/ton
$30/ton

The average hay yield was 1.55 tons/acre. Table A.13 and figure A.20 present the distribution of hay yields. Forty one percent of hayed acreage generated yields of 1 ton per acre or less, figure A.21.

Table A.13. Frequency Distribution of Hay Yields

Tons/acre	Frequency
1.0	10
1.5	1
2.0	1
2.5	2
More	1

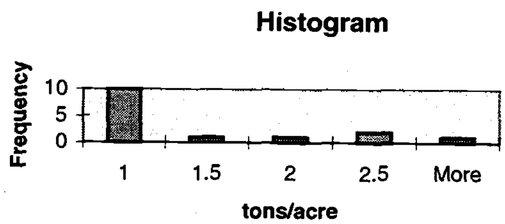

Figure A.20. Histogram of Hay Yield

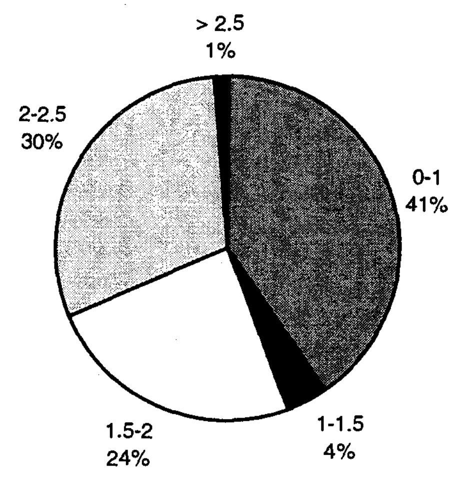

Figure A.21. Percent of Total Hayed Acreage in each Yield Class

A.2.5 Cropping, Forestry and Other Activities

One respondent engaged in cropping activities. Cropping activities covered a very small percentage of the total land area surveyed. 20% of respondents engaged in forestry activities. Of these, 70% indicated that they expected to cut their trees at some date in the future. The most common expected harvest age was between 40 and 60 years old.

16% of respondents indicated that they engaged in irrigation activities. No respondent could account for the amount of irrigation water that they used. 50% of respondents did not know how many times a week they irrigated. The remaining 50% irrigated between 4 and 5 times a week on average. The average length of the irrigation season was 25 weeks. Approximately 38% of respondents that irrigated used the water to irrigate their lawns, an additional 38% used irrigation water on pasture, 12% irrigated hay and 12% irrigated shrubs. Table A.14 indicates the percentage of the total land area surveyed that was irrigated.

Table A.14. Percent of Survey Area that was Irrigated

Zone	Percentage of Total Area that was Irrigated
E40	10.9
F2	5.3
RR10	6.4
RR5	3.5

A.2.6 Income Generation

Twenty five percent of the households surveyed indicated that their livestock and timber or land rental activities contributed to their income. Estimates of the percentage of income that these activities generated ranged from 1% to 50% of total household income. There is a strong positive correlation of 0.76 between total land holdings and percentage of household income generated through production activities. A one tailed t-test is conducted at 95% and 90% confidence levels, to see if there is a difference in the mean percentage of income generated on holdings less than 25 acres and greater than 25 acres, table A.15. Only those holdings that reported income generation were considered. Results suggest that there is a statistically significant difference in income generated on lots in these size categories.

Table A.15 Difference in Income Generated on lots > 25 acres and Lots < 25 Acres

Ho: $\bar{x}_1 - \bar{x}_2 = 0$
Ha: $\bar{x}_1 - \bar{x}_2 < 0$

	Percent income on holdings > 25 acres	Percent income on holdings <25 acres
Mean	16.50	2.14
Variance	468.00	21.97
Observations	8.00	14.00
Hypothesized Mean Difference	0.00	
df	7.00	
t Stat	1.85	
P(T<=t) one-tail	0.05	
t Critical one-tail	1.89	
P(T<=t) two-tail	0.10	
t Critical two-tail	2.36	

$t_{\alpha} = 1.89$ and t-stat = 1.85; therefore we cannot reject Ho at the 95% level as t-stat $< t_{\alpha}$.

At the 90% level of confidence, $t_{\alpha} = 1.41$ and t-stat = 1.85; therefore we can reject Ho at the 90% level as t-stat $> t_{\alpha}$.

Appendix B

Model Data

Table B.1. Production Land Area and Length of Riparian Frontage by Land Type

	Land Area (acres)[1]	Riparian Frontage (feet)[1]	Total Frontage Modeled (feet)[2]
F1PUB River Property	17831	388727	111000
F1PRI River Property	48892	1071573	226000
F2 River Property	1809	99718	4400
RDEV River Property	14	3004	4000
RR River Property	699	47226	47000
OTH River Property	352	11397	8000
E40 River Property	2525	124849	77000
F1PUB Non-River Property	4935	N/A	N/A
F1PRI Non-River Property	25259	N/A	N/A
F2 Non-River Property	5337	N/A	N/A
RDEV Non-River Property	304	N/A	N/A
RR Non-River Property	1875	N/A	. N/A
OTH Non-River Property	50	N/A	N/A
E40 Non-River Property	3091	N/A	N/A

[1] Total river frontage calculated using a GIS. This total includes frontage on tributaries not included in the stream temperature modeling effort.

[2] Total frontage modeled using Heat Source. This frontage length may differ from the true frontage length in column two for two reasons. Firstly, not all tributaries were included in the modeling effort. Secondly model runs were conducted over 1000 to 2000 feet which resulted in some slight overestimates of riparian frontage for some land classes.

Exhibit B.1. Mint Production Enterprise Budget

Enterprise Budget

Peppermint Production, Mohawk Area

Adapted from:
Taylor, M. L., Gingrich, G., and M. Mellbye. January 1992. "Enterprise Budget. Peppermint Production, Willamette Valley Region". EM 8489. Oregon State University Extension Service.
By:
Siân Mooney, Ross Penhalligon, Brenda Turner.

General

This enterprise budget estimates costs and returns associated with an established peppermint acreage in the Mohawk watershed. Figures identified by *italic* type are those costs not used in the economic model developed in this dissertation. The established stand is assumed to have a five year life, including an establishment year. The budget is a general guide to actual costs and does not represent a particular farm. Typical cultural practices are reported below however these are not the only production methods that could be used. **To date local growers have *not* been consulted regarding the accuracy of this budget.** Establishment costs were calculated in an earlier budget "Peppermint Establishment, Mohawk Area"; based on Taylor, M. L. Gingrich, G. and M. Mellbye. January 1992. "Enterprise Budget. Peppermint Establishment, Willamette Valley Region". EM 8490. Oregon State University Extension Service.

Land and Irrigation Equipment

This budget is based on a 50 acre parcel of peppermint produced on a 100 acre farm. It is assumed the additional 50 acres are in rotation between sweet corn, beans and wheat. A yield of 80lbs/acre is assumed sold at the five year average price of $14.11/lb. Yield may differ to that used in this budget according to variations in soil type and management practices. Annual costs for land are based on the area's rental value of $125/acre. Irrigation equipment costs are based upon side-roll systems with an estimated annual fixed cost of $30.00 per acre. Operating costs are based on electricity, repair and maintenance costs of $1.61 per acre-inch of water applied.

Establishment Charges

An annual non cash fixed cost of $164.01 is included to cover the expenses of establishing the peppermint crop.

Exhibit B.1. (continued)

Labor

Hired labor is paid at $7 per hour; owner labor is paid at $11 per hour. These figures include worker's compensation, unemployment insurance, and other labor overhead expenses. Labor is treated as a cash variable cost in this budget.

Interest

Interest on operating funds is charged at 10 percent and treated as a cash variable expense. Intermediate and long term capital is assumed to be provided by the operator, and is also charged at 10 percent.

Machinery and Equipment

The machinery and equipment reflect the likely machinery complement of a 100 acre mixed crop farm in the Mohawk watershed region. Machinery purchase costs were obtained from cost estimates provided by farm equipment dealers in the Eugene/Corvallis area. All estimates reflect prices as of March 1996. All machinery and equipment is assumed to be half depreciated. Estimated machinery life is obtained from Rotz and Bowers. Field efficiency and speed are obtained from American Society of Agricultural Engineers standards 1991. Repair and depreciation factors are obtained from Rotz and Bowers. Gasoline costs $1.05/gallon and diesel fuel costs $1.00/gallon.

Operations

The cultural operations are listed approximately in the order in which they are performed.

Propane burn: Post harvest, a propane burn is conducted followed by pest control and irrigation.

Growing Season: In the growing season, the crop is fertilized, pests are treated and another burning takes place.

Harvest: Crop is custom harvested.

Miscellaneous: It is assumed that the pickup truck is used for about 10,000 miles/year in business related to farm enterprises on the 100 acre area. A charge of 100 miles per acre of peppermint established is charged to the peppermint enterprise.

Exhibit B.1. (continued)

== ECONOMIC COSTS and RETURNS ==

Owner Budget
by Operation

PEPPERMINT, PRODUCTION YEAR
50 acres Mohawk Watershed

GROSS INCOME Description	Quantity	Unit	$ / Unit	Total
PEPPERMINT	80.000	lb	14.1100	1128.80
Total GROSS Income				**1128.80**

VARIABLE COST Description			Labor	Machinery	Materials	Total
DORMANT SEASON						
PROPANE BURN (F)	Operation		1.66	1.10	15.60	18.36
PROPANE	24.000 gal	x		0.650 =	15.60	
FALL HERBICIDE	Operation		0.00	0.00	41.30	41.30
SINBAR	1.500 lb	x		24.200 =	36.30	
CUSTOM SPRAY	1.000 acre	x		5.000 =	5.00	
ROOT BORER	Operation		3.50	0.00	9.00	12.50
LORSBAN	0.250 gal	x		36.000 =	9.00	
IRRIGATE-FALL 2"	Operation		7.00	0.00	3.22	10.22
IRRIG OPERATION	2.000 inch	x		1.610 =	3.22	
DORMANT HERB	Operation		0.00	0.00	36.88	36.88
GOAL	0.375 gal	x		65.000 =	24.37	
GRAMOXONE	1.250 pint	x		6.000 =	7.50	
CUSTOM SPRAY	1.000 acre	x		5.000 =	5.00	
Total DORMANT SEASON						**119.26**
GROWING SEASON						
SPRING HERB SPR	Operation		0.00	0.00	20.44	20.44
SINBAR	0.700 lb	x		24.200 =	16.94	
CUSTOM SPRAY	0.700 acre	x		5.000 =	3.50	
SPR FERTILIZER	Operation		0.00	0.00	46.63	46.63
10-20-20	0.225 ton	x		185.000 =	41.62	
CUSTOM APPLIC	1.000 acre	x		5.000 =	5.00	
INSECTICIDE SPR	Operation		0.00	0.00	14.85	14.85
DYFONATE	0.300 gal	x		39.500 =	11.85	
CUSTOM APPLIC	0.600 acre	x		5.000 =	3.00	
PROPANE BURN (S)	Operation		1.66	1.10	19.50	22.26
PROPANE	30.000 gal	x		0.650 =	19.50	
FERTILIZE	Operation		13.94	5.76	25.00	44.71
NITROGEN	100.000 lb.	x		0.250 =	25.00	
IRRIGATION 20"	Operation		70.00	0.00	82.20	152.20
NITROGEN	200.000 lb.	x		0.250 =	50.00	
IRRIG OPERATION	20.000 inch	x		1.610 =	32.20	
HARV & DISTILL	Operation		0.00	0.00	192.50	192.50
HARV & DISTILL	70.000 lb	x		2.750 =	192.50	
Total GROWING SEASON						**493.58**

Exhibit B.1. (continued)

MISCELLANEOUS					
GENERAL OVERHEADMINT					25.00
HOEING	Operation	14.00	0.00	0.00	14.00
MITE CONTROL	Operation	0.00	0.00	15.80	15.80
COMITE		1.500 pint x	8.530 =	12.79	
CUSTOM APPLIC		0.600 acre x	5.000 =	3.00	
CUTWORM CONTROL	Operation	0.00	0.00	18.05	18.05
ORTHENE		1.332 lb x	9.790 =	13.04	
CUSTOM APPLIC		1.000 acre x	5.000 =	5.00	
PICKUP 4WD	Operation	27.50	14.55	0.00	42.05
Total MISCELLANEOUS					**114.89**
Total VARIABLE COST					**727.73**

Break-Even Price, Total Variable Cost $ 9.09 per lb of PEPPERMINT

GROSS INCOME minus VARIABLE COST **401.07**

FIXED COST Description	**Unit**	**Total**
AMORT ESTAB COSTMINT	acre	164.01
IRR.SYS.FIXED MINT	acre	30.00
Machinery and Equipment	Acre	32.67
Land	*Acre*	*125.00*
Total FIXED Cost		**351.68**

Break-Even Price, Total Cost $ 13.49 per lb of PEPPERMINT

Total of ALL Cost **1079.41**

NET PROJECTED RETURNS **49.39**

Exhibit B.2. Sweet Corn Enterprise Budget

Enterprise Budget

Sweet Corn, Mohawk Area

Adapted from:
Lisec, B., McGrath, D., and L. Kerns. August 1995. "Enterprise Budget. Sweet Corn, Willamette Valley Region". EM 8376. Oregon State University Extension Service.
By:
Siân Mooney, Ross Penhalligon, Brenda Turner.

General

This enterprise budget estimates costs and returns associated with producing sweet corn in the Mohawk watershed. Costs highlighted by *italic* type were not included in costs estimates generated for the model in this dissertation. It is a general guide to actual costs and does not represent a particular farm. Typical cultural practices are reported below however these are not the only production methods that could be used. **To date local growers have *not* been consulted regarding the accuracy of this budget.**

Land and Irrigation Equipment

This budget is based on a 50 acre parcel of sweet corn in rotation with wheat and beans on a 100 acre farm. A yield of 9 tons/acre is assumed to be sold at the five year average price of $82.31/ton. Yield may differ from that used in this budget according to variations in soil type and management practices. Annual costs for land are based on the area's rental value of $100/acre. Irrigation equipment costs are based on a good used system with a $15/acre/year repair and maintenance cost. The irrigation system is composed of "overhead" types of systems such as travelers, linear pivots and/or permanent big guns. Pumping expenses are based on a electricity charge of $2.25/inch of water applied during the growing season.

Labor

Hired labor is paid at $7 per hour; owner labor is paid at $11 per hour. These figures include worker's compensation, unemployment insurance, and other labor overhead expenses. Labor is treated as a cash variable cost in this budget.

Interest

Interest on operating funds is charged at 10 percent and treated as a cash variable expense. Intermediate and long term capital is assumed to be provided by the operator, and is also charged at 10 percent.

Exhibit B.2. (continued)

Machinery and Equipment

The machinery and equipment used in this budget reflect the likely machinery complement of a 100 acre mixed crop farm in the Mohawk watershed region. Machinery purchase costs were obtained from cost estimates provided by farm equipment dealers in the Eugene/Corvallis area. All estimates reflect prices as of March 1996. All machinery and equipment is assumed to be half depreciated. Estimated machinery life is obtained from Rotz and Bowers. Field efficiency and speed are obtained from American Society of Agricultural Engineers standards 1991. Repair and depreciation factors are obtained from Rotz and Bowers. Gasoline costs $1.05/gallon and diesel fuel costs $1.00/gallon.

Operations

The cultural operations are listed approximately in the order in which they are performed.

Pre Plant and Plant: These operations consist of eradicating and turning under the cover crop and preparing the field for planting in May or June. Herbicides are applied before planting, followed by fertilizer and ten pounds of seed per acre.

Harvest: It is assumed that the corn is custom harvested at a cost of $56/acre. Two grain trucks are used to haul the harvested corn to the cannery.

Post Harvest: After harvest, lime is applied every 4 years and a soil test is taken every other year on the 50 acre plot. It is assumed that the charge for a soil test is $19.50.

Post Harvest: Corn stalks are disked and the ground prepared for the winter cover crop.

Exhibit B.2. (continued)

== ECONOMIC COSTS and RETURNS ==

Owner Budget
by Operation

Willamette Valley Sweet Corn Production
50 Irrigated Acres

GROSS INCOME Description		Quantity	Unit	$ / Unit	Total
SWEET CORN	PROCESSD	9.000	Ton	82.3100	740.79
Total GROSS Income					**740.79**

VARIABLE COST Description		Labor	Machinery	Materials	Total
PRE PLANT					
CHISEL	Operation	1.83	4.80	0.00	6.63
DISC-1	Operation	1.52	4.16	0.00	5.68
DRAG AND ROLL	Operation	0.86	1.86	0.00	2.72
PRE PLANT HERB	Operation	1.38	2.72	38.46	42.55
DUAL HERB	2.000 Qt	x	16.650 =	33.30	
ATRAZINE 4L	1.500 Qt	x	3.437 =	5.15	
INC HERB	Operation	0.36	1.38	0.00	1.74
Total PRE PLANT					**59.33**
PLANTING					
PLANTING	Operation	4.31	7.49	67.78	79.58
SEED SW CORN	10.000 Lb.	x	3.660 =	36.60	
NITROGEN (UREA)	108.000 Lb.	x	0.112 =	12.09	
PHOSPHORUS	134.000 Lb.	x	0.115 =	15.41	
POTASH	36.000 Lb.	x	0.084 =	3.02	
SULPHUR	26.000 Lb.	x	0.025 =	0.65	
Total PLANTING					**79.58**
PRE HARVEST					
FERTILIZE	Operation	3.29	5.36	36.51	45.16
NITROGEN (UREA)	326.000 Lb.	x	0.112 =	36.51	
IRRIGATION	Operation	35.00	0.00	37.50	72.50
IRG MAINT REPRS	1.000 Acre	x	15.000 =	15.00	
ELECTRICITY	10.000 Inch	x	2.250 =	22.50	
POST PLANT HERB	Operation	1.38	0.94	6.88	9.20
ATRAZINE 4L	2.000 Qt	x	3.437 =	6.87	
TOPPING	Operation	0.00	0.00	7.00	7.00
TOPPING SW CORN	1.000 Acre	x	7.000 =	7.00	
Total PRE HARVEST					**133.86**
HARVEST					
HARVEST	SW CORN				56.00
HAUL CORN	Operation	6.72	25.25	0.00	31.97
HAUL CORN-1	Operation	7.06	30.30	0.00	37.36
Total HARVEST					**125.33**

Exhibit B.2. (continued)

POST HARVEST					
SOIL TEST	Operation	0.00	0.00	9.75	9.75
SOIL TEST	0.500 Test x		19.500 =	9.75	
LIME	Operation	0.00	0.00	26.25	26.25
CUSTOM LIMING	0.625 Ton x		42.000 =	26.25	
DISC	Operation	1.01	2.77	0.00	3.79
PLANT COVER CROP	Operation	3.27	2.55	12.50	18.31
SEED, COVER CROP	1.000 Acre x		12.500 =	12.50	

Total POST HARVEST					**58.10**
MISCELLANEOUS					
PICKUP	Operation	2.92	2.16	0.00	5.07
ATV	Operation	7.00	2.20	0.00	9.20

Total MISCELLANEOUS					**14.28**
Interest - OC Borrowed					*31.16*
					===========
Total VARIABLE COST					**501.64**

Break-Even Price, Total Variable Cost $ 55.73 per Ton of SWEET CORN

GROSS INCOME minus VARIABLE COST	**239.15**

FIXED COST Description	**Unit**	**Total**
IRR SYS FIXED SW CORN	Acre	12.18
Machinery and Equipment	Acre	133.72
Land	Acre	*100.00*
		===========
Total FIXED Cost		**245.90**

Break-Even Price, Total Cost $ 83.05 per Ton of SWEET CORN

Total of ALL Cost	**747.53**

NET PROJECTED RETURNS -6.74

Exhibit B.3. Enterprise Budget for Bush Beans

Enterprise Budget

Bush Beans, Mohawk Area

Adapted from:
Lisec, B. McGrath, D. and L. Kerns. August 1995. "Enterprise Budget. Bush Beans, Willamette Valley Region". EM 8380. Oregon State University Extension Service.

By:
Siân Mooney, Ross Penhalligon, Brenda Turner.

General

This enterprise budget estimates costs and returns associated with producing bush beans in the Mohawk watershed. Costs identified in *italics* were not used to generate enterprise costs in the economic model used in this dissertation. It is a general guide to actual costs but does not represent a particular farm. Typical cultural practices are reported below however these are not the only production methods that could be used. **To date local growers have *not* been consulted regarding the accuracy of this budget.**

Land and Irrigation Equipment

This budget is based on a 50 acre parcel of bush beans in rotation with wheat and sweet corn on a 100 acre farm. A yield of 3.25 tons of #1 and #2 quality beans and 2.6 tons of #3 and #4 quality beans is assumed sold at the five year average price of $258/ton and $120/ton respectively. Yield may differ from that used in this budget according to variations in soil type and management practices. Annual costs for land are based on the area's rental value of $100/acre. Irrigation equipment costs are based on a good used system with a $15/acre/year repair and maintenance cost. The irrigation system is composed of "overhead" types of systems such as travelers, linear pivots and/or permanent big guns. Pumping expenses are based on a electricity charge of $2.25/inch of water applied during the growing season.

Labor

Hired labor is paid at $7 per hour; owner labor is paid at $11 per hour. These figures include worker's compensation, unemployment insurance, and other labor overhead expenses. Labor is treated as a cash variable cost in this budget.

Interest

Interest on operating funds is charged at 10 percent and treated as a cash variable expense. Intermediate and long term capital is assumed to be provided by the operator, and is also charged at 10 percent.

Exhibit B.3. (continued)

Machinery and Equipment

The machinery and equipment used in this budget reflect the likely machinery complement of a 100 acre mixed crop farm in the Mohawk watershed region. Machinery purchase costs were obtained from cost estimates provided by farm equipment dealers in the Eugene/Corvallis area. All estimates reflect prices as of March 1996. All machinery and equipment is assumed to be half depreciated. Estimated machinery life is obtained from Rotz and Bowers. Field efficiency and speed are obtained from American Society of Agricultural Engineers standards 1991. Repair and depreciation factors are obtained from Rotz and Bowers. Gasoline costs $1.05/gallon and diesel fuel costs $1.00/gallon.

Operations

The cultural operations are listed approximately in the order in which they are performed.

Pre Plant and Plant: These operations consist of eradicating and turning under the cover crop and preparing the field for planting. Herbicides are applied before planting, followed by fertilizer and treated seed is applied at a rate of 100lbs per acre. It is assumed that growers use seeding rates of 8-12 seeds per foot in rows 15 to 30 inches apart. The seedbed is then rolled and a postplant herbicide is applied to control weeds.

Pre Harvest: After planting, the field receives an average of six 1.5 inch waterings and additional nitrogen to promote growth. Weeds are controlled with a hoe or spot sprayer.

Harvest: It is assumed that the beans are custom harvested at a cost of $150/acre. Ten percent of the harvest is culled. Two grain trucks are used to haul the harvest to the cannery.

Post Harvest: After harvest, lime is applied every 4 years and a soil test is taken every other year on the 50 acre plot. It is assumed that the charge for a soil test is $19.50.

Post Harvest: The field is disked and a cover crop is planted.

Miscellaneous: It is assumed that the pickup truck is used for about 10,000 miles/year in business related to farm enterprises on the 100 acre area. A charge of 100 miles per acre of beans in production is charged to the bean enterprise.

Exhibit B.3. (continued)

== ECONOMIC COSTS and RETURNS ==
Owner Budget
by Operation
Mohawk Valley Bush Bean Production
50 Irrigated Acres

GROSS INCOME Description	Quantity	Unit	$ / Unit	Total
BEANS #1 & 2 50%	3.250	Ton	258.0000	838.50
BEANS #3 & 4 40%	2.600	Ton	120.0000	312.00
Total GROSS Income				**1150.50**

VARIABLE COST Description		Labor	Machinery	Materials	Total
PRE PLANT					
CHISEL	Operation	1.83	4.80	0.00	6.63
DISC	Operation	1.01	2.77	0.00	3.79
ROTO-TILL	Operation	0.36	1.38	0.00	1.74
PRE-PLANT HERB	Operation	1.38	1.81	39.04	42.23
DUAL HERB	2.000 Qt x		16.650 =	33.30	
TREFLAN	1.500 Pint x		3.825 =	5.73	
INCORPORATE HERB	Operation	1.00	1.77	0.00	2.77
PRE-PLANT FERT	Operation	4.44	3.44	31.37	39.24
NITROGEN (UREA)	109.000 Lb. x		0.112 =	12.20	
PHOSPHORUS	128.000 Lb. x		0.115 =	14.72	
POTASH	43.000 Lb. x		0.084 =	3.61	
SULPHUR	33.000 Lb. x		0.025 =	0.82	
INCORP FERT	Operation	0.86	0.85	0.00	1.70
Total PRE PLANT					**98.10**
PLANTING					
PLANTING	Operation	4.31	7.49	146.35	158.15
SEED GR BEAN	100.000 Lb. x		1.280 =	128.00	
RIDOMIL	1.000 Pint x		18.350 =	18.35	
ROLL SEED BED	Operation	0.86	0.85	0.00	1.70
POST PLANT HERB	Operation	1.38	0.94	12.09	14.41
BASAGRAN	1.500 Pint x		8.060 =	12.09	
Total PLANTING					**174.27**
PRE HARVEST					
FERTILIZE	Operation	4.44	3.44	7.28	15.16
NITROGEN (UREA)	65.000 Lb. x		0.112 =	7.28	
BLOOM SPRAY	Operation	1.38	0.94	27.11	29.43
ROVRAL 50WP	1.000 Lb. x		21.800 =	21.80	
SEVIN	1.250 Lb. x		4.250 =	5.31	
BLOOM SPRAY-1	Operation	1.38	0.94	2.81	5.13
DIAZINON 50W	0.750 Lb. x		3.750 =	2.81	
SPOT SPRAY	Operation	1.75	0.28	1.20	3.23
ROUND-UP	0.250 Apl x		4.800 =	1.20	
POST PLANT HERB	Operation	2.07	1.42	18.14	21.62
BASAGRAN	2.250 Pint x		8.060 =	18.13	
IRRIGATION	Operation	42.00	0.00	35.25	77.25
IRG MAINT REPRS	1.000 Acre x		15.000 =	15.00	
ELECTRICITY	9.000 Inch x		2.250 =	20.25	
HOE	Operation	14.00	0.00	0.00	14.00
Total PRE HARVEST					**165.82**

Exhibit B.3. (continued)

HARVEST					
HARVEST	GR-BEAN				150.00
HAUL BEANS	Operation	6.99	11.36	0.00	18.35
HAUL BEANS-1	Operation	2.23	11.36	0.00	13.59

Total HARVEST					**181.94**
POST HARVEST					
CUSTOM LIMING	GR BEAN				10.50
DISC	Operation	1.52	4.16	0.00	5.68
SOIL TEST	GR BEAN				10.50
PLANT COVER CROP	Operation	2.08	2.55	12.50	17.13
SEED, COVER CROP	1.000 Acre x		12.500 =	12.50	

Total POST HARVEST					**43.81**
MISCELLANEOUS					
ATV	Operation	7.00	2.20	0.00	9.20
PICKUP	Operation	17.50	12.95	0.00	30.45

Total MISCELLANEOUS					**39.65**
Interest - OC Borrowed					*43.73*
					===========
Total VARIABLE COST					**747.32**
GROSS INCOME minus VARIABLE COST					**403.18**

FIXED COST Description	**Unit**	**Total**
IRR SYS FIXED GR BEAN	Acre	21.25
Machinery and Equipment	Acre	140.90
Land	*Acre*	*100.00*
		===========
Total FIXED Cost		**262.15**
Total of ALL Cost		**1009.47**

NET PROJECTED RETURNS **141.03**

Exhibit B.4. Enterprise Budget for Hazelnuts/Filberts

Enterprise Budget

Hazelnuts, Barcelona, Mohawk Area

Adapted from:
Lisec, B., Olsen, J., and T. Cross. October 1993. "Enterprise Budget. Filbert, Barcelona, Willamette Valley Region". EM 8556. Oregon State University Extension Service.

By:
Siân Mooney, Ross Penhalligon, Brenda Turner.

General

This enterprise budget estimates costs and returns associated with producing hazelnuts in the Mohawk Watershed. Costs identified in *italic* type were not used in the costs generated for the economic model used in this dissertation. It is a general guide to actual costs but does not represent a particular farm. Typical cultural practices are reported below however, these are not the only production methods that could be used. **To date, local growers have *not* been consulted regarding the accuracy of this budget.**

Land

This budget is based on 60 bearing acres of mature Barcelona hazelnut trees planted at a density of 108 trees per acre. The budget presented is based on a per acre yield of 2050 lbs sold at the five year average price of 37 cents per lb. Yield may differ from that used in this budget due to variations in soil type and management practices. Annual costs for land and trees are based on the Orchard's rental value of $200/acre.

Labor

Hired labor is paid at $7 per hour; owner labor is paid at $11 per hour. These figures include worker's compensation, unemployment insurance, and other labor overhead expenses. Labor is treated as a cash variable cost in this budget.

Interest

Interest on operating funds is charged at 10 percent and treated as a cash variable expense. Intermediate and long term capital is assumed to be provided by the operator, and is also charged at 10 percent.

Exhibit B.4. (continued)

Machinery and Equipment

The machinery and equipment used in this budget reflect the likely machinery complement of a 60 acre filbert orchard in the Mohawk watershed region. Machinery purchase costs were obtained from cost estimates provided by farm equipment dealers in the Eugene/Corvallis area. Prices for some specialty equipment are obtained from dealers in the Portland area. All estimates reflect prices as of March 1996. All machinery and equipment is assumed to be half depreciated. Estimated machinery life is obtained from Rotz and Bowers. Field efficiency and speed are obtained from American Society of Agricultural Engineers standards 1991. Repair and depreciation factors are obtained from Rotz and Bowers. Gasoline costs $1.05/gallon and diesel fuel costs $1.00/gallon.

Operations

The cultural operations are listed approximately in the order in which they are performed.

Production Pruning: This operation is undertaken one in three years (or one third of the trees per year) at a rate of approximately four hours per acre. The operation takes place from the ground.

Maintenance Pruning: Occurs once a year and takes about 1.5 hours per acre.

Brush Removal: This operation uses a 4WD 65hp tractor; brush rake and operator.

Fertilizer and Liming: It is assumed that these are custom operations. Representative custom charges were obtained from a selection of custom service providers within the Willamette Valley. It is assumed that the producer will rent machinery at the same time that fertilizer is purchased. The custom for fertiliser is $23/acre. It is assumed that custom liming can be completed at a cost of $50.60/acre; liming at a rate of 0.2142 tons of active ingredient per acre. It is assumed that this operation takes place one in ten years.

Herbicide Spray: A 4WD 65hp tractor, spray tank and boom are used to distribute one pint each of Sticker oil, Round-up and Simazine.

Spot Spray: Takes place at a rate of about 15mins/acre using a spot sprayer and one application of Round-up.

Soil Leaf Analysis: It is assumed that a leaf test costs $32.50 per sample and if completed in conjunction with a soil analysis would cost approximately $47.50 per joint sample. It is assumed that a soil leaf analysis is conducted once every 3 years and that one sample is taken from the 60 acre parcel of hazelnuts under production.

Exhibit B.4. (continued)

Sucker Control, Solubor Spray, Worm Spray, Insect control: These operations use a 4WD 65hp tractor, spray tank with boom and appropriate chemical applications. Herbicides used for strip maintenance are applied to one third of each acre, assuming one third of the orchard is strips between trees.

Flail Orchard: The orchard is flailed five times using a 4WD 65hp tractor and 10ft flail chopper.

Sweeping: this operation uses a self propelled sweeper and operator.

Harvesting nuts: A 4WD 65hp tractor, and hazelnut harvester are used to harvest the nuts. The harvest operation is assumed to cover the planting one and a half times to ensure maximum yield.

Loading Totes: Uses a 70hp tractor with loader and a loading trailer.

Wash and Dry: Is a custom operation. It is assumed that the producer is charged $40/ton of filberts and trash delivered and an additional $1/ton for each percentage of disappearance. In this budget it is assumed that there is 20% disappearance. This assumption was used after discussions with hazelnut dryers.

Exhibit B.4. (continued)

== ECONOMIC COSTS and RETURNS ==

Owner Budget
by Operation

60 Acre Mature Filbert Orchard - Mohawk

GROSS INCOME Description		Quantity	Unit	$ / Unit	Total
FILBERTS	BARCELNA	2050.000	Lb	0.3700	758.50
Total GROSS Income					**758.50**

VARIABLE COST Description		Labor	Machinery	Materials	Total
PRE-HARVEST					
PROD PRUNING	Operation	9.33	0.00	0.00	9.33
MAINT PRUNING	Operation	10.50	0.00	0.00	10.50
BRUSH REMOVAL	Operation	1.40	1.25	0.00	2.65
FERT	Operation	1.38	0.00	23.00	24.38
CUSTOM FERT	1.000 acre x		23.000 =	23.00	
LIME	Operation	0.00	0.00	1.10	1.10
CUSTOM LIMING	0.019 Ton x		55.000 =	1.09	
HERBICIDE SPRAY	Operation	0.46	0.49	2.53	3.48
STICKER OIL	0.333 Pint x		1.000 =	0.33	
ROUND-UP	0.333 Pint x		4.950 =	1.64	
SIMAZINE	0.333 Pint x		1.650 =	0.54	
SPOT SPRAY WEEDS	Operation	1.75	0.68	4.80	7.23
ROUND-UP	1.000 Apl x		4.800 =	4.80	
NUTRIENT ANALYS	Operation	0.00	0.00	0.26	0.26
SOIL ANALYSIS	0.005 test x		15.000 =	0.08	
LEAF ANALYSIS	0.005 test x		32.500 =	0.17	
SUCKER CTRL 3X	Operation	4.13	4.42	18.33	26.88
STICKER OIL	3.000 Pint x		1.000 =	3.00	
2,4-D AMINE 1X	3.000 Pint x		1.210 =	3.63	
GRAMOXONE 1X	3.000 Pint x		3.900 =	11.70	
SOLUBOR SPRAY	Operation	0.69	0.74	2.28	3.70
SOLUBOR	3.500 Lb x		0.650 =	2.27	
FILBERT WORM SPR	Operation	2.07	2.21	15.53	19.80
POUNCE 10 OZ-APL	1.500 appl x		9.350 =	14.02	
STICKER OIL	1.500 Pint x		1.000 =	1.50	
FLAIL ORCHARD 5X	Operation	8.73	10.54	0.00	19.28
INSECT CONTL SPR	Operation	1.38	1.47	11.44	14.29
LORSBAN	2.000 pint x		5.719 =	11.43	
RODENT CONTROL	Operation	0.00	0.00	3.00	3.00
RODENT CONTROL	1.000 Acre x		3.000 =	3.00	
Total PRE-HARVEST					**145.88**
HARVEST					
SWEEPING FLOOR	Operation	8.25	5.35	0.00	13.60
HARVESTING NUTS	Operation	6.75	7.12	0.00	13.87
LOADING TOTES	Operation	12.61	13.59	0.00	26.19
WASH & DRY NUTS	Operation	0.00	0.00	76.86	76.86
DRYING	1.281 Ton x		60.000 =	76.86	
Total HARVEST					**130.53**

Exhibit B.4. (continued)

MISC MAINTENANCE	Operation	3.50	0.00	2.50	6.00
MATERIALS	1.000 acre x		2.500 =	2.50	
MISC COSTS	Operation	0.00	0.00	14.00	14.00
COMM AND FEES	1.000 ton x		9.000 =	9.00	
SHOP SUPPLIES	1.000 Acre x		5.000 =	5.00	
FARM PICKUP 4WD	Operation	23.33	8.89	0.00	32.22
Interest - OC Borrowed					*15.47*
					===========
Total VARIABLE COST					**344.12**

Break-Even Price, Total Variable Cost $ 0.16 per Lb of FILBERTS

GROSS INCOME minus VARIABLE COST 414.38

FIXED COST Description	Unit	Total
Machinery and Equipment	Acre	146.68
Land	*Acre*	*200.00*
		===========
Total FIXED Cost		**346.68**

Break-Even Price, Total Cost $ 0.33 per Lb of FILBERTS

Total of ALL Cost 690.80

NET PROJECTED RETURNS **67.70**

Exhibit B.5. Enterprise Budget for Winter Wheat

Enterprise Budget

Winter Wheat, Mohawk Area

Adapted from:

Taylor, M. Cross, T. and G. Gingrich. February 1990. "Enterprise Budget. Wheat, Willamette Valley Region". EM 8424. Oregon State University Extension Service.

By:

Siân Mooney, Mark Mellbye, Brenda Turner.

General

This enterprise budget estimates costs and returns associated with producing winter wheat in the Mohawk watershed. Costs represented in *italic* type were not used in the costs calculations for the economic model. It is a general guide to actual costs and does not represent a particular farm. Typical cultural practices are reported below however these are not the only production methods that could be used. **To date local growers have *not* been consulted regarding the accuracy of this budget.**

Land and Irrigation Equipment

This budget is based on a 50 acre parcel of wheat in rotation with bush beans and sweet corn on a 100 acre farm. A yield of 110 bushels/acre is assumed sold at the five year average price of $3.90/bu. Yield may differ from that used in this budget according to variations in soil type and management practices. Annual costs for land are based on the area's rental value of $100/acre.

Labor

Hired labor is paid at $7 per hour; owner labor is paid at $11 per hour. These figures include worker's compensation, unemployment insurance, and other labor overhead expenses. Labor is treated as a cash variable cost in this budget.

Interest

Interest on operating funds is charged at 10 percent and treated as a cash variable expense. Intermediate and long term capital is assumed to be provided by the operator, and is also charged at 10 percent.

Machinery and Equipment

The machinery and equipment reflect the likely machinery complement of a 100 acre mixed crop farm in the Mohawk Watershed region. Machinery purchase costs were obtained from cost estimates provided by

Exhibit B.5. (continued)

farm equipment dealers in the Eugene/Corvallis area. All estimates reflect prices as of March 1996. All machinery and equipment is assumed to be half depreciated. Estimated machinery life is obtained from Rotz and Bowers. Field efficiency and speed are obtained from American Society of Agricultural Engineers standards 1991. Repair and depreciation factors are obtained from Rotz and Bowers. Gasoline costs $1.05/gallon and diesel fuel costs $1.00/gallon.

Operations

The cultural operations are listed approximately in the order in which they are performed.

Preparation: These operations consist of preparing the field for planting, and then planting and fertilizing. It is assumed that certified and treated wheat seed is applied at a rate of 100 lb. per acre (or 1 cwt./acre).

Pre Harvest: Appropriate herbicides and fertilizer are applied between fall and spring.

Harvest: It is assumed that the wheat is custom harvested at a cost of $30/acre. One grain truck is used to haul the grain.

Miscellaneous: It is assumed that the pickup truck is used for about 10,000 miles/year in business related to farm enterprises on the 100 acre area. A charge of 100 miles per acre of wheat in production is charged to the wheat enterprise.

Exhibit B.5. (continued)

== ECONOMIC COSTS and RETURNS ==

Owner Budget
by Operation

Mohawk Valley Winter Wheat Production
50 acres

GROSS INCOME Description	**Quantity**	**Unit**	**$ / Unit**	**Total**
WHEAT	110.000	BU.	3.9000	429.00
Total GROSS Income				**429.00**

VARIABLE COST Description		**Labor**	**Machinery**	**Materials**	**Total**
PREPARATION					
DISC	Operation	3.04	7.98	0.00	11.03
PLOW	Operation	4.44	7.51	0.00	11.94
HARROW	Operation	1.35	1.42	0.00	2.77
DRILL	Operation	3.27	3.95	36.00	43.22
15-15-15	200.000 Lb. x		0.110 =	22.00	
SEED	1.000 cwt x		14.000 =	14.00	
Total PREPARATION					**68.96**
PRODUCTION					
FALL HERB CUST	Operation	0.00	0.00	10.25	10.25
KARMEX	1.500 Lb. x		3.500 =	5.25	
HERB CUST	1.000 Acre x		5.000 =	5.00	
WINTER HERB CUST	Operation	0.00	0.00	13.06	13.06
HOELON	2.500 pint x		3.224 =	8.06	
HERB CUST	1.000 Acre x		5.000 =	5.00	
SPRING FERT	Operation	0.00	0.00	41.00	41.00
40-0-0-6	0.150 ton x		240.000 =	36.00	
FERT. CUST	1.000 Acre x		5.000 =	5.00	
SPR BLEAF HERB	Operation	0.00	0.00	12.00	12.00
BANVEL	0.062 gal x		84.000 =	5.25	
2,4-D	0.125 gal x		14.000 =	1.75	
HERB CUST	1.000 Acre x		5.000 =	5.00	
SPRING FUNG.	Operation	0.00	0.00	26.25	26.25
TILT	0.062 gal x		340.000 =	21.25	
FUNG. CUST	1.000 acre x		5.000 =	5.00	
COMBINE CUST	WHEAT				30.00
HAUL GRAIN	Operation	1.39	11.36	0.00	12.75
Total PRODUCTION					**145.31**
PICKUP	Operation	140.00	41.35	0.00	181.35
Interest - OC Borrowed					*19.15*
Interest - Earned					-0.02
Total VARIABLE COST					**414.74**

Break-Even Price, Total Variable Cost $ 3.77 per BU. of WHEAT

Exhibit B.5. (continued)

GROSS INCOME minus VARIABLE COST 14.26

FIXED COST Description	Unit	Total
MISCELLANEOUS WHEAT	acre	5.00
WHEAT ASSESSMENT	bu	1.50
Machinery and Equipment	Acre	109.18
Land	*Acre*	*100.00*
Total FIXED Cost		**215.68**

Break-Even Price, Total Cost $ 5.73 per BU. of WHEAT

Total of ALL Cost 630.42

NET PROJECTED RETURNS **-201.42**

Exhibit B.6. Enterprise Budget for Blueberries

Enterprise Budget

Blueberry, Mohawk Area

Adapted from:
Lisec, B., Strick, B., and L. Kerns. August 1995. "Enterprise Budget. Blueberry, Willamette Valley Region". EM 8570. Oregon State University Extension Service.
By:
Siân Mooney, Ross Penhalligon, Brenda Turner.

General

This enterprise budget estimates costs and returns associated with producing blueberries in the Mohawk Watershed. Cost identified by *italic* type were not used in costs estimates for the economic model generated in this dissertation. It is a general guide to actual costs but does not represent a particular farm. Typical cultural practices are reported below however these are not the only production methods that could be used. **To date local growers have *not* been consulted regarding the accuracy of this budget.**

Land and Irrigation Equipment

This budget is based on a 5 acre parcel of blueberries. A yield of 18,000 lbs/acre is assumed to be sold in the processed blueberry market at the five year average price of 41.5 cents/lb. The stand is assumed to be established with a 25 year life. Yield may differ from that used in this budget according to variations in soil type and management practices. Annual costs per acre of land are based on the area's rental value of $125/acre. An overhead irrigation system is used to water and cool the plantings when needed. The system is valued at $1500/acre.

Labor

Hired labor is paid at $7 per hour; owner labor is paid at $11 per hour. These figures include worker's compensation, unemployment insurance, and other labor overhead expenses. Labor is treated as a cash variable cost in this budget.

Interest

Interest on operating funds is charged at 10 percent and treated as a cash variable expense. Intermediate and long term capital is assumed to be provided by the operator, and is also charged at 10 percent.

Exhibit B.6. (continued)

Machinery and Equipment

The machinery and equipment used in this budget reflect the likely machinery complement of a 5 acre blueberry enterprise in the Mohawk watershed region. Machinery purchase costs were obtained from cost estimates provided by farm equipment dealers in the Eugene/Corvallis area. All estimates reflect prices as of March 1996. All machinery and equipment is assumed to be half depreciated. Estimated machinery life is obtained from Rotz and Bowers. Field efficiency and speed are obtained from American Society of Agricultural Engineers standards 1991. Repair and depreciation factors are obtained from Rotz and Bowers. Gasoline costs $1.05/gallon and diesel fuel costs $1.00/gallon.

Operations

The cultural operations are listed approximately in the order in which they are performed.

Establishment: This budget is based on a 7-year establishment period of a common highbush variety. The blueberry bushes are planted at a spacing of 4 feet by 10 feet, allowing for the potential of machine harvest. This budget includes an amortized establishment cost of $711.57 per acre. This figure is based on a total establishment cost of $9,096 per acre amortized at 6 percent over a 25 year life. The charge of $711.57 per acre represents the annual payment required to repay a loan taken out to establish blueberries. Detailed establishment cost information can be found in *EM 8526, Blueberry Economics: The Costs of Establishing and Producing Blueberries in the Willamette Valley, 1993*. This can be obtained from Publications Orders, Agricultural Communications, OSU, Administrative Services Bldg. A422, Corvallis, OR 97331-2219.

Prune and Rake: Pruning is done by hand in the dormant season.

Pest Control: Is done when needed prior to harvest.

Fertilizer: This operation is assumed to be completed by hand. It is assumed that it takes 3 employees a total of 1 hour per acre each to complete this operation.

Sawdust Mulch: A 2 inch sawdust mulch is applied by hand every 5 years using 3 employees, shovels and a pickup. It is assumed that it takes 24 man hours to complete an acre (or one eight hour day for three employees). Alternatively this can be thought of as a time commitment of 1.6 hours per employee per acre per year or a total of 4.8 labor hours per acre per year.

Harvest and Shipping: It is assumed in this budget that the berries are harvested by hand at a cost of $0.25/lb. Approximately 1000lbs of berries are harvested each day. It is assumed that the harvest season is approximately 60 days long and that berries are actually harvested for about 18 of these days. The

Exhibit B.6. (continued)

harvested berries are picked up 3 times a day, at 10.00am, 1.00pm and 3.00pm using a 35 hp tractor and trailer. It is assumed that the tractor/trailer combination can cover 2.5 acres per hour. Each acre is visited 54 times over the 18 days of actual harvest in order to pick up berries (i.e. 3 visits * 18 days = 54) Once harvested, the berries are shipped to the processor at a cost of $0.02/lb.

Pickup Truck: It is assumed that the pickup truck travels approximately 1000 miles per year in business associated with the blueberry enterprise. A pickup truck charge consistent with 200 miles/acre is charged on a per acre basis.

Exhibit B.6. (continued)

== ECONOMIC COSTS and RETURNS ==

Owner Budget
by Operation

Mohawk Watershed Blueberries - 5 acres
Establishment Year 7

Date of Printing : 05/03/96

GROSS INCOME Description	Quantity	Unit	$ / Unit	Total
BLUEBERRY PROCES	18000.000	Lb	0.4150	7470.00
Total GROSS Income				**7470.00**

VARIABLE COST Description		Labor	Machinery	Materials	Total
PRE-HARVEST					
PRUNE AND RAKE	Operation	280.00	0.00	0.00	280.00
COPPER SPRAY	Operation	11.62	4.43	13.60	29.65
BORDEAUX 8-8-100	2.000 appl x		6.800 =	13.60	
FUNGICIDE 2X	Operation	11.62	4.43	7.80	23.85
CAPTAN 2 LBS	2.000 acre x		3.900 =	7.80	
FUNGICIDE 2X	Operation	11.62	4.43	15.80	31.85
BENLATE 2 LBS	2.000 acre x		7.900 =	15.80	
FERTILIZER HAND	Operation	25.00	0.00	34.50	59.50
21-0-0 FULL PROD	0.250 ton x		138.000 =	34.50	
BEE HIVES	Operation	0.00	0.00	36.00	36.00
BEES FULL PROD	2.000 hive x		18.000 =	36.00	
MOW STRIPS 3X	Operation	6.55	2.96	0.00	9.51
SPOT SPRAY WEEDS	Operation	11.00	1.13	4.80	16.93
ROUND-UP	1.000 Apl x		4.800 =	4.80	
SAWDUST MULCH	Operation	40.00	0.00	0.00	40.00
IRRIGATION	Operation	25.30	0.00	34.50	59.80
IRRG 1 1/2 IN	23.000 sets x		1.500 =	34.50	
IRRIG MAINT	Operation	21.00	0.00	59.00	80.00
IRG MAINT REPRS	1.000 acre x		59.000 =	59.00	
TISSUE ANALY	Operation	0.00	0.00	6.50	6.50
TISSUE ANALYSIS	0.200 smpl x		32.500 =	6.50	
Total PRE-HARVEST					**673.60**
HARVEST					
BIRD CONTROL	Operation	0.00	0.00	41.50	41.50
SCARE EYES-CANON	1.000 acre x		41.500 =	41.50	
HARVEST-PROCESSR	Operation	0.00	0.00	4860.00	4860.00
PROCESS-LOAD-SHP	18000.000 lb x		0.020 =	360.00	
PICKING	18000.000 lb x		0.250 =	4500.00	
Total HARVEST					**4901.50**
MISCELLANEOUS					
TRACTOR 2-WHL TR	Operation	287.49	73.54	0.00	361.03
PICKUP TRUCK	Operation	55.00	25.90	0.00	80.90
Total MISCELLANEOUS					**441.93**
Interest - OC Equity					0.02

Exhibit B.6. (continued)

VARIABLE COST Description	Labor	Machinery	Materials	Total
MISCELLANEOUS				
GENERAL OVERHEAD Operation	0.00	0.00	20.00	20.00
GENERAL OVERHEAD 1.000 acre x 20.000 = 20.00				
Total MISCELLANEOUS				**20.00**
Total VARIABLE COST				**6037.06**

Break-Even Price, Total Variable Cost $ 0.33 per Lb of BLUEBERRY PROCES

GROSS INCOME minus VARIABLE COST	**1432.94**

FIXED COST Description	Unit	Total
AMORT EST COST BLUE 7	Acre	711.57
IRR.SYS.FIXED BLUE BER	acre	165.00
Machinery and Equipment	Acre	834.58
Land	Acre	125.00
Total FIXED Cost		**1836.15**

Break-Even Price, Total Cost $ 0.43 per Lb of BLUEBERRY PROCES

Total of ALL Cost	**7873.20**
NET PROJECTED RETURNS	**-403.21**

Exhibit B.7. 100 Cow Enterprise Budget

Enterprise Budget

100 Cow/Calf/Yearling Operation, Mohawk Area

Adapted from:
Cross, T., Day, P., Pirelli, G., Leffel, J., and D. Passon. March 1988. "Enterprise Budget, Cow-Calf, Willamette Valley Region". EM 8372. Oregon State University Extension Service.

By:
Siân Mooney, Paul Day and Brenda Turner.

General

This enterprise budget estimates the costs and returns associated with producing calves and yearlings in the Mohawk area of the Willamette valley. Costs identified by *italic* type were not used in costs calculations for the economic model used in this dissertation. It is a general guide to actual costs and does not represent a particular farm. Typical production practices are reported below, however these are not the only production methods possible. **To date, local producers have *not* been consulted regarding the accuracy of this budget.**

Description of operations for a 100 head herd.

This reflects a cow/calf/yearling operation.

Livestock

The herd consists of 100 cows and 4 bulls. It is assumed that conception is at 98 %, and 95% of the cows give birth. Calf death loss is assumed to be 2%, while a 1% death loss is assumed for the cows and bulls. Mature cows are culled at a rate of 10% annually; all replacement heifers are raised. All steers and additional heifers are marketed. All non breeding calves are implanted with growth stimulants in the spring. Calves and cows are treated for internal and external parasites. All cows and replacement heifers are pregnancy tested. Cows and calves are vaccinated in the spring, and cows are vaccinated again in the fall. A livestock production flowchart is shown on page X.

On or about 5th April, the bulls are turned out with 100 cows and left until on or about June 20th. At this time remove the bulls and pasture them at another locale. Approximately 60 days after removing the bulls the cows are pregnancy checked (late August to early October). Calving takes place from mid January to early March with an assumed birth rate of 95% resulting in 95 calves. Of these, 2% die leaving 93 calves

Exhibit B.7. (continued)

(47 heifers and 46 steers). The calves are kept until September/October when they are weaned. Steers are weaned at 500lbs and heifers at 450lbs. Approximately 36 steers and 32 heifers are sold at this point and 15 heifers are kept as replacements. In late November to early December, an additional 4 yearling heifers are sent to market (at about 800lbs) and 11 are kept as replacements. The replacement cows are bred in March and join the herd in August when the older cows are culled after pregnancy checking. Current market values and years of useful life for all livestock are shown in the lower portion of Table 1. The calculations for livestock fixed costs are shown in Table 3.

Approximate timing of calving and replacement and corresponding number of head

Month	J	F	M	A	M	J	J	A	S	O	N	D
Cow	100	100	100	100	100	100	100	100	100	100	100	100
Calf	24	71	95	95	94	93	93	93	15	15	15	0
Yearling	11	11	0	0	0	0	0	0	0	0	0	11
Bull	4	4	4	4	4	4	4	4	4	4	4	4
Rep. Cow	0	0	11	11	11	11	11	11	0	0	0	0

Feeding

The herd is on pasture from March to the end of November. They receive additional feed for the later part of November and full feed during December, January, February and half feed again during March. This amounts to about 120 days for feeding hay and other supplements.

The herd can be feed grass hay between December to March which has about 6% protein. This may also be supplemented with protein blocks or Alfalfa hay (16% protein). In this budget, it is assumed that the livestock are fed grass hay and protein blocks. Feed requirements were calculated in the following manner:

Grass Hay August 15th to September 15th = 1 month

It was assumed that each cow is fed 10lb of hay per day (personal communication with Paul Day). The total number of livestock to be fed during this period is calculated as 100 cows and 11 replacements (calculated at 0.75 of a full grown cow) for 15 days in August. For the 15 days of September it is assumed that 100 cows will be fed.

Exhibit B.7. (continued)

Total hay requirements for this period are:

15*(10*(100+0.75*11)) = 16238 lb.

15*10*100 = 15000 lb.

Total = 31238 lb., or 15.6 tons.

Grass Hay - November 15th to March 15th = 120 days

For 15 days it is assumed that there are 100 cows and for 105 days it is assumed that there are 100 cows and 11 yearling/replacements fed at 0.5. During this period each cow is fed 30lbs of hay per day (Personal communication with Paul Day).

Total hay requirements for this period are:

100*30*15 = 45,000 lb.

105*(30*(100+11*0.5)) = 332,325 lb.

Total = 377,325 lb., or 189 tons

Total Hay Requirement

Total hay requirement per year is 408,563 lb., or 204 tons.

Protein Supplement

It is assumed that in addition to hay, the cattle receive a protein supplement. It is assumed that each cow receives 60 lb. per year. The total protein requirement for the herd is 100*60 = 6,000 lb.

Pasture

It is assumed that the herd spends the following days on pasture:

In March 15 days; there are 100 cows and 11 replacements. The number of AUMs (animal unit months) required are; (100+0.75*11)/2 = 54 AUM. In April, May, June, July and August the herd requires (100+0.5*11)+4(100+0.75*11) = 538.5 AUM. In September, October and half November the herd requires 2.5(100) = 250.

Total AUM = 842.5

It is assumed that on average the productivity of pasture in the area is 7 AUM/acre/year. Therefore, the enterprise requires 120 acres. Pasture costs are based on charges of $7/AUM. This reflects the current typical pasture rental rate in the area, and includes all costs of maintenance except fence repair.

Exhibit B.7. (continued)

Salt and Minerals

These are fed at 15lb. per cow per year from a mineral feeder.

Capital

Opportunity cost of capital is charged at a rate of 10% annually for current, intermediate and long term capital provided by the owner.

Machinery and Equipment

The Machinery and equipment reflect the likely machinery complement of a 100 cow operation in the Mohawk Watershed region. Machinery purchase costs were obtained from cost estimates provided by farm equipment dealers in the Eugene/Corvallis area. All estimates reflect prices as of March 1996. All machinery and equipment is assumed to be half depreciated. Estimated useful life was obtained from Rotz and Bowers. Field efficiency and speed are obtained from the American Society of Agricultural Engineers standards 1991. Repair and depreciation factors are obtained from Rotz and Bowers. Gasoline costs $1.05/gallon and diesel fuel costs $1.00/gallon.

Exhibit B.7. (continued)

Cow-Calf Production Flow Chart
Mohawk area - 100 cow herd

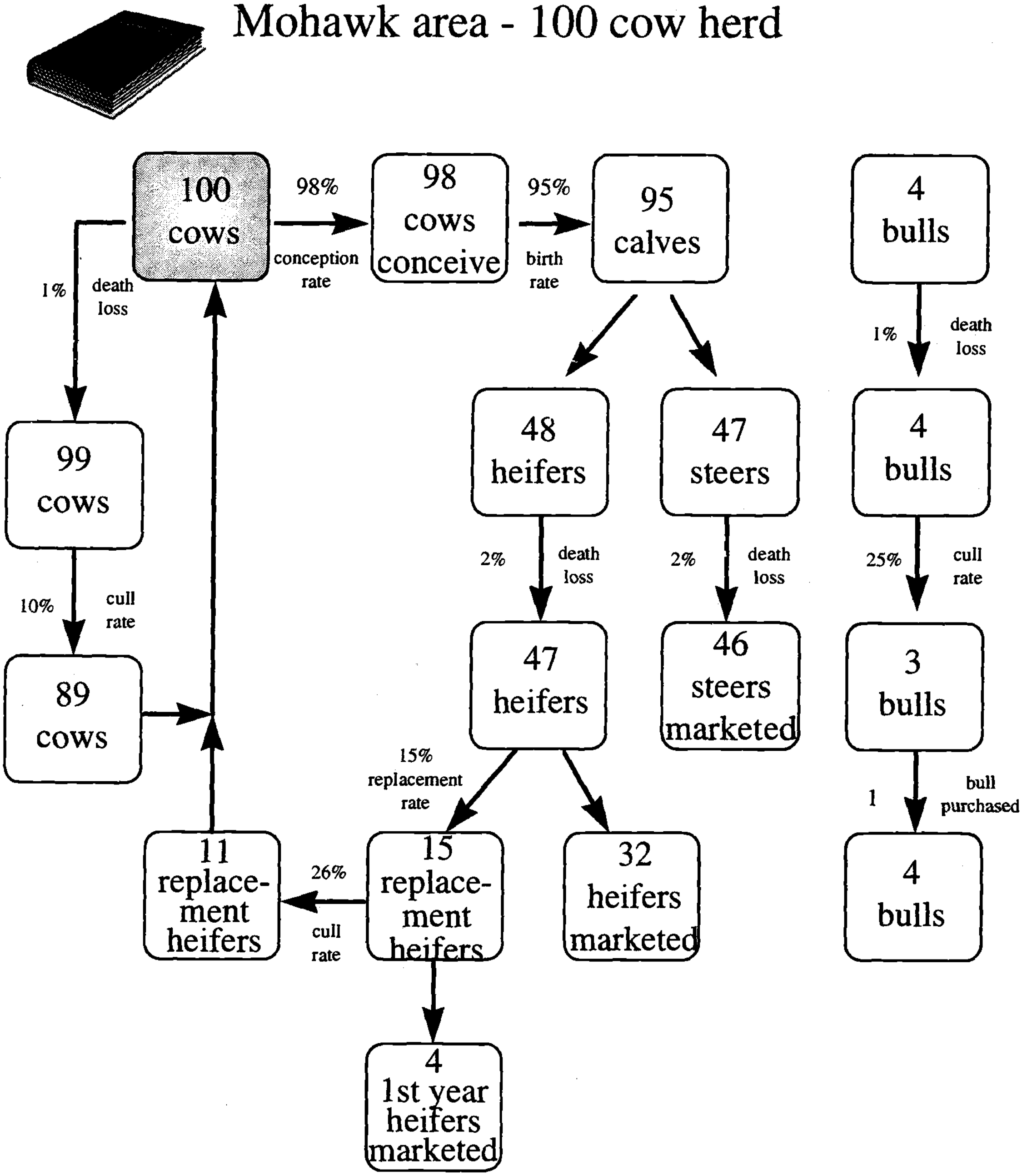

Exhibit B.7. (continued)

GROSS INCOME	**Quantity**	**Unit**	**Quantity**	**Unit**	**$/Unit**	**Total**	**Per Cow**
CASH Income							
Cull Bulls	1.00	hd	1800.00	lb	0.52	936.00	9.36
Cull Cows	10.00	hd	1100.00	lb	0.42	4620.00	46.20
Heifer Calves	32.00	hd	450.00	lb	0.74	10656.00	106.56
Yearling Heifers	4.00	hd	800.00	lb	0.66	2112.00	21.12
Steer Calves	46.00	hd	500.00	lb	0.80	18400.00	184.00
Total GROSS Income						**$36,724.00**	**$367.24**
	93.00						

VARIABLE COST Description	**Quantity**	**Unit**	**$/Unit**	**Total**	**Per Cow**
CASH Cost					
Bedding	100.00	hd	2.00	200.00	2.00
Bull Purchase	1.00	hd	2000.00	2000.00	20.00
Fence Repair	1.00	year	250.00	250.00	2.50
Native hay	204.00	ton	60.00	12240.00	122.40
Alfalfa hay	0.00	ton	125.00	0.00	0.00
Implants	46.00	hd	1.74	79.95	0.80
Marketing Costs	82.00	hd	11.40	935.04	9.35
Parasite Control	100.00	hd	6.60	660.00	6.60
Pasture	*843.00*	*aum*	*7.00*	*5901.00*	*59.01*
Protein Supplement	6000.00	lb	0.24	1440.00	14.40
Salt & Minerals	1500.00	lb	0.08	120.00	1.20
Utilities	1.00	year	600.00	600.00	6.00
Vaccine - cows	100.00	hd	3.30	330.00	3.30
Vaccine - calves	95.00	hd	3.16	300.20	3.00
Vet-med	100.00	hd	4.00	400.00	4.00
Miscellaneous	100.00	hd	5.00	500.00	5.00
Fuel, Lube, Repairs				2564.14	25.64
Total CASH Cost				**$28,520.33**	**$283.20**
OTHER Cost					
Interest - Operating Capital(10% for 6 mo.)				*1426.02*	*14.26*
Owner Labour	1040.00	hrs	7.00	7280.00	72.80
Total OTHER Cost				**$8,706.02**	**$87.06**
Total VARIABLE COST				**$37,226.34**	**$372.26**
GROSS INCOME minus VARIABLE COST				**($502.34)**	**($5.02)**

FIXED COST Description	**Total**	**Per Cow**
CASH Cost		
Annual taxes	0.00	0.00
Machinery & Equipment Insurance	430.89	4.31
Total CASH Cost	**$430.89**	**$4.31**

NON-CASH Cost		
Opportunity Cost - Livestock(10%)	*7517.80*	*75.18*
Interest & Depreciation - Machinery & Equipment(10%)	5365.91	53.66
Land Interest Charge ((number acres)(value land)(2.5%))	*375.00*	*3.75*
Total NON-CASH Cost	**$13,258.71**	**$132.59**
TOTAL FIXED Cost	**$13,689.60**	**$136.90**
Total COST	**$50,915.94**	**$509.16**
NET PROJECTED RETURNS	($14,191.94)	($141.92)

Exhibit B.7. (continued)

Table 1. Machinery and Livestock Cost Assumptions

Item	Size	List Price	Current Market Price	Salvage Value	Useful Life	Remaining Life	Units	Annual Use for Enterprise
Machine & Equipment								
Loader Tractor	50HP	24000.00	14400.00	4800.00	10000.00	6000.00	hr	420.00
ATV		5195.00	3117.00	1039.00	5000.00	3000.00	miles	320.00
Stock Trailer	10head	8000.00	4800.00	1600.00	1600.00	960.00	hr	8.00
Pickup	3/4 Ton	20000.00	12000.00	4000.00	100000.00	60000.00	miles	6000.00
Barn		12050.00	7230.00	2410.00	30.00	18.00	years	1.00
Feed bunks with hay racks		2390.00	1434.00	478.00	20.00	12.00	years	1.00
Mineral Feeders	(2)	179.90	107.94	35.98	12.00	7.20	years	1.00
Livestock								
Bulls		2000.00	1432.00	864.00	4.00	2.00	years	
Cows			700.00	462.00	10.00	5.00	years	
Replacement Heifers			650.00	528.00	10.00	6.00	years	

Exhibit B.7. (continued)

Table 2: Machinery and Equipment Cost Calculations

Machine and Equipment	Size	Fuel & Lube	Units	Repair & Maint.	Depreciation	Interest	Insurance	Total	Hours/miles/years/head
Loader Tractor	50 hp	2.50	$/hr	1.41	1.92	2.29	0.34	8.46	4.20
ATV		0.03	$/mile	0.16	0.83	0.65	0.10	1.76	3.20
Stock Trailer	7-10 head	0.00	$/hr	0.03	4.00	40.00	6.00	50.03	0.08
Pickup	3/4 Ton	0.07	$/mile	0.04	0.16	0.13	0.02	0.43	60.00
Barn		0.00	$/year	100.00	321.33	482.00	72.30	975.63	0.01
Feed bunks		0.00	$/year	70.00	95.60	95.60	14.34	275.54	0.01
Mineral Feeders	(2)	0.00	$/year	3.00	11.99	7.20	1.08	23.27	0.01
Total									

"-----Costs per cow-----"

Machine and Equipment	Size	Insurance	Fuel and lube	Repair and M	Depreciation.	Interest	Variable	Fixed
Loader Tractor	50 hp	1.44	10.49	5.94	8.06	9.60	16.43	19.10
ATV		0.31	0.09	0.50	2.66	2.08	0.59	5.05
Stock Trailer	7-10 head	0.48	0.00	0.00	0.32	3.20	0.00	4.00
Pickup	3/4 Ton	1.20	4.40	2.50	9.60	8.00	6.89	18.80
Barn		0.72	0.00	1.00	3.21	4.82	1.00	8.76
Feed bunks		0.14	0.00	0.70	0.96	0.96	0.70	2.06
Mineral Feeders	(2)	0.01	0.00	0.03	0.12	0.07	0.03	0.20
Total		4.31	14.97	10.67	24.93	28.73	25.64	57.97

Depreciation: ((annual use/remaining life)*current market price*0.8))/annual use

Interest: (current mkt price+salvage value)*0.1/(2*annual use)

Insurance: (0.01*current mkt value)/annual use

Exhibit B.7. (continued)

Table 3. Livestock Fixed Cost Calculations

	- Cost per Head -		Cost per Cow
Livestock	**Interest**	**Head**	**Interest**
Bulls	143.20	4.00	5.73
Cows	70.00	89.00	62.30
Replacement Heifers	65.00	11.00	7.15
Total	**$278.20**	**$104.00**	**$75.18**

Table B.2. 5 Year Average Price of Agricultural Products, 1991-1995

Year	Filberts ($/lb)[1]	Alfalfa Hay ($/ton)[1]	Grass Hay ($/ton)[1]	Corn ($/ton)[1]	Beans ($/ton)[1]	Blueberries ($/lb)[2]	Wheat ($/bu)[1]	Mint ($/lb)[1]
1995	0.46	100.00	65.00	83.45	170.02	0.33	4.70	14.75
1994	0.42	109.00	65.00	78.60	168.90	0.34	4.02	15.65
1993	0.32	104.80	65.00	84.40	187.00	0.34	3.14	13.30
1992	0.27	95.10	63.00	83.20	205.20	0.65	3.81	13.30
1991	0.36	100.00	65.80	81.90	185.40	---------	3.81	13.55
5 Year Average	0.37	101.78	64.76	82.31	183.30	0.415	3.90	14.11

[1] Extension Economic Information Office, Oregon State University.

[2] Oregon Agricultural Statistics Service. 1996. 1995 Berry Crop Production.
Oregon Agricultural Statistics Service. 1994. 1993 Berry Crops Summary.

Table B.3. 5 Year Average Cattle Prices, 1991-1995

	Cull Bulls ($/lb)[1]	Cull Cows ($/lb)[1]	Heifer Calves ($/lb)[1]	Yearling Heifer ($/lb)[1]	Steer Calves ($/lb)[1]
1995	0.40	0.32	0.54	0.55	0.60
1994	0.48	0.39	0.70	0.62	0.75
1993	0.56	0.45	0.87	0.73	0.92
1992	0.56	0.45	0.80	0.69	0.86
1991	0.62	0.48	0.80	0.72	0.88
5 Year Average	0.52	0.42	0.74	0.66	0.80

[1] Extension Economic Information Office. Cattle worksheets by county. 1991-1995 Lane County. Oregon State University.

Table B.4. Yield of Agricultural Products by Land Type

	Corn (tons)[2]	Wheat (bu)[2]	Beans (tons)[2]	Mint (lbs)[2]	Blueberries (lbs)[1,2]	Filberts (lbs)[2]	Alfalfa Hay (tons)[1]	Grass Hay (tons)[1,3]	Pasture (aums)[1]
F1PUB River Property	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F1PRI River Property	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F2 River Property	9.00	110.00	5.85	74	18000	2050	4.37	1.43	6.75
RDEV River Property	N/A	N/A	N/A	N/A	N/A	N/A	No Yield Available	1.43	12.20
RR River Property	9.00	110.00	5.85	74	18000	2050	4.47	3	8.27
OTH River Property	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E40 River Property	9.00	110.00	5.85	74	18000	2050	4.47	3	9.81
F1PUB Non-River Property	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F1PRI Non-River Property	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F2 Non-River Property	9.00	110.00	5.85	74	18000	2050	5.57	2.71	6.49
RDEV Non-River Property	N/A	N/A	N/A	N/A	N/A	N/A	No Yield Available	1.43	11.33
RR Non-River Property	9.00	110.00	5.85	74	18000	2050	4.15	3	7.42
OTH Non-River Property	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E40 Non-River Property	9.00	110.00	5.85	74	18000	2050	4.9	2.99	8.34

[1] John Hagan, USDA Natural Resources Conservation Service, Portland, Oregon.

[2] Personal communication with Ross Penhalligon, Oregon State University Extension Service, Lane County.

[3] Where no yield for grass hay is available, the average yield of 1.43 tons is used. This yield is obtained from the results of a personal interview survey of Mohawk residents (appendix A).

Table B.5. Timber Yields on Industrial Public Lands - Short Log 16' Scale Volume

Age Class	Regeneration Board Feet/acre	Thinning Board Feet/acre
0	0	
10	0	
20	0	
30	0	
40	0	
50	30,359	9,554
60	37,149	12,766
70	46,356	
80	38,666	
90	56,684	

These yields were adjusted for a 32' scale before use in the mathematical programming model.
Source: Art Emmons, Eugene BLM.

Table B.6. Estimated Timber Yields on Non-Industrial Forest Land - 32' Scale Volume

Age Class	Regeneration Board Feet/acre	Thinning Board Feet/acre
40		6,000
60-65	40,000 to 45,000	

Estimates provided by Norm Elwood, Forest Economist, Oregon State University Extension Service.

Table B.7. Residential Land Area, Value and Riparian frontage by Value Type

	Area (acres)[1]	Mean property value (dollars)[2]	Mean Property Size (acres)[1]	Average value/acre (dollars)	Total riparian frontage (feet)[1]	Modeled Riparian Frontage Length (feet)
River Property Low Value/Acre	744	119851	9.70	12355.77	85099	
River Property Medium Value/Acre	203	137979	3.66	37699.18	36418	
River Property High Value/Acre	16	139039	1.25	111231.20	5323	
					Total = 126,840	**Total = 98,000**
Non-River Property Low Value/Acre	1933	101367	8.92	11364.01	N/A	
Non-River Property Medium Value/Acre	740	132959	3.22	41291.61	N/A	
Non-River Property High Value/Acre	237	120451	0.84	143394.00	N/A	

[1] Calculated using a GIS.

[2] Assessed values and market values are obtained from the Lane County Department of Assessment and Taxation. Values are entered into a GIS.

Table B.8. Money Market Mortgage Rates, percent per year 1991-1995

	1991	1992	1993	1994	1995	Average
Conventional New Home	9.2	8.43	7.37	8.58	8.05	8.326
Conventional, Existing Home	9.2	8.43	7.37	8.58	8.05	8.326

Source: Board of Governors of the Federal Reserve System, *Federal Reserve Bulletin*, monthly, and *Annual Statistical Digest* cited in US Department of Commerce (1996).

Table B.9. Property sale price and attribute data used in the hedonic pricing analysis

Sale Price of Property (dollars)[1]	Sale Date (Y/M/D)[1]	Size of Lot (acres)[2]	Size of residence (square feet)[1]	Year Residence Built[1]	Stat. Class[1,3]	Levy code[1,4]	Distance from Main Highway to Eugene (feet)[2]	River Frontage 1=yes[2]	Length of River Front (feet)[2]	Riparian Area in trees (square feet)[5]
52500	870302	0.81	1432	1965	130	1905	32818	0	0	0
89000	870313	1.14	2962	1975	150	7902	68249	0	0	0
24900	870527	0.16	858	1920	120	7903	43555	0	0	0
72500	870708	4.11	1614	1979	140	1905	11867	0	0	0
85000	870717	4.20	1873	1966	140	1905	90704	0	0	0
136850	870807	1.12	3096	1971	140	1905	26764	1	231	2310
264700	870819	9.22	4653	1979	160	1905	12400	0	0	0
40000	870826	1.09	1513	1979	130	7903	46451	0	0	0
15000	870829	0.37	728	1910	120	7903	44210	0	0	0
48000	870922	1.00	1048	1977	140	1905	19145	0	0	0
46500	871109	1.28	1044	1920	120	1905	32200	0	0	0
65000	880122	1.18	925	1970	130	1905	27742	0	0	0
72000	880202	1.10	768	1970	120	7902	34420	0	0	0
93750	880601	2.84	1419	1980	140	7902	56249	0	0	0
93000	880629	5.58	1720	1976	140	1905	21703	1	364	25480
90000	880727	1.04	2436	1968	140	1905	16506	0	0	0
76000	880802	5.00	1264	1980	130	7902	52926	0	0	0
89900	880804	1.35	1902	1973	140	1905	29065	1	287	287
90000	880810	2.48	2520	1967	140	1905	22268	0	0	0
80000	880824	3.88	1266	1966	140	7902	59954	0	0	0
92000	880916	5.15	1932	1973	140	1905	22700	0	0	0
107000	881101	1.96	2320	1976	140	1905	26567	0	0	0
28500	881118	2.36	1020	1950	120	1905	9672	0	0	0
68350	890119	1.61	1284	1968	130	7902	55061	0	0	0
50000	890203	0.90	1880	1964	130	7902	55375	0	0	0
26500	890216	0.37	1164	1905	120	7903	44303	0	0	0
35000	890227	0.47	1024	1968	130	7903	43723	0	0	0
160000	890310	5.27	2637	1981	150	7902	57169	0	0	0
71700	890401	15.00	900	1930	130	7903	47430	1	387	0
59900	890508	1.09	1632	1970	130	7902	48498	0	0	0
48000	890512	0.40	1344	1946	130	7902	61830	0	0	0
35000	890822	3.50	1743	1990	140	1905	30295	0	0	0
99900	890907	1.68	1640	1962	140	1905	21385	0	0	0

Table B.9. (continued)

Sale Price of Property (dollars)[1]	Sale Date (Y/M/D)[1]	Size of Lot (acres)[2]	Size of residence (square feet)[1]	Year Residence Built[1]	Stat. Class[1,3]	Levy code[1,4]	Distance from Main Highway to Eugene (feet)[2]	River Frontage 1=yes[2]	Length of River Front (feet)[2]	Riparian Area in trees (square feet)[5]
202000	891012	10.00	3913	1966	140	1905	28224	0	0	0
134900	891013	15.98	1890	1976	140	1905	18658	0	0	0
24500	891113	1.40	836	1958	120	1905	0	0	0	0
63000	891120	5.70	1526	1979	140	1905	0	0	0	0
30000	900115	15.97	1095	.	130	7902	86792	0	0	0
140000	900218	23.53	2478	1922	140	1905	1435	0	0	0
172000	900220	15.02	2392	1949	140	7902	45186	1	1204	30100
85900	900430	0.59	1372	1977	140	1905	32489	0	0	0
235000	900508	4.84	2615	1978	140	1905	27109	1	315	0
55000	900731	3.75	1322	1923	120	7902	54900	0	0	0
90000	900801	5.00	2688	1952	140	7903	47894	0	0	0
59900	900820	0.67	1704	1890	120	7903	40328	0	0	0
133000	900828	19.34	1441	1910	130	1915	7582	0	0	0
45000	901101	2.73	1340	1880	120	7902	62931	0	0	0
56000	910412	0.37	1040	1981	130	7903	43626	0	0	0
106000	910501	0.90	1340	1970	130	1905	22260	0	0	0
122500	910508	5.51	2196	1966	140	1905	26366	0	0	0
126000	910530	0.95	1856	1973	130	1905	22428	0	0	0
53300	910627	3.90	1248	1915	120	7903	48587	0	0	0
140000	910716	8.42	2425	1986	150	1905	7592	0	0	0
70000	910828	2.75	1244	1914	130	7902	62048	1	839	50340
150000	910905	6.02	1866	1979	140	1905	17823	0	0	0
169000	911009	3.66	2190	1980	140	1905	30742	1	323	0
85000	911014	8.20	2280	1910	140	1905	26013	1	955	57300
90000	911024	1.23	1291	1976	140	7902	63835	0	0	0
135000	911105	4.03	1804	1971	140	1905	36787	0	0	0
172500	911114	3.98	2924	1979	150	1905	11878	0	0	0
45000	911215	15.51	2194	1993	140	1905	29306	0	0	0
59500	920102	0.75	.	.	190	7903	44616	0	0	0
140500	920205	5.01	1872	1992	140	7902	57782	0	0	0
127900	920225	0.99	1887	1971	140	1905	20739	0	0	0
45000	920301	0.50	1050	1920	130	7903	44039	0	0	0

Table B.9. (continued)

Sale Price of Property (dollars)[1]	Sale Date (Y/M/D)[1]	Size of Lot (acres)[2]	Size of residence (square feet)[1]	Year Residence Built[1]	Stat. Class[1,3]	Levy code[1,4]	Distance from Main Highway to Eugene (feet)[2]	River Frontage 1=yes[2]	Length of River Front (feet)[2]	Riparian Area in trees (square feet)[5]
80000	920319	1.05	1436	1942	130	7903	42864	0	0	0
134000	920320	1.04	2436	1968	140	1905	16506	0	0	0
49500	920327	2.04	768	1985	130	7902	79738	1	324	32400
80000	920424	3.34	2770	1947	130	1905	12403	1	624	78000
151500	920605	5.02	2820	1917	130	1905	0	0	0	0
225000	920623	1.38	2536	1979	150	1905	19102	0	0	0
180000	920624	4.61	2036	1979	150	7902	88276	0	0	0
90000	920711	10.37	1868	1996	150	1905	20317	0	0	0
225000	920716	10.24	2562	1976	140	1905	29170	0	0	0
130000	920730	1.64	1430	1972	140	1905	33433	0	0	0
154530	920915	7.00	1680	1971	140	1905	21385	0	0	0
98500	920918	5.75	1703	1969	140	7902	86792	0	0	0
60000	921028	0.79	1815	1890	130	7903	42915	0	0	0
131000	921111	5.78	1862	1962	130	7902	38732	1	820	0
94000	930127	1.15	1554	1977	130	7902	53390	0	0	0
124900	930210	9.73	1416	1928	130	1905	8733	0	0	0
78000	930430	0.64	1310	1925	130	7903	43524	0	0	0
132500	930603	1.61	1543	1970	140	1905	24758	0	0	0
130500	930615	4.43	1428	1980	130	1905	12956	0	0	0
145000	930623	3.02	1516	1968	140	1905	45262	0	0	0
136000	930625	4.71	1580	1968	130	7902	48851	0	0	0
89000	930702	0.57	2142	1955	130	7903	43943	0	0	0
210500	930706	11.83	1888	1974	140	1905	22144	0	0	0
69500	930715	4.63	959	1928	120	7902	49630	0	0	0
149000	930715	1.14	2250	1972	140	1905	16506	0	0	0
177000	930726	6.28	676	1925	120	1905	32551	0	0	0
139900	930728	0.90	1485	1971	140	1905	3049	0	0	0
39000	930811	1.00	800	.	120	7902	46436	0	0	0
23000	930827	0.21	912	1900	120	7903	44335	0	0	0
180000	930831	20.57	1328	1969	130	7902	78960	0	0	0
127000	930927	1.00	1460	1954	130	1905	28952	0	0	0
99500	931004	20.00	832	1900	110	7902	69362	0	0	0
118000	931012	1.91	1242	1961	130	1905	18500	0	0	0

Table B.9. (continued)

Sale Price of Property (dollars)[1]	Sale Date (Y/M/D)[1]	Size of Lot (acres)[2]	Size of residence (square feet)[1]	Year Residence Built[1]	Stat. Class[1,3]	Levy code[1,4]	Distance from Main Highway to Eugene (feet)[2]	River Frontage 1=yes[2]	Length of River Front (feet)[2]	Riparian Area in trees (square feet)[5]
116600	931020	1.15	1492	1970	140	7902	58386	0	0	0
87500	931027	1.04	1176	1982	130	7902	54906	0	0	0
73000	931109	1.00	.	.	190	1905	28098	0	0	0
192000	931121	1.80	2280	1965	140	1905	22850	0	0	0
275000	940113	11.97	2718	1980	140	1905	33258	0	0	0
122000	940115	0.32	2011	1905	130	1905	23501	0	0	0
159500	940115	3.15	2113	1984	140	7902	73461	0	0	0
140000	940202	3.57	1627	1941	130	1905	23391	1	599	32945
64500	940216	0.50	1403	1920	120	7903	44047	0	0	0
140000	940218	6.00	720	1935	120	1905	29367	0	0	0
75000	940306	2.18	943	1930	130	7902	84259	1	357	10710
63000	940425	0.25	1500	1900	120	7903	44132	0	0	0
151000	940425	3.64	1592	1964	130	7903	43026	0	0	0
157450	940526	3.00	1628	1950	130	1905	25031	0	0	0
90000	940714	0.57	1616	1900	120	7903	44799	0	0	0
260000	940714	1.68	2152	1970	140	1905	41974	1	163	5705
59900	940728	0.30	.	.	190	7903	45648	0	0	0
152000	940816	4.63	1410	1965	130	7902	73752	0	0	0
282500	940917	13.48	672	1978	130	7902	74614	0	0	0
282500	940917	2.66	2718	1979	150	7902	74614	0	0	0
168000	941013	5.28	1760	1972	140	7902	49381	0	0	0
59500	941024	2.73	.	.	190	1905	13956	0	0	0
155000	941213	4.99	1248	1973	130	7902	45186	0	0	0
285000	950317	2.10	3200	1977	150	7902	60217	1	368	7360
168000	950417	14.33	1796	1974	140	7902	52475	0	0	0
87700	950501	0.85	1188	1907	130	7904	44905	0	0	0
164900	950523	0.99	1764	1969	140	1905	20970	0	0	0
96500	950524	15.72	1112	1920	130	1905	27732	0	0	0
165000	950524	1.60	1592	1992	140	1905	27343	0	0	0
192000	950626	1.47	2686	1967	130	1905	16532	0	0	0
122500	950630	1.22	1480	1973	130	1905	13314	0	0	0
218000	950630	3.86	2512	1962	140	1905	719	0	0	0
125000	950701	1.24	1884	1973	130	7902	84596	0	0	0

Table B.9. (continued)

Sale Price of Property (dollars)[1]	Sale Date (Y/M/D)[1]	Size of Lot (acres)[2]	Size of residence (square feet)[1]	Year Residence Built[1]	Stat. Class[1,3]	Levy code[1,4]	Distance from Main Highway to Eugene (feet)[2]	River Frontage 1=yes[2]	Length of River Front (feet)[2]	Riparian Area in trees (square feet)[5]
75000	950705	0.39	1500	1910	120	7903	46294	0	0	0
275000	950719	14.18	2844	1976	140	1905	16506	0	0	0
255000	950720	5.00	2007	1991	140	1905	42607	0	0	0
98800	950820	0.54	1268	1991	130	7903	41191	0	0	0
88000	950908	2.87	864	1930	120	7902	92185	0	0	0
172000	950913	2.20	3085	1910	130	1905	25882	1	500	27500
151500	950915	1.89	1152	1978	130	1905	27343	1	135	0
129900	950918	0.68	1132	1980	140	7902	83739	0	0	0
260000	950925	1.02	2716	1972	150	1905	28850	1	336	6720
85000	951215	6.77	880	1967	120	7902	99851	1	494	12350
179900	951215	5.02	1172	1959	130	1905	13011	0	0	0
219000	960209	4.26	1724	1979	140	1905	27095	0	0	0
30000	960215	0.34	864	1938	120	7902	48630	0	0	0
209900	960305	2.44	2224	1945	130	7902	48450	0	0	0
180000	960528	2.98	1600	1960	130	1905	21700	0	0	0
80000	960530	2.14	862	1920	120	7902	54263	0	0	0
250000	960624	8.46	1755	1978	140	1905	20334	0	0	0
162000	960628	0.99	1507	1973	140	1905	20739	0	0	0
122500	960715	0.40	1436	1924	130	7902	53770	0	0	0
113000	960718	1.35	1890	1947	130	7902	51492	0	0	0
132000	960731	0.75	1168	1952	130	1905	992	0	0	0
75000	960828	10.40	.	.	190	7902	85933	0	0	0
205000	960903	1.87	.	.	190	1905	27652	0	0	0
79900	960913	0.46	1440	1920	130	7903	44043	0	0	0
197000	960925	1.60	1608	1925	120	1905	24460	0	0	0
120000	961024	1.83	1032	1928	120	7902	37182	0	0	0
180500	961105	7.53	2238	1990	140	7902	47732	0	0	0
52500	961114	0.24	725	1925	120	7903	43738	0	0	0
90000	961114	2.00	1586	1945	130	1905	29876	0	0	0
345000	961122	4.90	3414	1981	150	1905	27652	0	0	0

[1] Lane County Department of Assessment and Taxation, Eugene, Oregon.
[2] GIS tax lot coverage.
[3] Stat. classes 110, 120 and 190 represent low quality housing; classes 150 and 160 represent high quality housing. All other classes are medium quality housing.
[4] Levy code 7902, 7903 and 7904 are within the Marcola school district.
[5] Aerial photo interpretation.

Table B.10. Data for Stylized representation of Shotgun Creek

Distance from Mohawk (feet)	Elevation (feet)[1]	Stream Width (feet)[2]	Channel Depth (feet)[2]	Flow (cfs)[2]	Velocity (cfs/s)	Percent Bedrock (percent)[2]	Stream Bed Slope (percent)[3]
0	600.00	20.00	2.50	3.00	0.06	0.00	1.67
1000	616.67	22.00	0.50	2.20	0.20	12.60	1.67
3000	650.00	28.00	1.00	2.75	0.10	12.60	1.67
5000	683.33	30.00	1.00	2.56	0.09	12.60	1.67
7000	716.67	15.00	0.50	2.00	0.27	50.00	1.67
9000	750.00	26.50	2.00	2.30	0.04	75.00	1.67
11000	783.33	25.00	1.50	2.20	0.06	35.00	1.67
13000	816.67	35.00	0.75	2.00	0.08	10.00	1.67
15000	850.00	32.00	0.75	2.00	0.08	25.00	1.67
17000	883.33	22.00	0.75	2.20	0.13	0.00	1.67
19000	930.00	18.00	0.50	1.90	0.21	0.00	3.00
21000	990.00	24.00	1.00	1.20	0.05	20.00	3.00
23000	1050.00	15.00		0.70	0.01	50.00	3.00
25000	1110.00	12.00		0.70	0.02	70.00	3.00
27000	1170.00	18.00	0.75	1.10	0.08	0.00	3.00
29000	1400.00	10.00	0.50	0.60	0.12	0.00	20.00
31000	1800.00	9.00	0.75	0.50	0.07	0.00	20.00

Table B.10. (continued)

Distance from Mohawk (feet)	Tree Type[3]	Tree Height (feet)	Vegetation Shade Angle (degrees)	Canopy Cover (percent)[4]	Topographic Shade Angle (Right) (degrees)	Topographic Shade Angle (Left) (degrees)	Buffer Width (feet)[4,5]
0	YC	120	85.23	80.00	6.01	13.42	100
1000	YC	120	84.75	80.00	5.90	13.06	100
3000	YC	120	83.33	90.00	5.68	12.34	100
5000	MC	140	83.87	90.00	5.46	11.61	100
7000	OH	80	84.63	25.00	5.24	10.88	100
9000	OH	80	80.59	80.00	5.01	10.15	100
11000	MH	80	81.11	20.00	4.79	9.41	100
13000	YH	50	70.70	70.00	4.57	8.67	100
15000	YH	50	72.25	70.00	4.35	7.93	100
17000	MH	80	82.16	85.00	4.13	7.18	100
19000	OH	80	83.57	50.00	20.71	12.21	100
21000	OH	80	81.46	40.00	18.69	11.39	100
23000	OH	80	84.63	95.00	16.62	10.56	100
25000	OH	80	85.70	50.00	14.50	9.73	100
27000	OH	80	83.57	90.00	11.79	17.13	100
29000	OH	80	86.41	90.00	7.55	13.06	100
31000	OH	80	86.77	95.00	0.00	5.68	100

[1] Oregon Atlas and Gazetteer (1991).
[2] Personal communication, Karen Dodge, Eugene BLM.
[3] BLM (1995)
[4] Aerial photograph interpretation.
[5] Oregon Forest Practices Act minimum widths assumed.

Table B.11. Data for Stylized representation of Parsons Creek

Distance from Mohawk (feet)	Elevation (feet)[1]	Aspect (degrees)[1]	Stream Width (feet)[2,3,4]	Channel Depth (feet)[2,3]	Flow (cfs)[5]	Velocity (cfs/s)	Percent Bedrock (percent)[2,6]	Stream Bed Slope (percent)[6]
0	500	180	15.00	1.31	2.90	0.15	12.60	0.02
2000	533	180	18.00	1.25	2.71	0.12	12.60	0.02
4000	566	180	18.00	1.19	2.52	0.12	12.60	0.02
6000	600	130	10.00	1.14	2.34	0.21	12.60	0.04
8000	671	130	10.00	1.08	2.15	0.20	12.60	0.04
10000	742	130	10.00	1.02	1.98	0.19	12.60	0.04
12000	813	130	11.41	0.96	1.80	0.16	12.60	0.04
14000	884	130	12.82	0.90	1.63	0.14	12.60	0.04
16000	955	97	14.23	0.85	1.46	0.12	12.60	0.04
18000	1025	97	15.64	0.79	1.30	0.11	12.60	0.04
20000	1100	97	17.06	0.79	1.14	0.08	0.00	
22000	1300	97	17.06	0.79	0.98	0.07	0.00	
24000	1400	97	17.06	0.79	0.84	0.06	0.00	
26000	1500	97	15.91	0.80	0.69	0.05	12.60	0.05
28000	1600	97	14.75	0.80	0.55	0.05	12.60	0.05
30000	1700	97	13.60	0.80	0.42	0.04	12.60	0.05
32000	1800	97	12.45	0.80	0.30	0.03	12.60	0.05
34000	1900	97	11.30	0.80	0.19	0.02	12.60	0.05
36000	2000	97	10.15	0.80	0.09	0.01	12.60	0.25

Table B.11. (continued)

Distance from Mohawk (feet)	Tree Type[6]	Tree Height (feet)	Vegetation Shade Angle (degrees)	Canopy Cover (percent)[2,3]	Topographic Shade Angle (right) (degrees)	Topographic Shade Angle (left) (degrees)	Buffer Width (feet)[3,7]
0	Mix.H	80	84.63	30	3.32	1.90	20
2000	Mix.H	80	83.57	55	3.16	1.74	60
4000	Mix.H	80	83.57	55	4.24	9.58	40
6000	Mix.H	80	86.41	55	4.01	9.24	40
8000	Mix.H	80	86.41	65	3.54	8.52	40
10000	Mix.H	80	86.41	30	3.07	7.80	40
12000	Mix.H	80	85.91	50	2.59	7.08	
14000	Mix.H	80	85.41	50	16.82	10.76	
16000	Mix.H	80	84.91	50	15.89	10.35	
18000	Mix.H	80	84.40	50	14.96	9.94	
20000	H and YC	120	85.92	67	13.96	9.51	
22000	H and YC	120	85.92	64	11.25	8.34	
24000	YC	50	80.31	82	9.87	7.75	
26000	YC	120	86.20	70	8.48	7.16	
28000	YC	120	86.47	70	7.08	6.57	
30000	YC	120	86.74	70	5.68	5.98	
32000	YC	120	87.02	70	4.26	5.38	
34000	CS	50	83.54	70	2.85	4.79	
36000	CS	50	84.19	70	1.42	4.19	

[1] Oregon Atlas and Gazetteer (1991).
[2] ODFW - Aquatic Inventory.
[3] Aeriai photo interpretation.
[4] Some points are estimated.
[5] Estimated using regression equation developed from Shotgun Creek.
[6] BLM (1995).
[7] Oregon Forest Practices Act, minimum widths assumed.

Table B.12. Data for Stylized representation of Mill Creek

Distance from Mohawk (feet)	Elevation (feet)[1]	Aspect (degrees)[1]	Stream Width (feet)[2,3,4]	Channel Depth (feet)[2,3]	Flow (cfs)[5]	Velocity (cfs/s)	Percent Bedrock (percent)[2,3]	Stream Bed Slope (percent)[6]
0	535	270	30.50	1.64	4.75	0.09	8.00	0.80
2000	555	270	30.50	1.64	4.54	0.09	58.00	0.80
4000	578	270	30.50	1.64	4.33	0.09	0.00	0.80
6000	592	270	30.50	1.64	4.12	0.08	15.00	0.80
8000	606	270	30.50	1.64	3.91	0.08	27.00	0.80
10000	620	270	30.50	1.64	3.71	0.07	23.00	0.80
12000	635	270	30.50	1.64	3.51	0.07	65.00	0.80
14000	663	270	24.60	1.54	3.31	0.09	23.00	1.10
16000	692	270	25.26	1.94	3.11	0.06	62.00	1.30
18000	720	270	28.54	1.87	2.92	0.05	8.00	1.10
20000	723	270	26.57	1.41	2.73	0.07	31.00	1.80
22000	777	270	24.60	1.54	2.54	0.07	19.00	1.40
24000	806	270	24.60	1.54	2.35	0.06	35.00	1.40
26000	820	270	19.02	1.57	2.17	0.07	0.00	2.20
28000	863	270	19.02	1.57	1.99	0.07	88.00	2.20
30000	906	270	19.02	1.57	1.82	0.06	46.00	2.20
32000	948	270	19.02	1.57	1.65	0.05	8.00	2.20
34000	991	270	19.02	1.57	1.48	0.05	0.00	2.20
36000	1034	270	15.74	1.15	1.31	0.07	0.00	3.00
38000	1091	270	15.74	1.15	1.15	0.06	8.00	3.00
40000	1177	270	15.74	1.15	1.00	0.06	8.00	3.00
42000	1371	270	14.38	1.15	0.85	0.05	8.00	8.00
44000	1542	270	13.46	1.15	0.71	0.05	8.00	8.00
46000	1713	270	12.55	1.15	0.57	0.04	8.00	8.00
48000	1884	270	11.63	1.15	0.44	0.03	8.00	8.00
50000	2055	270	10.72	1.15	0.31	0.03	8.00	8.00
52000	2226	270	9.81	1.15	0.20	0.02	8.00	8.00
54000	2400	270	8.89	1.15	0.10	0.01	8.00	8.00
56000	2400	270	7.98	1.15	0.02	0.00	8.00	8.00

Table B.12. (continued)

Distance from Mohawk (feet)	Tree Type[2]	Tree Height (feet)	Vegetation Shade Angle (degrees)	Canopy Cover[2,7] (percent)	Topographic Shade Angle (right) (degrees)	Topographic Shade Angle (left) (degrees)	Buffer Width (feet)[4,8]
0	YH	30	63.04	55	0.28	2.47	40
2000	YH	30	63.04	55	0.28	2.47	40
4000	YH	30	63.04	30	0.28	2.47	35
6000	YH	30	63.04	47	0.28	2.47	60
8000	YH	30	63.04	77	3.72	8.32	60
10000	YH	30	63.04	55	3.72	8.32	40
12000	YH	30	63.04	30	3.72	8.32	60
14000	YH/C	22	60.78	30	3.72	8.32	30
16000	YH/C	75	80.43	30	3.72	8.32	30
18000	YH	17	49.99	90	8.15	4.22	90
20000	H	30	66.11	90	8.15	4.22	90
22000	YH/C	22	60.78	90	8.15	4.22	90
24000	YH/C	22	60.78	90	8.14	5.88	90
26000	YH/C	25	69.16	30	8.14	5.88	80
28000	YH/C	25	69.16	50	8.14	5.88	100
30000	YH/C	25	69.16	50	7.69	5.66	100
32000	YH/C	25	69.16	50	7.69	5.66	100
34000	YH/C	25	69.16	50	10.14	10.69	100
36000	H and C	80	84.37	80	10.14	10.69	100
38000	H and C	80	84.37	80	10.14	10.69	100
40000	H and C	80	84.37	80	6.98	8.04	100
42000	MMD	80	84.85	80	6.98	8.04	100
44000	MMD	80	85.18	80	6.98	8.04	100
46000	MMD	80	85.50	80	5.68	5.68	100
48000	MMD	80	85.83	80	5.68	5.68	100
50000	MMD	80	86.16	80	0.64	1.71	100
52000	MYD	25	78.89	80	0.64	1.71	100
54000	MYD	25	79.91	80	0.64	1.71	100
56000	MYD	25	80.92	80	0.64	1.71	100

[1] Oregon Atlas and Gazetteer (1991).
[2] Stream survey data from ODFW (199X).
[3] Some points are estimated.
[4] Aerial photo interpretation.
[5] Estimated using regression equation developed from Shotgun Creek.
[6] Elevation change/Distance.
[7] Weyerhaeuser (1994).
[8] Oregon Forest Practices Act, minimum widths assumed.

Table B.13. Data for Stylized representation of Cash Creek

Distance from Mohawk (feet)	Elevation (feet)[1]	Aspect (degrees)[1]	Stream Width (feet)[2,3]	Channel Depth (feet)[2,3]	Flow (cfs)[2,4]	Velocity (cfs/s)	Percent Bedrock (percent)[2,5]	Stream Bed Slope (percent)[5]
0	600	135	12.00	0.35	2.52	0.60	7.40	0.03
1500	650	135	12.00	0.35	2.38	0.57	7.40	0.03
2500	680	135	12.00	0.35	2.29	0.54	7.40	0.03
4500	740	135	8.00	0.75	2.11	0.35	7.40	0.03
6500	800	135	8.00	0.40	1.93	0.60	7.40	0.03
8500	870	135	9.00	0.30	2.00	0.74	0.00	0.04
10500	940	135	10.00	0.50	2.00	0.40	0.00	0.04
12500	1020	72	16.00	0.30	1.50	0.31	10.00	0.04
14500	1100	72	14.90	0.29	1.26	0.29	7.40	0.04
16500	1200	72	13.80	0.28	1.10	0.28	7.40	0.05
18500	1320	72	12.70	0.27	0.94	0.28	7.40	0.06
20500	1440	72	11.60	0.26	0.80	0.26	7.40	0.06
22500	1575	72	10.50	0.25	0.65	0.25	7.40	0.08
24500	1725	72	9.40	0.24	0.52	0.23	7.40	0.08
26500	1875	72	8.30	0.23	0.39	0.20	7.40	0.08
28500	2025	72	7.20	0.22	0.27	0.17	7.40	0.08
30500	2200	72	6.10	0.21	0.16	0.13	7.40	0.10
32500	2400	72	5.00	0.20	0.07	0.07	7.40	0.10

Table B.13. (continued)

Distance from Mohawk (feet)	Tree Type[5]	Tree Height (feet)	Vegetation Shade Angle (feet)	Canopy Cover (percent)[2,6]	Topographic Shade Angle (right) (degrees)	Topographic Shade Angle (left) (degrees)	Buffer Width (feet)[6,7]
0	YC	120	87.13	30	4.76	3.79	20
1500	YC	120	87.13	30	4.50	3.16	20
2500	YC	120	87.13	30	4.34	2.78	20
4500	YC	120	88.08	70	4.98	2.28	100
6500	YC	120	88.08	70	4.33	1.42	100
8500	YC	120	87.84	95	3.58	0.43	100
10500	YC	120	87.60	80	3.98	0.00	100
12500	YC	120	86.17	85	3.41	0.00	100
14500	YC	120	86.44	70	2.85	0.00	100
16500	MM	80	85.06	70	11.25	0.00	100
18500	YC	120	86.96	70	6.05	13.42	100
20500	YC	120	87.22	70	7.13	0.98	100
22500	YC	120	87.48	70	5.68	0.00	100
24500	YC	120	87.75	70	4.06	0.00	100
26500	YC	120	88.01	70	2.44	0.00	100
28500	YC	120	88.27	70	8.48	1.07	100
30500	YC	120	88.53	70	6.30	0.00	100
32500	YC	120	88.79	70	3.79	0.00	100

[1] Oregon Atlas and Gazetteer (1991).
[2] Personal communication, Karen Dodge, Eugene BLM.
[3] Some data points are estimated.
[4] Estimated using regression equation developed from Shotgun Creek.
[5] BLM (1995).
[6] Aerial photo interpretation.
[7] Oregon Forest Practices Act, minimum widths assumed.

Table B.14. Data for Stylized representation of McGowan Creek

Distance from Mohawk (feet)	Elevation (feet)[1]	Aspect (degrees)[1]	Stream Width (feet)[2,3]	Channel Depth (feet)[2,3]	Flow (cfs)[2,3,4]	Velocity (cfs/s)	Percent Bedrock (percent)[2,5]	Stream Bed Slope (percent)[5]
0	500	156	12.00	1.00	1.60	0.13	4.00	0.01
1000	505	156	12.00	0.96	1.60	0.14	4.00	0.01
3000	520	156	12.00	0.89	1.55	0.14	4.00	0.01
5000	540	95	11.00	0.82	1.45	0.16	4.00	0.01
7000	560	95	10.00	0.75	1.35	0.18	4.00	0.01
9000	580	95	10.00	0.68	1.25	0.18	4.00	0.01
11000	642	146	9.00	0.61	1.15	0.21	4.00	0.04
13000	726	146	9.00	0.54	1.05	0.22	0.00	0.04
15000	810	146	9.00	0.50	0.96	0.21	0.00	0.04
17000	900	146	9.00	0.50	0.88	0.20	4.00	0.05
19000	1050	146	9.00	0.50	0.81	0.18	4.00	0.08
21000	1200	146	9.00	0.50	0.73	0.16	4.00	0.08
23000	1400	146	9.00	0.50	0.65	0.15	4.00	0.10
25000	1600	146	9.00	0.50	0.58	0.13	4.00	0.10
27000	1800	146	9.00	0.50	0.50	0.11	4.00	0.10

Table B.14. (continued)

Distance from Mohawk (feet)	Tree Type[5]	Tree Height (feet)	Vegetation Shade Angle (feet)	Canopy Cover (percent)[2,3,6]	Topographic Shade Angle (right) (degrees)	Topographic Shade Angle (left) (degrees)	Buffer Width (feet)[6,7]
0	Ag	3	26.56	10	3.79	2.33	10
1000	Ag	3	26.56	10	3.77	2.30	10
3000	OH	80	85.70	90	3.72	2.21	20
5000	OH	80	86.06	30	2.21	6.01	10
7000	OH	80	86.41	80	2.14	5.88	60
9000	MH	80	86.41	30	2.08	5.76	30
11000	MH	80	86.77	80	10.94	6.80	60
13000	MH	80	86.77	70	10.32	6.14	
15000	MH	80	86.77	80	14.39	11.65	
17000	MH	80	86.77	80	13.42	10.62	
19000	YC	120	87.84	80	11.79	8.88	
21000	YC	120	87.84	80	10.15	7.13	
23000	MH	80	86.77	80	7.92	4.76	
25000	MH	80	86.77	80	5.68	2.39	
27000	MH	80	86.77	80	3.41	0.00	

[1] Oregon Atlas and Gazetteer (1991).
[2] Personal communication, Karen Dodge, Eugene BLM.
[3] Some points are estimated.
[4] Flow at 2000ft is from Oregon Water Resources Department. Flow at 14000ft is from USGS-WRD.
[5] BLM (1995).
[6] Aerial photo interpretation.
[7] Oregon Forest Practices Act, minimum widths assumed.

Table B.15. Data for Stylized representation of the Mohawk River

Distance from Mohawk (feet)	Elevation (feet)[1]	Aspect (degrees)[1]	Stream Width (feet)[2,3,4]	Channel Depth (feet)[2,5]	Flow (cfs)[3,6]	Velocity (cfs/s)	Percent Bedrock (percent)[2,6]	Stream Bed Slope (percent)[7]
0	450	220	48.00	0.76	40.09	1.10	21.00	0.21
1000	452	220	48.00	0.76	39.89	1.09	21.00	0.21
3000	456	220	48.00	0.77	39.48	1.06	21.00	0.21
5000	461	220	48.00	0.78	39.07	1.04	21.00	0.21
7000	465	220	48.00	0.79	38.67	1.02	21.00	0.21
9000	469	220	48.00	0.80	38.26	1.00	21.00	0.21
11000	473	220	48.00	0.81	37.85	0.97	21.00	0.21
13000	477	220	48.00	0.82	37.45	0.95	21.00	0.21
15000	482	220	48.00	0.83	37.04	0.93	21.00	0.21
17000	486	220	48.00	0.84	36.63	0.90	21.00	0.21
19000	490	220	48.00	0.86	36.23	0.88	21.00	0.21
21000	494	220	40.00	1.04	35.82	0.86	21.00	0.21
23000	499	220	40.00	1.06	35.41	0.83	21.00	0.21
25000	503	220	40.00	1.08	35.01	0.81	21.00	0.21
27000	507	220	40.00	1.10	34.60	0.79	21.00	0.21
29000	511	220	60.00	0.74	34.19	0.77	21.00	0.21
30000	513	220	60.00	0.75	33.99	0.75	21.00	0.21
32000	518	220	60.00	0.77	33.58	0.73	21.00	0.21
34000	522	220	40.00	1.17	33.18	0.71	21.00	0.21
36000	526	220	35.00	1.37	32.86	0.68	21.00	0.21
38000	530	220	35.00	1.41	32.54	0.66	21.00	0.21
40000	535	220	30.00	1.68	32.22	0.64	21.00	0.21
42000	539	220	50.00	1.04	31.90	0.62	21.00	0.21
44000	543	220	50.00	1.07	31.58	0.59	21.00	0.21
46000	547	220	40.00	1.37	31.26	0.57	21.00	0.21
47000	549	220	40.00	1.39	31.10	0.56	21.00	0.21
49000	554	220	40.00	1.44	30.78	0.53	21.00	0.21
51000	558	220	30.00	1.98	30.46	0.51	21.00	0.21
53000	562	220	30.00	2.06	30.14	0.49	21.00	0.21
55000	566	220	27.00	2.37	29.82	0.47	21.00	0.21
57000	570	220	25.00	2.66	29.50	0.44	21.00	0.21
59000	575	220	25.00	2.62	27.55	0.42	21.00	0.21
61000	579	220	25.00	2.58	25.59	0.40	21.00	0.21
62000	581	220	25.00	2.56	24.62	0.39	21.00	0.21
64000	585	220	25.00	2.50	22.66	0.36	21.00	0.21
66000	589	220	25.00	2.44	20.71	0.34	21.00	0.21
67000	592	220	25.00	2.41	19.73	0.33	21.00	0.21
69000	596	220	25.00	2.33	17.78	0.30	21.00	0.21
71000	600	220	25.00	2.42	17.01	0.28	21.00	0.21
73000	611	220	25.00	2.51	16.24	0.26	21.00	0.53
75000	621	220	25.00	2.63	15.48	0.24	21.00	0.53
77000	632	220	25.00	2.77	14.71	0.21	21.00	0.53
79000	643	220	25.00	2.94	13.94	0.19	21.00	0.53
81000	653	220	25.00	3.16	13.17	0.17	21.00	0.53
83000	664	220	25.00	3.46	12.41	0.14	21.00	0.53
85000	674	220	25.00	3.86	11.64	0.12	21.00	0.53
87000	685	220	38.05	2.36	10.87	0.12	0.00	1.20
89000	711	250	38.05	2.36	10.10	0.11	0.00	1.20
91000	737	250	38.05	2.36	9.34	0.10	18.31	1.20
93000	763	250	38.05	2.36	8.57	0.10	49.30	1.20

Table B.15. (continued)

Distance from Mohawk (feet)	Tree Type[2]	Tree Height (feet)	Vegetation Shade Angle (degrees)	Canopy Cover (percent)[2,4,8]	Topographic Shade Angle (right) (degrees)	Topographic Shade Angle (left) (degrees)	Buffer Width (feet)[4,8,9]
0	OH	80	73.29	20	5.36	7.21	20
1000	OH	80	73.29	20	5.35	7.20	20
3000	OH	20	39.80	20	5.33	7.17	20
5000	OH	80	73.29	20	5.31	7.14	20
7000	OH	20	39.80	20	5.30	7.11	20
9000	OH	80	73.29	20	5.28	7.08	20
11000	OH	80	73.29	20	5.26	7.05	20
13000	OH	20	39.80	20	6.88	8.79	20
15000	YH	20	39.80	10	6.87	8.77	20
17000	YH	20	39.80	10	6.85	8.74	20
19000	YH	50	64.35	20	6.83	8.71	20
21000	YH	50	68.19	30	4.72	7.59	30
23000	YH	50	68.19	30	4.71	7.56	30
25000	YH	50	68.19	30	4.70	7.53	20
27000	YH	50	68.19	30	4.68	7.50	20
29000	YH	50	59.03	20	4.67	7.47	30
30000	OH	60	63.43	20	4.67	7.45	15
32000	OH	60	63.43	20	4.65	7.42	15
34000	OH	60	71.56	20	4.99	6.16	15
36000	OH	60	73.73	20	4.98	6.12	20
38000	OH	80	77.65	30	4.97	6.08	100
40000	OH	80	79.37	30	6.92	7.54	100
42000	OH	20	38.65	10	6.91	7.49	10
44000	OH	80	72.64	30	6.89	7.44	25
46000	OH	80	75.95	30	4.21	5.88	25
47000	OH	80	75.95	55	4.20	5.87	40
49000	OH	80	75.95	55	4.19	5.85	40
51000	OH	80	79.37	55	4.18	5.84	40
53000	OH	80	79.37	55	4.18	5.82	20
55000	R	80	80.41	55	4.17	5.81	30
57000	R	80	81.11	55	5.51	3.78	30
59000	R	80	81.11	55	5.50	3.77	20
61000	R	80	81.11	55	5.49	3.76	20
62000	R	80	81.11	55	5.48	3.76	30
64000	R	80	81.11	55	5.47	3.75	30
66000	R	80	81.11	55	4.15	3.21	50
67000	OH	80	81.11	55	4.14	3.19	50
69000	OH	80	81.11	55	4.13	3.15	50
71000	YC	120	84.04	55	3.02	2.85	50
73000	YC	120	84.04	55	2.99	2.75	50
75000	YC	120	84.04	55	2.95	2.64	40
77000	OH	80	81.11	55	5.01	7.86	40
79000	H/CM	120	84.04	55	4.92	7.77	40
81000	H/CM	120	84.04	55	4.82	7.67	40
83000	H/CM	120	84.04	55	2.51	3.12	40
85000	MH	80	81.11	55	2.46	3.08	40
87000	H/C	30	57.61	68	2.41	3.04	100
89000	H/C	30	57.61	68	2.29	2.95	100
91000	H/C	30	57.61	92	2.17	2.85	100
93000	H/C	30	57.61	76	2.04	2.75	100

Table B.15. (continued)

Distance from Mohawk (feet)	Elevation (feet)[1]	Aspect (degrees)[1]	Stream Width (feet)[2,3,4]	Channel Depth (feet)[2,5]	Flow (cfs)[3,6]	Velocity (cfs/s)	Percent Bedrock (percent)[2,6]	Stream Bed Slope (percent)[7]
95000	790	250	38.05	2.36	7.80	0.09	49.30	1.20
97000	816	250	38.05	2.36	7.61	0.08	59.15	1.20
99000	842	250	38.05	2.36	7.43	0.08	30.99	1.20
101000	870	250	32.47	1.84	7.24	0.12	29.58	1.40
103000	898	250	32.47	1.84	7.05	0.12	2.82	1.40
105000	927	250	32.47	1.84	6.87	0.12	2.82	1.40
107000	955	310	32.47	1.84	6.68	0.11	45.07	1.40
109000	984	310	32.47	1.84	6.49	0.11	14.08	1.40
111000	1013	310	32.47	1.84	6.31	0.11	14.08	1.40
113000	1041	310	32.47	1.84	6.12	0.10	9.86	1.40
115000	1090	310	24.60	2.59	5.93	0.09	29.58	2.80
117000	1143	310	27.88	1.77	5.75	0.12	16.90	1.70
119000	1175	310	27.88	1.77	5.56	0.11	5.63	1.70
121000	1207	310	27.88	1.77	5.37	0.11	5.63	1.70
123000	1239	310	27.88	1.77	5.19	0.11	9.86	1.70
125000	1283	310	23.94	1.90	5.00	0.11	5.63	2.00

Table B.15. (continued)

Distance from Mchawk (feet)	Tree Type[2]	Tree Height (feet)	Vegetation Shade Angle (degrees)	Canopy Cover (percent)[2,4,8]	Topographic Shade Angle (right) (degrees)	Topographic Shade Angle (left) (degrees)	Buffer Width (feet)[4,8,9]
95000	H/C	30	57.61	76	1.92	2.65	100
97000	H/C	30	57.61	72	6.16	8.54	100
99000	H/C	30	57.61	92	5.99	8.37	100
101000	H	50	72.00	68	5.82	8.19	100
103000	H	50	72.00	35	5.65	8.00	100
105000	H	50	72.00	35	8.18	9.24	100
107000	H	50	72.00	47	7.98	9.07	100
109000	H	50	72.00	76	7.79	8.89	100
111000	H	50	72.00	76	7.59	8.71	100
113000	H	50	72.00	19	7.39	8.54	100
115000	H/C	70	80.02	99	7.06	8.24	100
117000	H/C	55	75.77	29	6.79	10.13	100
119000	H/C	55	75.77	82	6.62	9.87	100
121000	H/C	55	75.77	82	6.45	9.62	100
123000	H/C	55	75.77	92	6.28	9.37	100
125000	H	45	75.09	92	6.04	9.02	100

1 Oregon Atlas and Gazetteer (1991).
2 ODFW (199X).
3 USGS gauging station Number....
4 Aerial photo interpretation.
5 Calculated using estimates of width, flow and velocity.
6 Some data points are estimated.
7 Elevation change/Distance.
8 Weyerhaeuser (1994).
9 Oregon Forest Practices Act, minimum widths assumed.

Appendix C

Model Output

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**************Base riparian buffers base tax policy*********

* This model incorporates changes in consumer welfare
* in response to a greater riparian area planted in trees
* the welfare response is calculated as a change in property value
* property values are given on a per acre basis as an annuity
* value that extends to 30 years
* The discount rate is the mortgage lending rate.

SETS
      NRP NON RIVER FRONT PROPERTY TYPES
      /LOWNR          low value per acre properties not adjacent to the
                                                                    river
       MEDNR          medium value per acre properties not adjacent to
                                                                the river
       HIGHNR         high value per acre properties not adjacent to the
                                                                   river/

      RP RIVER FRONT PROPERTY TYPES
      /LOWRIV         low value per acre properties adjacent to the river
       MEDRIV         medium value per acre properties adjacent to the
                                                                    river
       HIGHRIV        high value per acre properties not adjacent to the
                                                                   river/

     LRP RIVERFRONT LAND TYPES
     / LLOWRIV        low value land acre next to river
       LMEDRIV        medium value land per acre next to river
       LHIGHRIV       high value land per acre next to river/

     LNRP NON RIVER LAND TYPES
      /LLOWNR         low value per acre non river residential property
       LMEDNR         medium value per acre non river residential
                                                                 property
       LHIGHNR        high value per acre non river residential property/

**now defining sets for the production aspect


     ACTRP  PRODUCTION ACTIVITIES ON RIVER FRONT LAND
      /FPB56RP        Public Forest activity age class 50 to 60 on Fl
                                                           riparian land
       FPB67RP                             age class 60 to 70
       FPBHVRP                             harvest 70 to 80
       FPBSTRP                             standing trees
       FPBPLRP                             reforrested acres
       FPV56RP        Private Forest activity age class 50 to 60 on Fl
                                                           riparian land
       FPV67RP                             age class 60 to 70
       FPVHVRP                             harvest 70 to 80
       FPVSTRP                             standing trees
       FPVPLRP                             reforreted acres
       F245RP         Small woodlot operation age class 40 to 50
       F2HVRP                              harvest age class 60 to 70
       F2STRP                              all other trees
       F2PLRP                              reforrested acres
       AHAYRP         Alfalfa hay riparian area
       GHAYLRP        Grass hay low yield practice riparian area
       MINTRP         Mint riparian area
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        WHTRP         Wheat riparian land
        BEANRP        Beans riparian land
        CORNRP        Corn riparian land
        BERRYRP       Berries riparian land
        NUTSRP        Hazelnuts riparian land/


      ACTNRP  PRODUCTION ACTIVITIES ON NON RIVER LAND
       /FPB56NRP      Public Forest activity age class 50 to 60 on F1
                                                         riparian land
        FPB67NRP                         age class 60 to 70
        FPBHVNRP                         harvest 70 to 80
        FPBSTNRP                         standing trees
        FPBPLNRP                         reforrested acres
        FPV56NRP      Private Forest activity age class 50 to 60 on F1
                                                         riparian land
        FPV67NRP                         age class 60 to 70
        FPVHVNRP                         harvest 70 to 80
        FPVSTNRP                         standing trees
        FPVPLNRP                         refforested acres
        F245NRP       Small woodlot operation age class 40 to 50
        F2HVNRP                          harvest age class 60-70
        F2STNRP                          all other trees
        F2PLNRP                          reforrested acres
        F2SMLNRP      Small woodlot operation on F2 non  riparian land
        AHAYNRP       Alfalfa hay non riparian area
        GHAYLNRP      Grass hay low yield production non riparian area
        MINTNRP       Mint non riparian area
        WHTNRP        Wheat non riparian land
        BEANNRP       Beans non riparian land
        CORNNRP       Corn non riparian land
        BERRYNRP      Berries non riparian land
        NUTSNRP       Hazelnuts non riparian land/


      LPRODRP  RIVER FRONT PRODUCTION LAND TYPES
       /F1PUBRP       F1 public river front property in production
        F1PRIRP       F1 private river front property in production
        F2RP          F2 river front property in production
        RDEVRP        Residential developed river front property in
                                                            production
        RRRP          Rural residential river front property in
                                                            production
        OTHRP         Other river front property in production
        E40RP         E40 agriculture river front property in production/


      LPRODNRP  NON RIVER PRODUCTION LAND TYPES
       /F1PUBNRP      F1 public non river property in production
        F1PRINRP      F1 private non river property in production
        F2NRP         F2 non river property in production
        RDEVNRP       Residential developed non river front property in
                                                            production
        RRNRP         Rural residential non river front property in
                                                            production
        OTHNRP        Other non river front property in production
        E40NRP        E40 agriculture non river front property in
                                                           production/

**finish defining sets for production aspect

**start defining cattle production

    COWRP    CATTLE PRODUCTION ON RIVER PROPERTY
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      /COW1RP   1 cow on river property/

    COWNRP    CATTLE PRODUCTION ON NON RIVER PROPERTY
      /COW1NRP   1 cow on non river/;

***end cattle definitions


TABLE AREARP(LRP,RP)  ACRES TAKEN BY EACH UNIT OF RIVER PROPERTY
                      LOWRIV       MEDRIV     HIGHRIV
       LLOWRIV          1
       LMEDRIV                       1
       LHIGHRIV                                  1;


TABLE AREANRP(LNRP,NRP) ACRES TAKEN BY EACH UNIT OF NON RIVER PROPERTY
                      LOWNR         MEDNR      HIGHNR
       LLOWNR          1
       LMEDNR                        1
       LHIGHNR                                   1;


PARAMETERS

* The price for river property per acre is defined below

     PRCE1NRP(NRP) mean value non annuity per acre of non river
                                                              properties
      /LOWNR       11364
       MEDNR       41292
       HIGHNR      143394/

     MEANVAL2(NRP) mean property value non annuity for non river
                                                              properties
     /LOWNR        101367
      MEDNR        132959
      HIGHNR       120451/

     MNSIZE(NRP) mean size of non river properties
     /LOWNR        8.92
      MEDNR        3.22
      HIGHNR       0.84/

     LANDRP(LRP) total acres of Mohawk currently taken by river
                                                              properties
     / LLOWRIV     744
       LMEDRIV     203
       LHIGHRIV    16/

     LANDNRP(LNRP) total acres of Mohawk currently taken by non river
                                                              properties
      /LLOWNR      1933
       LMEDNR      740
       LHIGHNR     237/

*production land parameters

     PRICERP(ACTRP) Price per unit of activity produced on production
                                                           riparian land
      /FPB56RP     525
       FPB67RP     525
       FPBHVRP     650
       FPBSTRP       0
       FPBPLRP       0
```

```
         FPV56RP     525
         FPV67RP     525
         FPVHVRP     650
         FPVSTRP       0
         FPVPLRP       0
         F245RP      525
         F2HVRP      650
         F2STRP        0
         F2PLRP        0
         AHAYRP      101.78
         GHAYLRP     64.76
         MINTRP      14.11
         WHTRP       3.90
         BEANRP      183.30
         CORNRP      82.31
         BERRYRP     0.415
         NUTSRP      0.37/

      PRICENRP(ACTNRP) Price per unit of activity produced on production
                                                      non riparian land
        /FPB56NRP     525
         FPB67NRP     525
         FPBHVNRP     650
         FPBSTNRP       0
         FPBPLNRP       0
         FPV56NRP     525
         FPV67NRP     525
         FPVHVNRP     650
         FPVSTNRP       0
         FPVPLNRP       0
         F245NRP      525
         F2HVNRP      650
         F2STNRP        0
         F2PLNRP        0
         AHAYNRP      101.78
         GHAYLNRP     64.76
         MINTNRP      14.11
         WHTNRP       3.90
         BEANNRP      183.30
         CORNNRP      82.31
         BERRYNRP     0.415
         NUTSNRP      0.37/

** note that all activities are in different units eg tons lbs board
                                                             feet etc

*the following cost figures include all expenditure except land taxes
**cost is per acre for all forest and crops


      COSTRP(ACTRP)  Variable Cost per acre of activity produced on
                                              production riparian land
        /FPB56RP       0
         FPB67RP       0
         FPBHVRP       0
         FPBSTRP       0
         FPBPLRP       929
         FPV56RP       0
         FPV67RP       0
         FPVHVRP       0
         FPVSTRP       0
         FPVPLRP       929
         F245RP        0
         F2HVRP        0
```

```
          F2STRP       0
          F2PLRP      633
          AHAYRP      536.78
          GHAYLRP      91.40
          MINTRP      954.41
          WHTRP       511.27
          BEANRP      865.74
          CORNRP      616.37
          BERRYRP     7748.20
          NUTSRP      475.33/


        COSTNRP(ACTNRP)  Variable Cost per acre of activity produced on
                                            production non riparian land
         /FPB56NRP       0
          FPB67NRP       0
          FPBHVNRP       0
          FPBSTNRP       0
          FPBPLNRP      929
          FPV56NRP       0
          FPV67NRP       0
          FPVHVNRP       0
          FPVSTNRP       0
          FPVPLNRP      929
          F245NRP        0
          F2HVNRP        0
          F2STNRP        0
          F2PLNRP       633
          AHAYNRP       536.78
          GHAYLNRP      91.40
          MINTNRP       954.41
          WHTNRP        511.27
          BEANNRP       865.74
          CORNNRP       616.37
          BERRYNRP      7748.20
          NUTSNRP       475.33/

       TRCOWRP(COWRP)  Total revenue generated by each cow on river
                                                                property
         /COW1RP       367.24 /

       TRCOWNRP(COWNRP) Total revenue generated by each cow on non river
                                                                property
         /COW1NRP      367.24 /

       TCCOWRP(COWRP)   Total cost exludes owner land rent and property
                                                       tax river property
         /COW1RP        343.82/

       TCCOWNRP(COWNRP)  Cost exludes owner land rent and property tax non
                                                           river property
         /COW1NRP       343.82/


        ACPRORP(LPRODRP) total area in acres of production land types
                                                       adjacent to rivers
         /F1PUBRP       17831
          F1PRIRP       48892
          F2RP          1809
          RDEVRP        14
          RRRP          699
          OTHRP         352
          E40RP         2525/
```

```
      ACPRONRP(LPRODNRP) total area in acres of production land NOT
                                                     adjacent to rivers
       /F1PUBNRP      4935
        F1PRINRP      25259
        F2NRP         5337
        RDEVNRP       304
        RRNRP         1875
        OTHNRP        50
        E40NRP        3091/;


TABLE APRODRP(LPRODRP,ACTRP) ACRES OF EACH RIVER LAND TYPE TAKEN BY
                                                  EACH UNIT OF ACTIVITY
                 FPB56RP FPB67RP FPBHVRP AHAYRP GHAYLRP    BEANRP
        F1PUBRP     1       1        1
        F1PRIRP
        F2RP                                1      1          1
        RDEVRP                              1      1          1
        RRRP                                1      1          1
        OTHRP                               1      1          1
        E40RP                               1      1          1
         +       MINTRP     WHTRP     CORNRP     BERRYRP    NUTSRP
        F1PUBRP
        F1PRIRP
        F2RP       1          1          1          1          1
        RDEVRP     1          1          1          1          1
        RRRP       1          1          1          1          1
        OTHRP      1          1          1          1          1
        E40RP      1          1          1          1          1
         +        FPV56RP   FPV67RP   FPVHVRP    F245RP  F2HVRP  F2STRP
        F1PUBRP
        F1PRIRP      1         1         1
        F2RP                                       1       1       1
        RDEVRP
        RRRP                                       1       1       1
        OTHRP
        E40RP                                      1       1       1
         +        FPBSTRP     FPBPLRP    FPVSTRP   FPVPLRP    F2PLRP
        F1PUBRP      1           1
        F1PRIRP                            1          1
        F2RP                                                    1
        RDEVRP
        RRRP                                                    1
        OTHRP
        E40RP                                                   1 ;


TABLE APRODNRP(LPRODNRP,ACTNRP) ACRES OF EACH NON RIVER LAND TYPE TAKEN
                                             BY EACH UNIT OF ACTIVITY
               FPB56NRP FPB67NRP FPBHVNRP AHAYNRP GHAYLNRP  BEANNRP
   F1PUBNRP    1       1          1
   F1PRINRP
   F2NRP                                   1       1          1
   RDEVNRP                                 1       1          1
   RRNRP                                   1       1          1
   OTHNRP                                  1       1          1
   E40NRP                                  1       1          1
    +         MINTNRP WHTNRP CORNNRP BERRYNRP NUTSNRP
   F1PUBNRP
   F1PRINRP
   F2NRP       1         1         1         1         1
   RDEVNRP     1         1         1         1         1
   RRNRP       1         1         1         1         1
```

```
    OTHNRP        1         1         1         1         1
    E40NRP        1         1         1         1         1
     +        FPV56NRP  FPV67NRP  FPVHVNRP   F245NRP F2HVNRP  F2STNRP
    F1PUBNRP
    F1PRINRP      1          1          1
    F2NRP                                        1        1       1
    RDEVNRP
    RRNRP                                        1        1       1
    OTHNRP
    E40NRP                                       1        1       1
     +        FPBSTNRP    FPBPLNRP   FPVSTNRP   FPVPLNRP    F2PLNRP
    F1PUBNRP     1          1
    F1PRINRP                            1          1
    F2NRP                                                     1
    RDEVNRP
    RRNRP                                                     1
    OTHNRP
    E40NRP                                                    1 ;

 TABLE YIELDRP(LPRODRP,ACTRP) YIELD ON RIVER LAND TYPES
                 FPB56RP FPB67RP FPBHVRP AHAYRP GHAYLRP  BEANRP
         F1PUBRP  8.3      10.93  38.21
         F1PRIRP
         F2RP                             4.37    1.43    5.85
         RDEVRP                                   1.43
         RRRP                             4.47    1.43    5.85
         OTHRP
         E40RP                            4.47    1.43    5.85
           +       MINTRP WHTRP CORNRP BERRYRP NUTSRP
         F1PUBRP
         F1PRIRP
         F2RP      74     110     9.0    18000   2050
         RDEVRP
         RRRP      74     110     9.0    18000   2050
         OTHRP
         E40RP     74     110     9.0    18000   2050
          +        FPV56RP   FPV67RP   FPVHVRP    F245RP  F2HVRP  F2STRP
         F1PUBRP
         F1PRIRP   8.3        10.93      38.21
         F2RP                                       6        42       0
         RDEVRP
         RRRP
         OTHRP
         E40RP
          +        FPBSTRP    FPBPLRP    FPVSTRP    FPVPLRP    F2PLRP
         F1PUBRP   0          0
         F1PRIRP                          0          0
         F2RP                                                   0
         RDEVRP
         RRRP                                                   0
         OTHRP
         E40RP                                                  0;


 TABLE YIELDNRP(LPRODNRP,ACTNRP) YIELD ON NON RIVER LAND TYPES
              FPB56NRP FPB67NRP FPBHVNRP AHAYNRP GHAYLNRP  BEANNRP
   F1PUBNRP  8.3      10.93     38.21
   F1PRINRP
   F2NRP                                 5.57   1.43       5.85
   RDEVNRP                                      1.43
   RRNRP                                 4.15   1.43       5.85
   OTHNRP
   E40NRP                                4.9    1.43       5.85
     +        MINTNRP WHTNRP CORNNRP BERRYNRP NUTSNRP
```

```
    F1PUBNRP
    F1PRINRP
    F2NRP       74      110     9.0      18000      2050
    RDEVNRP
    RRNRP       74      110     9.0      18000      2050
    OTHNRP
    E40NRP      74      110     9.0      18000      2050
     +        FPV56NRP   FPV67NRP   FPVHVNRP    F245NRP  F2HVNRP  F2STNRP
     F1PUBNRP
     F1PRINRP   8.3        10.93      38.21
     F2NRP                                          6        42        0
     RDEVNRP
     RRNRP
     OTHNRP
     E40NRP
     +        FPBSTNRP    FPBPLNRP   FPVSTNRP   FPVPLNRP    F2PLNRP
    F1PUBNRP     0           0
    F1PRINRP                            0          0
    F2NRP                                                      0
    RDEVNRP
    RRNRP
    OTHNRP
    E40NRP                                                       ;


**land area requirements for herds of each type

TABLE ACCOWRP(LPRODRP,COWRP) LAND REQUIREMENTS IN ACRES FOR HERDS ON
                                                                  RIVER LAND
                COW1RP
   F1PUBRP
   F1PRIRP
   F2RP        1.248
   RDEVRP
   RRRP        1.019
   OTHRP
   E40RP       0.859;


TABLE ACCOWNRP(LPRODNRP,COWNRP) LAND REQUIREMENTS IN ACRES FOR HERDS ON
                                                              NON RIVER LAND
                 COW1NRP
   F1PUBNRP
   F1PRINRP
   F2NRP         1.298
   RDEVNRP
   RRNRP         1.136
   OTHNRP
   E40NRP        1.010;


*now try and define all the scalars and other information needed to
                                                     calculate river prices

PARAMETERS

     MEANVAL(RP) mean property value for river front properties
      /LOWRIV     119851
       MEDRIV     137979
       HIGHRIV    139039/

     MEANSIZE(RP)  mean property size in acres
      /LOWRIV     9.7
       MEDRIV     3.66
```

```
          HIGHRIV     1.25/

        MEANLGTH(RP)  mean river front length in feet
         /LOWRIV      574
          MEDRIV      324
          HIGHRIV     166/

        MEANWDTH(RP)  width of riparian buffer above base in feet
         /LOWRIV      37.24
          MEDRIV      37.24
          HIGHRIV     37.24/

        ORIGBUFF(RP) original buffer area on each property
         /LOWRIV      21375.76
          MEDRIV      12065.76
          HIGHRIV      6181.84 /;


SCALARS

        BUFCOEF  riparian buffer coefficient from hedonic model
                                                            /0.0000117/;

PARAMETER  PRCE1RP(RP) price adjustment as a result of planting a
                                                         riparian buffer;

        PRCE1RP('LOWRIV')= (MEANVAL('LOWRIV')/MEANSIZE('LOWRIV'))
                    -(((MEANVAL('LOWRIV')*BUFCOEF)*((MEANLGTH('LOWRIV')
                                   *MEANWDTH('LOWRIV'))-ORIGBUFF('LOWRIV')))
                    /MEANSIZE('LOWRIV'));
        PRCE1RP('MEDRIV')= (MEANVAL('MEDRIV')/MEANSIZE('MEDRIV'))
                    -(((MEANVAL('MEDRIV')*BUFCOEF)*((MEANLGTH('MEDRIV')
                                   *MEANWDTH('MEDRIV'))-ORIGBUFF('MEDRIV')))
                    /MEANSIZE('MEDRIV'));
        PRCE1RP('HIGHRIV')= (MEANVAL('HIGHRIV')/MEANSIZE('HIGHRIV'))
                    -(((MEANVAL('HIGHRIV')*BUFCOEF)*((MEANLGTH('HIGHRIV')
                                 *MEANWDTH('HIGHRIV'))-ORIGBUFF('HIGHRIV')))
                  /MEANSIZE('HIGHRIV'));


DISPLAY "THE CALCULATED PARAMETER",PRCE1RP;

**calculating the total amount of each land area that should be taken
                                                    out of production in
**reponse to planting varying riparion buffer widths

PARAMETERS

        FRNTLGTH(LPRODRP) total riparian frontage length in feet by
                                                production property type
         /F1PUBRP        111000
          F1PRIRP        226000
          F2RP           4400
          RDEVRP         4000
          RRRP           47000
          OTHRP          8000
          E40RP          77000 /


        BUFWDTH(LPRODRP) average riparian frontage width in feet by
                                                production property type
         /F1PUBRP        79.55
          F1PRIRP        82.17
          F2RP           39.09
```

```
          RDEVRP          40.00
          RRRP            53.40
          OTHRP           42.50
          E40RP           31.95/;

*calculating the area of land taken out of production due to riparian
                                                                    buffers

PARAMETERS

     ACMINUS(LPRODRP) acres taken out of production due to riparion
                                                                    buffer;

     ACMINUS('F1PUBRP')=(FRNTLGTH('F1PUBRP')*BUFWDTH('F1PUBRP'))/43560;

     ACMINUS('F1PRIRP')=(FRNTLGTH('F1PRIRP')*BUFWDTH('F1PRIRP'))/43560;

     ACMINUS('F2RP')=(FRNTLGTH('F2RP')*BUFWDTH('F2RP'))/43560;

     ACMINUS('RDEVRP')=(FRNTLGTH('RDEVRP')*BUFWDTH('RDEVRP'))/43560;

     ACMINUS('RRRP')=(FRNTLGTH('RRRP')*BUFWDTH('RRRP'))/43560;

     ACMINUS('OTHRP')=(FRNTLGTH('OTHRP')*BUFWDTH('OTHRP'))/43560;

     ACMINUS('E40RP')=(FRNTLGTH('E40RP')*BUFWDTH('E40RP'))/43560;

DISPLAY ACMINUS;

*calculating available land area for production minus riparian areas

PARAMETERS

     TOTACRP(LPRODRP)  total land area available for production
                                                 adjacent to rivers;

     TOTACRP(LPRODRP)=ACPRORP(LPRODRP)-ACMINUS(LPRODRP);

DISPLAY TOTACRP;


*Calculating the denominator to convert the objective function value
                                                          into an annuity


SCALARS

     DA  DISCOUNT RATE FOR ANNUITY             /0.08326/
     K   NUMBER OF YEARS                       /30/;

PARAMETERS
       DENOMRP(RP) denominator for annuity calculation river property
       DENOMNRP(NRP) denominator for annuity calculation non river
                                                              property;

       DENOMRP(RP)=((1/DA)*(1-(1/((1+DA)**K))));

       DENOMNRP(NRP)=((1/DA)*(1-(1/((1+DA)**K))));

DISPLAY DENOMRP, DENOMNRP;

******calculating the value of annual taxes both rp and nrp properties
```

```
SCALARS

     TAXRATE PROPERTY TAX RATE PAID BY EACH RESIDENTIAL PROPERTY
                                                                  /10.03/


PARAMETER TAXRP(RP) yearly tax payment for each class of riverside
                                                                property;

      TAXRP(RP)=((MEANVAL(RP)/MEANSIZE(RP))/1000)*TAXRATE;


PARAMETER TAXNRP(NRP) yearly tax payment for each class of non river
                                                                property;

      TAXNRP(NRP)=((MEANVAL2(NRP)/MNSIZE(NRP))/1000)*TAXRATE;


DISPLAY TAXRP,TAXNRP;

*****end of tax calculation for residential property

*********Start tax calcs for all other properties

PARAMETERS
    ASSVAL(LPRODRP) assessed value per acre of these land types
    /F1PUBRP         0
     F1PRIRP        95.25
     F2RP          325.91
     RDEVRP      14316.41
     RRRP        14316.41
     OTHRP           0
     E40RP         489.61/


   ASSVAL2(LPRODNRP) assessed value per acre of these land types
    /F1PUBNRP        0
     F1PRINRP       95.25
     F2NRP         325.91
     RDEVNRP     14316.41
     RRNRP       14316.41
     OTHNRP          0
     E40NRP        489.61/;


PARAMETER TAXPRP(LPRODRP) yearly per acre tax payments for river
                                                                property;

      TAXPRP(LPRODRP)=((ASSVAL(LPRODRP)/1000)*TAXRATE);

PARAMETER TAXPNRP(LPRODNRP) yearly per acre tax for non river property;

      TAXPNRP(LPRODNRP)=((ASSVAL2(LPRODNRP)/1000)*TAXRATE);




VARIABLES
    Z       objective value
    ACRP(RP)    acres of river properties
    ACNRP(NRP) acres of non river properties
    PRODRP(LPRODRP,ACTRP) acres of production of various activities by
                                                        river land type
    PRODNRP(LPRODNRP,ACTNRP) acres of production of activities on
```

```
                                                           nonriver land
      HERDRP(LPRODRP,COWRP)    herds on river land
      HERDNRP(LPRODNRP,COWNRP) herds on non river land
      REV1(RP)     total revenue on amenity river property
      REV2(NRP)    total rev on amentity non river property
      REV3(LPRODRP) total revenue river production land
      REV4(LPRODNRP) total revenue non river production;

POSITIVE VARIABLES ACRP,ACNRP,PRODRP,PRODNRP,HERDRP,HERDNRP;


EQUATIONS
    OBJ          objective function constrained utility maximisation
    ACRERP(LRP)  land constraint residential non river properties
    ACRENRP(LNRP)    land constraint for residential river properties
    LNDRP(LPRODRP)     land constraint for productive river land with
                                                       buffer adjustment
    LNDNRP(LPRODNRP)   land constraint for productive land non river
    BNRPRD(LPRODRP)    land constrain for no beans on residential
                                                     developed river land
    BNNRPRD(LPRODNRP) land constraint for no beans on residential
                                                   developed nonriver land
    TOTBER             total berries produced
    TOTMINT            total mint produced
    TOTNUT             total nuts produced
    TOTROT             total corn beans wheat produced
    CORNEQ             equality constraint
    WHTEQ              equality constraint
    BEANEQ             equality constraint
    HAYNOTF2           total hay production in areas which are not F2
    CF1PBRP(LPRODRP)    cow herd bounded on f1 public river land
    CF1PBNRP(LPRODNRP)  cow herd bounded on f1 public non river land
    CF1PVRP(LPRODRP)    cow herd bounded on f1 private river land
    CF1PVNRP(LPRODNRP)  cow herd bounded on f1 public non river land
    CRDEVRP(LPRODRP)    cow herd bounded on res dev rive property
    CRDEVNRP(LPRODNRP)  cow herd bounded on res dev non river property
    COTHRP(LPRODRP)      cow restriction on river other
    COTHNRP(LPRODNRP)   cow restriction on non river other
    COWTOT               total cow numbers in the watershed
    T56PB               tree production on public forest age 50 to 60
                                                                  land
    T67PB                tree production age 60 to 70 public land
    THVPB                tree harvest public land
    TPLPB                tree plant on public land
    TSTPB                tree standing public land
    T56PV                tree production private forest age 50 to 60
    T67PV                tree production private forest age 60 to 70
    THVPV                tree harvest private forest
    TPLPV                tree plant private land
    TSTPV                tree standing private land
    TF245                tree production age 40 to 50 on F2 lands
    TF2HV                tree production harvest F2 land
    TF2PL                tree planting on private land
    TF2ST                Tree production other non harvest F2 lands
    TREV1(RP)              total rev river amenity
    TREV2(NRP)             total rev non river amenityi
    TREV3(LPRODRP)           total reve river production
    TREV4(LPRODNRP)          total rev non river production;


    OBJ..  Z =E= SUM(RP,((PRCE1RP(RP)/DENOMRP(RP))*ACRP(RP)))
                 +SUM(NRP,((PRCE1NRP(NRP)/DENOMNRP(NRP))*ACNRP(NRP)))
                 +SUM((LPRODRP,ACTRP),(PRICERP(ACTRP)*YIELDRP(LPRODRP,
                                                               ACTRP)*
```

```
                        PRODRP(LPRODRP,ACTRP))
                        - (COSTRP(ACTRP)*PRODRP(LPRODRP,ACTRP)))
                  +SUM((LPRODNRP,ACTNRP),(PRICENRP(ACTNRP)*YIELDNRP(LPRODN
                                                            RP,ACTNRP)*
                        PRODNRP(LPRODNRP,ACTNRP))
                        - (COSTNRP(ACTNRP)*PRODNRP(LPRODNRP,ACTNRP)))
                  +SUM((LPRODRP,COWRP),(TRCOWRP(COWRP)-TCCOWRP(COWRP))
                        *HERDRP(LPRODRP,COWRP))
                  +SUM((LPRODNRP,COWNRP),(TRCOWNRP(COWNRP)-TCCOWNRP(COWNRP
                                                                     ))
                        *HERDNRP(LPRODNRP,COWNRP))
                  -SUM(RP,(TAXRP(RP)*ACRP(RP)))-SUM(NRP,(TAXNRP(NRP)
                                                         *ACNRP(NRP)))
                  -SUM(LPRODRP,(TAXPRP(LPRODRP)*ACPRORP(LPRODRP)))
                  -SUM(LPRODNRP,(TAXPNRP(LPRODNRP)*ACPRONRP(LPRODNRP)));


ACRERP(LRP).. SUM(RP,ACRP(RP)*AREARP(LRP,RP)) =L= LANDRP(LRP);

ACRENRP(LNRP).. SUM(NRP,ACNRP(NRP)*AREANRP(LNRP,NRP)) =L=LANDNRP(LNRP
                                                                     );

LNDRP(LPRODRP)..SUM(ACTRP, (PRODRP(LPRODRP,ACTRP)*APRODRP(LPRODRP,
                                                           ACTRP)))
                        +SUM(COWRP,HERDRP(LPRODRP,COWRP)*ACCOWRP(LPRODR
                                                           P,COWRP))
                         =L=TOTACRP(LPRODRP);

LNDNRP(LPRODNRP)..SUM(ACTNRP, (PRODNRP(LPRODNRP,ACTNRP)
                                       *APRODNRP(LPRODNRP,ACTNRP)))
                        +SUM(COWNRP,HERDNRP(LPRODNRP,COWNRP)
                                       *ACCOWNRP(LPRODNRP,COWNRP))
                         =L=ACPRONRP(LPRODNRP);

BNRPRD('RDEVRP').. PRODRP('RDEVRP','BEANRP')+PRODRP('RDEVRP',
                          'CORNRP')+PRODRP('RDEVRP','WHTRP')=L=0;

BNNRPRD('RDEVNRP').. PRODNRP('RDEVNRP','BEANNRP')+PRODNRP('RDEVNRP',
                          'CORNNRP')+PRODNRP('RDEVNRP','WHTNRP')=L=0;

TOTBER..   SUM(LPRODRP,(PRODRP(LPRODRP,'BERRYRP')))
                         +SUM(LPRODNRP,(PRODNRP(LPRODNRP,'BERRYNRP')))
                                                             =L=15;

TOTMINT..   SUM(LPRODRP,(PRODRP(LPRODRP,'MINTRP')))
                         +SUM(LPRODNRP,(PRODNRP(LPRODNRP,'MINTNRP')))
                                                             =L=50;

TOTNUT..   SUM(LPRODRP,(PRODRP(LPRODRP,'NUTSRP')))
                         +SUM(LPRODNRP,(PRODNRP(LPRODNRP,'NUTSNRP')))
                                                             =L=60;

TOTROT..   SUM(LPRODRP,(PRODRP(LPRODRP,'CORNRP')))
                     +SUM(LPRODNRP,(PRODNRP(LPRODNRP,'CORNNRP')))
                     +SUM(LPRODRP,(PRODRP(LPRODRP,'BEANRP')))
                     +SUM(LPRODNRP,(PRODNRP(LPRODNRP,'BEANNRP')))
                     +SUM(LPRODRP,(PRODRP(LPRODRP,'WHTRP')))
                     +SUM(LPRODNRP,(PRODNRP(LPRODNRP,'WHTNRP')))=L=50;

CORNEQ..  2*(SUM(LPRODRP,(PRODRP(LPRODRP,'CORNRP'))))
                     +2*(SUM(LPRODNRP,(PRODNRP(LPRODNRP,'CORNNRP'))))
                     -SUM(LPRODRP,(PRODRP(LPRODRP,'BEANRP')))
                     -SUM(LPRODNRP,(PRODNRP(LPRODNRP,'BEANNRP')))
                     -SUM(LPRODRP,(PRODRP(LPRODRP,'WHTRP')))
```

```
                         -SUM(LPRODNRP,(PRODNRP(LPRODNRP,'WHTNRP')))=L=0;

   BEANEQ..  -SUM(LPRODRP,(PRODRP(LPRODRP,'CORNRP')))
                         -SUM(LPRODNRP,(PRODNRP(LPRODNRP,'CORNNRP')))
                         +2*SUM(LPRODRP,(PRODRP(LPRODRP,'BEANRP')))
                         +2*SUM(LPRODNRP,(PRODNRP(LPRODNRP,'BEANNRP')))
                         -SUM(LPRODRP,(PRODRP(LPRODRP,'WHTRP')))
                         -SUM(LPRODNRP,(PRODNRP(LPRODNRP,'WHTNRP')))=L=0;

   WHTEQ..  -SUM(LPRODRP,(PRODRP(LPRODRP,'CORNRP')))
                         -SUM(LPRODNRP,(PRODNRP(LPRODNRP,'CORNNRP')))
                         -SUM(LPRODRP,(PRODRP(LPRODRP,'BEANRP')))
                         -SUM(LPRODNRP,(PRODNRP(LPRODNRP,'BEANNRP')))
                         +2*SUM(LPRODRP,(PRODRP(LPRODRP,'WHTRP')))
                         +2*SUM(LPRODNRP,(PRODNRP(LPRODNRP,'WHTNRP')))
                                                                 =L=0;

   HAYNOTF2.. PRODRP('RDEVRP','AHAYRP')+PRODRP('RRRP','AHAYRP')
                                        +PRODRP('E40RP','AHAYRP')
              +PRODNRP('RDEVNRP','AHAYNRP')+PRODNRP('RRNRP','AHAYNRP')
                                  +PRODNRP('E40NRP','AHAYNRP')=L=64;

   CF1PBRP('F1PUBRP')..   SUM(COWRP,HERDRP('F1PUBRP',COWRP))=L=0;

   CF1PBNRP('F1PUBNRP')..   SUM(COWNRP,HERDNRP('F1PUBNRP',COWNRP))=L=0;

   CF1PVRP('F1PRIRP')..   SUM(COWRP,HERDRP('F1PRIRP',COWRP))=L=0;

   CF1PVNRP('F1PRINRP')..   SUM(COWNRP,HERDNRP('F1PRINRP',COWNRP))=L=0;

   CRDEVRP('RDEVRP')..   SUM(COWRP,HERDRP('RDEVRP',COWRP))=L=0;

   CRDEVNRP('RDEVNRP')..   SUM(COWNRP,HERDNRP('RDEVNRP',COWNRP))=L=0;

   COTHRP('OTHRP')..   SUM(COWRP,HERDRP('OTHRP',COWRP))=L=0;

   COTHNRP('OTHNRP')..   SUM(COWNRP,HERDNRP('OTHNRP',COWNRP))=L=0;

   COWTOT..             SUM((LPRODRP,COWRP),HERDRP(LPRODRP,COWRP))+
                            SUM((LPRODNRP,COWNRP),HERDNRP(LPRODNRP,
                                                  COWNRP))=L=1500;

   T56PB..              PRODRP('F1PUBRP','FPB56RP')+PRODNRP('F1PUBNRP',
                                        'FPB56NRP')=L=(10710/75);

   T67PB..              PRODRP('F1PUBRP','FPB67RP')+PRODNRP('F1PUBNRP',
                                        'FPB67NRP')=L=(10710/75);

   THVPB..              PRODRP('F1PUBRP','FPBHVRP')+PRODNRP('F1PUBNRP',
                                        'FPBHVNRP')=L=(10710/75);

   TPLPB..              PRODRP('F1PUBRP','FPBHVRP')+PRODNRP('F1PUBNRP',
                                                      'FPBHVNRP')
                           -(PRODRP('F1PUBRP','FPBPLRP')+PRODNRP('F1PUBNR
                                             P','FPBPLNRP'))=L=0;

   TSTPB..              PRODRP('F1PUBRP','FPBSTRP')+PRODNRP('F1PUBNRP',
                                                      'FPBSTNRP')
                        -(71*(PRODRP('F1PUBRP','FPBHVRP')+PRODNRP('F1PUB
                                          NRP','FPBHVNRP')))=E=0;

   T56PV..              PRODRP('F1PRIRP','FPV56RP')+PRODNRP('F1PRINRP',
                                                  'FPV56NRP')=L=
                                          (1/75)*(TOTACRP('F1PRIRP
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                                                   ')+ACPRONRP('F1PRINRP'));

T67PV..              PRODRP('F1PRIRP','FPV67RP')+PRODNRP('F1PRINRP',
                                                            'FPV67NRP')=L=
                                                   (1/75)*(TOTACRP('F1PRIRP
                                                   ')+ACPRONRP('F1PRINRP'));

THVPV..              PRODRP('F1PRIRP','FPVHVRP')+PRODNRP('F1PRINRP',
                                                            'FPVHVNRP')=L=
                                                   (1/75)*(TOTACRP('F1PRIRP
                                                   ')+ACPRONRP('F1PRINRP'));

TPLPV..              PRODRP('F1PRIRP','FPVHVRP')+PRODNRP('F1PRINRP',
                                                              'FPVHVNRP')
                        -(PRODRP('F1PRIRP','FPVPLRP')+PRODNRP('F1PRINR
                                                  P','FPVPLNRP'))=L=0;

TSTPV..              PRODRP('F1PRIRP','FPVSTRP')+PRODNRP('F1PRINRP',
                                                              'FPVSTNRP')
                       -(71*(PRODRP('F1PRIRP','FPVHVRP')+PRODNRP('F1PRI
                                                 NRP','FPVHVNRP')))=E=0;

TF245..              PRODRP('F2RP','F245RP')+PRODNRP('F2NRP','F245NRP')
                                                                      =L=
                                                (1/65)*(TOTACRP('F2RP')
                                                   +ACPRONRP('F2NRP'));

TF2HV..              PRODRP('F2RP','F2HVRP')+PRODNRP('F2NRP','F2HVNRP')-
                            (PRODRP('F2RP','F245RP')
                                +PRODNRP('F2NRP','F245NRP'))=E=0;

TF2PL..              PRODRP('F2RP','F2HVRP')+PRODNRP('F2NRP','F2HVNRP')-
                            (PRODRP('F2RP','F2PLRP')
                                +PRODNRP('F2NRP','F2PLNRP'))=L=0;

TF2ST..              PRODRP('F2RP','F2STRP')+PRODNRP('F2NRP','F2STNRP')-
                           (62*(PRODRP('F2RP','F245RP')
                               +PRODNRP('F2NRP','F245NRP')))=E=0;

TREV1(RP)..          REV1(RP)-(((PRCE1RP(RP)/DENOMRP(RP))*ACRP(RP))
                                       -(TAXRP(RP)*ACRP(RP)))=E=0;


TREV2(NRP)..         REV2(NRP)-(((PRCE1NRP(NRP)/DENOMNRP(NRP))
                                                              *ACNRP(NRP))
                                       -(TAXNRP(NRP)*ACNRP(NRP)))
                                                                    =E=0;


TREV3(LPRODRP)..   REV3(LPRODRP)-(SUM(ACTRP,(PRICERP(ACTRP)
                                                *YIELDRP(LPRODRP,ACTRP)*
                     PRODRP(LPRODRP,ACTRP))
                     - (COSTRP(ACTRP)*PRODRP(LPRODRP,ACTRP)))
                     +SUM(COWRP,(TRCOWRP(COWRP)-TCCOWRP(COWRP))
                     *HERDRP(LPRODRP,COWRP))
                     -(TAXPRP(LPRODRP)*ACPRORP(LPRODRP)))=E=0;

TREV4(LPRODNRP)..   REV4(LPRODNRP)-(SUM(ACTNRP,(PRICENRP(ACTNRP)
                                            *YIELDNRP(LPRODNRP,ACTNRP)*
                     PRODNRP(LPRODNRP,ACTNRP))
                     - (COSTNRP(ACTNRP)*PRODNRP(LPRODNRP,ACTNRP)))
                     +SUM(COWNRP,(TRCOWNRP(COWNRP)-TCCOWNRP(COWNRP))
                     *HERDNRP(LPRODNRP,COWNRP))
                     -(TAXPNRP(LPRODNRP)*ACPRONRP(LPRODNRP)))=E=0;
```

```
MODEL LP1 /ALL/;
OPTION LIMROW =8;
SOLVE LP1 USING LP MAXIMIZING Z;

DISPLAY ACRP.L,ACNRP.L,PRODRP.L,PRODNRP.L,HERDRP.L,HERDNRP.L, REV1.L,
                                                      REV2.L, REV3.L, REV4.L;
```

SETS

ACTNRP	PRODUCTION ACTIVITIES ON NON RIVER LAND
ACTRP	PRODUCTION ACTIVITIES ON RIVER FRONT LAND
COWNRP	CATTLE PRODUCTION ON NON RIVER PROPERTY
COWRP	CATTLE PRODUCTION ON RIVER PROPERTY
LNRP	NON RIVER LAND TYPES
LPRODNRP	NON RIVER PRODUCTION LAND TYPES
LPRODRP	RIVER FRONT PRODUCTION LAND TYPES
LRP	RIVERFRONT LAND TYPES
NRP	NON RIVER FRONT PROPERTY TYPES
RP	RIVER FRONT PROPERTY TYPES

PARAMETERS

ACCOWNRP	LAND REQUIREMENTS IN ACRES FOR HERDS ON NON RIVER LAND
ACCOWRP	LAND REQUIREMENTS IN ACRES FOR HERDS ON RIVER LAND
ACMINUS	acres taken out of production due to riparion buffer
ACPRONRP	total area in acres of production land NOT adjacent to rivers
ACPRORP	total area in acres of production land types adjacent to rivers
APRODNRP	ACRES OF EACH NON RIVER LAND TYPE TAKEN BY EACH UNIT OF ACTIVITY
APRODRP	ACRES OF EACH RIVER LAND TYPE TAKEN BY EACH UNIT OF ACTIVITY
AREANRP	ACRES TAKEN BY EACH UNIT OF NON RIVER PROPERTY
AREARP	ACRES TAKEN BY EACH UNIT OF RIVER PROPERTY
ASSVAL	assessed value per acre of these land types
ASSVAL2	assessed value per acre of these land types
BUFCOEF	riparian buffer coefficient from hedonic model
BUFWDTH	average riparian frontage width in feet by production property type
COSTNRP	Variable Cost per acre of activity produced on production non riparian land
COSTRP	Variable Cost per acre of activity produced on production riparian land
DA	DISCOUNT RATE FOR ANNUITY
DENOMNRP	denominator for annuity calculation non river property
DENOMRP	denominator for annuity calculation river property
FRNTLGTH	total riparian frontage length in feet by production property type
K	NUMBER OF YEARS
LANDNRP	total acres of Mohawk currently taken by non river properties
LANDRP	total acres of Mohawk currently taken by river properties
MEANLGTH	mean river front length in feet
MEANSIZE	mean property size in acres
MEANVAL	mean property value for river front properties
MEANVAL2	mean property value non annuity for non river properties
MEANWDTH	width of riparian buffer above base in feet
MNSIZE	mean size of non river properties
ORIGBUFF	original buffer area on each property
PRCE1NRP	mean value non annuity per acre of non river properties
PRCE1RP	price adjustment as a result of planting a riparian buffer
PRICENRP	Price per unit of activity produced on production non riparian land
PRICERP	Price per unit of activity produced on production riparian land
TAXNRP	yearly tax payment for each class of non river property
TAXPNRP	yearly per acre tax for non river property
TAXPRP	yearly per acre tax payments for river property
TAXRATE	PROPERTY TAX RATE PAID BY EACH RESIDENTIAL PROPERTY

TAXRP	yearly tax payment for each class of riverside property
TCCOWNRP	Cost exludes owner land rent and property tax non river property
TCCOWRP	Total cost exludes owner land rent and property tax river property
TOTACRP	total land area available for production adjacent to rivers
TRCOWNRP	Total revenue generated by each cow on non river property
TRCOWRP	Total revenue generated by each cow on river property
YIELDNRP	YIELD ON NON RIVER LAND TYPES
YIELDRP	YIELD ON RIVER LAND TYPES

VARIABLES

ACNRP	acres of non river properties
ACRP	acres of river properties
HERDNRP	herds on non river land
HERDRP	herds on river land
PRODNRP	acres of production of activities on nonriver land
PRODRP	acres of production of various activities by river land type
REV1	total revenue on amenity river property
REV2	total rev on amentity non river property
REV3	total revenue river production land
REV4	total revenue non river production
Z	objective value

EQUATIONS

ACRENRP	land constraint for residential river properties
ACRERP	land constraint residential non river properties
BEANEQ	equality constraint
BNNRPRD	land constraint for no beans on residential developed nonriver land
BNRPRD	land constrain for no beans on residential developed river land
CF1PBNRP	cow herd bounded on f1 public non river land
CF1PBRP	cow herd bounded on f1 public river land
CF1PVNRP	cow herd bounded on f1 public non river land
CF1PVRP	cow herd bounded on f1 private river land
CORNEQ	equality constraint
COTHNRP	cow restriction on non river other
COTHRP	cow restriction on river other
COWTOT	total cow numbers in the watershed
CRDEVNRP	cow herd bounded on res dev non river property
CRDEVRP	cow herd bounded on res dev rive property
HAYNOTF2	total hay production in areas which are not F2
LNDNRP	land constraint for productive land non river
LNDRP	land constraint for productive river land with buffer adjustment
OBJ	objective function constrained utility maximisation
T56PB	tree production on public forest age 50 to 60 land
T56PV	tree production private forest age 50 to 60
T67PB	tree production age 60 to 70 public land
T67PV	tree production private forest age 60 to 70
TF245	tree production age 40 to 50 on F2 lands
TF2HV	tree production harvest F2 land
TF2PL	tree planting on private land
TF2ST	Tree production other non harvest F2 lands
THVPB	tree harvest public land
THVPV	tree harvest private forest
TOTBER	total berries produced
TOTMINT	total mint produced
TOTNUT	total nuts produced
TOTROT	total corn beans wheat produced
TPLPB	tree plant on public land
TPLPV	tree plant private land
TREV1	total rev river amenity
TREV2	total rev non river amenityi

TREV3	total reve river production
TREV4	total rev non river production
TSTPB	tree standing public land
TSTPV	tree standing private land
WHTEQ	equality constraint

MODELS

LP1

MODEL STATISTICS

BLOCKS OF EQUATIONS	42	SINGLE EQUATIONS	74
BLOCKS OF VARIABLES	11	SINGLE VARIABLES	229
NON ZERO ELEMENTS	823		

S O L V E   S U M M A R Y

MODEL	LP1	OBJECTIVE	Z
TYPE	LP	DIRECTION	MAXIMIZE
SOLVER	MINOS5	FROM LINE	858

**** SOLVER STATUS 1 NORMAL COMPLETION
**** MODEL STATUS 1 OPTIMAL
**** OBJECTIVE VALUE 49661892.5091

RESOURCE USAGE, LIMIT	0.383	1000.000
ITERATION COUNT, LIMIT	41	1000

M I N O S 5.3 --- AXP/OSF 5.3.021-017
= = = = =

B. A. Murtagh, University of New South Wales
and
P. E. Gill, W. Murray, M. A. Saunders and M. H. Wright
Systems Optimization Laboratory, Stanford University.

EXIT -- OPTIMAL SOLUTION FOUND

	LOWER	LEVEL	UPPER	MARGINAL
---- EQU OBJ	-5.371E+5	-5.371E+5	-5.371E+5	1.000

OBJ objective function constrained utility maximisation

---- EQU ACRERP land constraint residential non river properties

	LOWER	LEVEL	UPPER	MARGINAL
LLOWRIV	-INF	744.000	744.000	1007.534
LMEDRIV	-INF	203.000	203.000	3074.127
LHIGHRIV	-INF	16.000	16.000	9070.192

---- EQU ACRENRP land constraint for residential river properties

LOWER	LEVEL	UPPER	MARGINAL

LLOWNR	-INF	1933.000	1933.000	926.661
LMEDNR	-INF	740.000	740.000	3367.102
LHIGHNR	-INF	237.000	237.000	11692.862

---- EQU LNDRP land constraint for productive river land with buffer adjustment

	LOWER	LEVEL	UPPER	MARGINAL
F1PUBRP	-INF	5775.000	17628.290	.
F1PRIRP	-INF	48465.682	48465.682	EPS
F2RP	-INF	1805.052	1805.052	458.723
RDEVRP	-INF	10.327	10.327	1.207
RRRP	-INF	641.383	641.383	1.207
OTHRP	-INF	.	344.195	.
E40RP	-INF	2468.523	2468.523	1.207

---- EQU LNDNRP land constraint for productive land non river

	LOWER	LEVEL	UPPER	MARGINAL
F1PUBNRP	-INF	4935.000	4935.000	EPS
F1PRINRP	-INF	25259.000	25259.000	.
F2NRP	-INF	5337.000	5337.000	458.723
RDEVNRP	-INF	304.000	304.000	1.207
RRNRP	-INF	1875.000	1875.000	1.207
OTHNRP	-INF	.	50.000	.
E40NRP	-INF	3091.000	3091.000	1.207

---- EQU BNRPRD land constrain for no beans on residential developed river land

	LOWER	LEVEL	UPPER	MARGINAL
RDEVRP	-INF	.	.	.

---- EQU BNNRPRD land constraint for no beans on residential developed nonriver land

	LOWER	LEVEL	UPPER	MARGINAL
RDEVNRP	-INF	.	.	.

	LOWER	LEVEL	UPPER	MARGINAL
---- EQU TOTBER	-INF	.	15.000	.
---- EQU TOTMINT	-INF	50.000	50.000	88.523
---- EQU TOTNUT	-INF	60.000	60.000	281.963
---- EQU TOTROT	-INF	50.000	50.000	81.698
---- EQU CORNEQ	-INF	.	.	68.897
---- EQU WHTEQ	-INF	.	.	.
---- EQU BEANEQ	-INF	.	.	96.278
---- EQU HAYNOTF2	-INF	.	64.000	.

TOTBER	total berries produced
TOTMINT	total mint produced
TOTNUT	total nuts produced
TOTROT	total corn beans wheat produced
CORNEQ	equality constraint
WHTEQ	equality constraint

```
  BEANEQ      equality constraint
  HAYNOTF2    total hay production in areas which are not F2


---- EQU CF1PBRP      cow herd bounded on f1 public river land

             LOWER     LEVEL     UPPER    MARGINAL

F1PUBRP      -INF        .         .         1.037


---- EQU CF1PBNRP     cow herd bounded on f1 public non river land

             LOWER     LEVEL     UPPER    MARGINAL

F1PUBNRP     -INF        .         .         1.037


---- EQU CF1PVRP      cow herd bounded on f1 private river land

             LOWER     LEVEL     UPPER    MARGINAL

F1PRIRP      -INF        .         .         1.037


---- EQU CF1PVNRP     cow herd bounded on f1 public non river land

             LOWER     LEVEL     UPPER    MARGINAL

F1PRINRP     -INF        .         .         1.037


---- EQU CRDEVRP      cow herd bounded on res dev rive property

             LOWER     LEVEL     UPPER    MARGINAL

RDEVRP       -INF        .         .         1.037


---- EQU CRDEVNRP     cow herd bounded on res dev non river property

             LOWER     LEVEL     UPPER    MARGINAL

RDEVNRP      -INF        .         .         1.037


---- EQU COTHRP       cow restriction on river other

             LOWER     LEVEL     UPPER    MARGINAL

OTHRP        -INF        .         .         1.037


---- EQU COTHNRP      cow restriction on non river other

             LOWER     LEVEL     UPPER    MARGINAL

OTHNRP       -INF        .         .         1.037

                         LOWER     LEVEL     UPPER    MARGINAL

---- EQU COWTOT           -INF   1500.000  1500.000     22.383
---- EQU T56PB            -INF    142.800   142.800   4357.500
---- EQU T67PB            -INF    142.800   142.800   5738.250
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---- EQU THVPB	-INF	142.800	142.800	23907.500
---- EQU TPLPB	-INF	.	.	929.000
---- EQU TSTPB	.	.	.	EPS
---- EQU T56PV	-INF	982.996	982.996	4357.500
---- EQU T67PV	-INF	982.996	982.996	5738.250
---- EQU THVPV	-INF	982.996	982.996	23907.500
---- EQU TPLPV	-INF	.	.	929.000
---- EQU TSTPV	.	.	.	EPS
---- EQU TF245	-INF	109.878	109.878	.
---- EQU TF2HV	.	.	.	25749.554
---- EQU TF2PL	-INF	.	.	1091.723
---- EQU TF2ST	.	.	.	-458.723

COWTOT	total cow numbers in the watershed
T56PB	tree production on public forest age 50 to 60 land
T67PB	tree production age 60 to 70 public land
THVPB	tree harvest public land
TPLPB	tree plant on public land
TSTPB	tree standing public land
T56PV	tree production private forest age 50 to 60
T67PV	tree production private forest age 60 to 70
THVPV	tree harvest private forest
TPLPV	tree plant private land
TSTPV	tree standing private land
TF245	tree production age 40 to 50 on F2 lands
TF2HV	tree production harvest F2 land
TF2PL	tree planting on private land
TF2ST	Tree production other non harvest F2 lands

---- EQU TREV1 total rev river amenity

	LOWER	LEVEL	UPPER	MARGINAL
LOWRIV	.	.	.	EPS
MEDRIV	.	.	.	EPS
HIGHRIV	.	.	.	EPS

---- EQU TREV2 total rev non river amenityi

	LOWER	LEVEL	UPPER	MARGINAL
LOWNR	.	.	.	EPS
MEDNR	.	.	.	EPS
HIGHNR	.	.	.	EPS

---- EQU TREV3 total reve river production

	LOWER	LEVEL	UPPER	MARGINAL
F1PUBRP	.	.	.	EPS
F1PRIRP	-4.671E+4	-4.671E+4	-4.671E+4	EPS
F2RP	-5913.399	-5913.399	-5913.399	EPS
RDEVRP	-2010.310	-2010.310	-2010.310	EPS
RRRP	-1.004E+5	-1.004E+5	-1.004E+5	EPS
OTHRP	.	.	.	EPS
E40RP	-1.240E+4	-1.240E+4	-1.240E+4	EPS

---- EQU TREV4 total rev non river production

LOWER	LEVEL	UPPER	MARGINAL

F1PUBNRP	.	.	.	EPS	
F1PRINRP	-2.413E+4	-2.413E+4	-2.413E+4	EPS	
F2NRP	-1.745E+4	-1.745E+4	-1.745E+4	EPS	
RDEVNRP	-4.365E+4	-4.365E+4	-4.365E+4	EPS	
RRNRP	-2.692E+5	-2.692E+5	-2.692E+5	EPS	
OTHNRP	.	.	.	EPS	
E40NRP	-1.518E+4	-1.518E+4	-1.518E+4	EPS	

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR Z	-INF	4.9662E+7	+INF	.

Z objective value

---- VAR ACRP acres of river properties

	LOWER	LEVEL	UPPER	MARGINAL
LOWRIV	.	744.000	+INF	.
MEDRIV	.	203.000	+INF	.
HIGHRIV	.	16.000	+INF	.

---- VAR ACNRP acres of non river properties

	LOWER	LEVEL	UPPER	MARGINAL
LOWNR	.	1933.000	+INF	.
MEDNR	.	740.000	+INF	.
HIGHNR	.	237.000	+INF	.

---- VAR PRODRP acres of production of various activities by river land type

	LOWER	LEVEL	UPPER	MARGINAL
F1PUBRP.FPB56RP	.	.	+INF	EPS
F1PUBRP.FPB67RP	.	142.800	+INF	.
F1PUBRP.FPBHVRP	.	142.800	+INF	.
F1PUBRP.FPBSTRP	.	5489.400	+INF	.
F1PUBRP.FPBPLRP	.	.	+INF	EPS
F1PUBRP.FPVPLRP	.	.	+INF	-929.000
F1PUBRP.F2PLRP	.	.	+INF	-633.000
F1PUBRP.AHAYRP	.	.	+INF	-536.780
F1PUBRP.GHAYLRP	.	.	+INF	-91.400
F1PUBRP.MINTRP	.	.	+INF	-1042.933
F1PUBRP.WHTRP	.	.	+INF	-427.793
F1PUBRP.BEANRP	.	.	+INF	-1071.098
F1PUBRP.CORNRP	.	.	+INF	-739.583
F1PUBRP.BERRYRP	.	.	+INF	-7748.200
F1PUBRP.NUTSRP	.	.	+INF	-757.293
F1PRIRP.FPBPLRP	.	.	+INF	-929.000
F1PRIRP.FPV56RP	.	.	+INF	EPS
F1PRIRP.FPV67RP	.	982.996	+INF	.
F1PRIRP.FPVHVRP	.	982.996	+INF	.
F1PRIRP.FPVSTRP	.	46499.690	+INF	.
F1PRIRP.FPVPLRP	.	.	+INF	EPS
F1PRIRP.F2PLRP	.	.	+INF	-633.000
F1PRIRP.AHAYRP	.	.	+INF	-536.780
F1PRIRP.GHAYLRP	.	.	+INF	-91.400
F1PRIRP.MINTRP	.	.	+INF	-1042.933

F1PRIRP	.WHTRP	.	.	+INF	-427.793
F1PRIRP	.BEANRP	.	.	+INF	-1071.098
F1PRIRP	.CORNRP	.	.	+INF	-739.583
F1PRIRP	.BERRYRP	.	.	+INF	-7748.200
F1PRIRP	.NUTSRP	.	.	+INF	-757.293
F2RP	.FPBPLRP	.	.	+INF	-929.000
F2RP	.FPVPLRP	.	.	+INF	-929.000
F2RP	.F245RP	.	109.878	+INF	.
F2RP	.F2HVRP	.	.	+INF	EPS
F2RP	.F2STRP	.	1585.296	+INF	.
F2RP	.F2PLRP	.	109.878	+INF	.
F2RP	.AHAYRP	.	.	+INF	-550.724
F2RP	.GHAYLRP	.	.	+INF	-457.516
F2RP	.MINTRP	.	.	+INF	-457.516
F2RP	.WHTRP	.	.	+INF	-457.516
F2RP	.BEANRP	.	.	+INF	-457.516
F2RP	.CORNRP	.	.	+INF	-457.516
F2RP	.BERRYRP	.	.	+INF	-736.923
F2RP	.NUTSRP	.	.	+INF	-457.516
RDEVRP	.FPBPLRP	.	.	+INF	-929.000
RDEVRP	.FPVPLRP	.	.	+INF	-929.000
RDEVRP	.F2PLRP	.	.	+INF	-633.000
RDEVRP	.AHAYRP	.	.	+INF	-537.987
RDEVRP	.GHAYLRP	.	10.327	+INF	.
RDEVRP	.MINTRP	.	.	+INF	-1044.140
RDEVRP	.WHTRP	.	.	+INF	-429.000
RDEVRP	.BEANRP	.	.	+INF	-1072.305
RDEVRP	.CORNRP	.	.	+INF	-740.790
RDEVRP	.BERRYRP	.	.	+INF	-7749.407
RDEVRP	.NUTSRP	.	.	+INF	-758.500
RRRP	.FPBPLRP	.	.	+INF	-929.000
RRRP	.FPVPLRP	.	.	+INF	-929.000
RRRP	.F245RP	.	.	+INF	-1.207
RRRP	.F2HVRP	.	.	+INF	-1.207
RRRP	.F2STRP	.	.	+INF	-1.207
RRRP	.F2PLRP	.	.	+INF	-634.207
RRRP	.AHAYRP	.	.	+INF	-83.030
RRRP	.GHAYLRP	.	531.383	+INF	.
RRRP	.MINTRP	.	50.000	+INF	.
RRRP	.WHTRP	.	.	+INF	EPS
RRRP	.BEANRP	.	.	+INF	EPS
RRRP	.CORNRP	.	.	+INF	EPS
RRRP	.BERRYRP	.	.	+INF	-279.407
RRRP	.NUTSRP	.	60.000	+INF	.
OTHRP	.FPBPLRP	.	.	+INF	-929.000
OTHRP	.FPVPLRP	.	.	+INF	-929.000
OTHRP	.F2PLRP	.	.	+INF	-633.000
OTHRP	.AHAYRP	.	.	+INF	-536.780
OTHRP	.GHAYLRP	.	.	+INF	-91.400
OTHRP	.MINTRP	.	.	+INF	-1042.933
OTHRP	.WHTRP	.	.	+INF	-427.793
OTHRP	.BEANRP	.	.	+INF	-1071.098
OTHRP	.CORNRP	.	.	+INF	-739.583
OTHRP	.BERRYRP	.	.	+INF	-7748.200
OTHRP	.NUTSRP	.	.	+INF	-757.293
E40RP	.FPBPLRP	.	.	+INF	-929.000
E40RP	.FPVPLRP	.	.	+INF	-929.000
E40RP	.F245RP	.	.	+INF	-1.207
E40RP	.F2HVRP	.	.	+INF	-1.207
E40RP	.F2STRP	.	.	+INF	-1.207
E40RP	.F2PLRP	.	.	+INF	-634.207
E40RP	.AHAYRP	.	.	+INF	-83.030
E40RP	.GHAYLRP	.	1163.356	+INF	.
E40RP	.MINTRP	.	.	+INF	EPS

E40RP .WHTRP	.	.	+INF	EPS
E40RP .BEANRP	.	16.667	+INF	.
E40RP .CORNRP	.	.	+INF	EPS
E40RP .BERRYRP	.	.	+INF	-279.407
E40RP .NUTSRP	.	.	+INF	EPS

---- VAR PRODNRP acres of production of activities on nonriver land

	LOWER	LEVEL	UPPER	MARGINAL
F1PUBNRP.FPB56NRP	.	142.800	+INF	.
F1PUBNRP.FPB67NRP	.	.	+INF	EPS
F1PUBNRP.FPBHVNRP	.	.	+INF	EPS
F1PUBNRP.FPBSTNRP	.	4649.400	+INF	.
F1PUBNRP.FPBPLNRP	.	142.800	+INF	.
F1PUBNRP.FPVPLNRP	.	.	+INF	-929.000
F1PUBNRP.F2PLNRP	.	.	+INF	-633.000
F1PUBNRP.AHAYNRP	.	.	+INF	-536.780
F1PUBNRP.GHAYLNRP	.	.	+INF	-91.400
F1PUBNRP.MINTNRP	.	.	+INF	-1042.933
F1PUBNRP.WHTNRP	.	.	+INF	-427.793
F1PUBNRP.BEANNRP	.	.	+INF	-1071.098
F1PUBNRP.CORNNRP	.	.	+INF	-739.583
F1PUBNRP.BERRYNRP	.	.	+INF	-7748.200
F1PUBNRP.NUTSNRP	.	.	+INF	-757.293
F1PRINRP.FPBPLNRP	.	.	+INF	-929.000
F1PRINRP.FPV56NRP	.	982.996	+INF	.
F1PRINRP.FPV67NRP	.	.	+INF	EPS
F1PRINRP.FPVHVNRP	.	.	+INF	EPS
F1PRINRP.FPVSTNRP	.	23293.008	+INF	.
F1PRINRP.FPVPLNRP	.	982.996	+INF	.
F1PRINRP.F2PLNRP	.	.	+INF	-633.000
F1PRINRP.AHAYNRP	.	.	+INF	-536.780
F1PRINRP.GHAYLNRP	.	.	+INF	-91.400
F1PRINRP.MINTNRP	.	.	+INF	-1042.933
F1PRINRP.WHTNRP	.	.	+INF	-427.793
F1PRINRP.BEANNRP	.	.	+INF	-1071.098
F1PRINRP.CORNNRP	.	.	+INF	-739.583
F1PRINRP.BERRYNRP	.	.	+INF	-7748.200
F1PRINRP.NUTSNRP	.	.	+INF	-757.293
F2NRP .FPBPLNRP	.	.	+INF	-929.000
F2NRP .FPVPLNRP	.	.	+INF	-929.000
F2NRP .F245NRP	.	.	+INF	EPS
F2NRP .F2HVNRP	.	109.878	+INF	.
F2NRP .F2STNRP	.	5227.122	+INF	.
F2NRP .F2PLNRP	.	.	+INF	EPS
F2NRP .AHAYNRP	.	.	+INF	-428.588
F2NRP .GHAYLNRP	.	.	+INF	-457.516
F2NRP .MINTNRP	.	.	+INF	-457.516
F2NRP .WHTNRP	.	.	+INF	-457.516
F2NRP .BEANNRP	.	.	+INF	-457.516
F2NRP .CORNNRP	.	.	+INF	-457.516
F2NRP .BERRYNRP	.	.	+INF	-736.923
F2NRP .NUTSNRP	.	.	+INF	-457.516
RDEVNRP .FPBPLNRP	.	.	+INF	-929.000
RDEVNRP .FPVPLNRP	.	.	+INF	-929.000
RDEVNRP .F2PLNRP	.	.	+INF	-633.000
RDEVNRP .AHAYNRP	.	.	+INF	-537.987
RDEVNRP .GHAYLNRP	.	304.000	+INF	.
RDEVNRP .MINTNRP	.	.	+INF	-1044.140
RDEVNRP .WHTNRP	.	.	+INF	-429.000
RDEVNRP .BEANNRP	.	.	+INF	-1072.305
RDEVNRP .CORNNRP	.	.	+INF	-740.790

RDEVNRP .BERRYNRP	.	.	+INF	-7749.407
RDEVNRP .NUTSNRP	.	.	+INF	-758.500
RRNRP .FPBPLNRP	.	.	+INF	-929.000
RRNRP .FPVPLNRP	.	.	+INF	-929.000
RRNRP .F245NRP	.	.	+INF	-1.207
RRNRP .F2HVNRP	.	.	+INF	-1.207
RRNRP .F2STNRP	.	.	+INF	-1.207
RRNRP .F2PLNRP	.	.	+INF	-634.207
RRNRP .AHAYNRP	.	.	+INF	-115.600
RRNRP .GHAYLNRP	.	1858.333	+INF	.
RRNRP .MINTNRP	.	.	+INF	EPS
RRNRP .WHTNRP	.	.	+INF	EPS
RRNRP .BEANNRP	.	.	+INF	EPS
RRNRP .CORNNRP	.	16.667	+INF	.
RRNRP .BERRYNRP	.	.	+INF	-279.407
RRNRP .NUTSNRP	.	.	+INF	EPS
OTHNRP .FPBPLNRP	.	.	+INF	-929.000
OTHNRP .FPVPLNRP	.	.	+INF	-929.000
OTHNRP .F2PLNRP	.	.	+INF	-633.000
OTHNRP .AHAYNRP	.	.	+INF	-536.780
OTHNRP .GHAYLNRP	.	.	+INF	-91.400
OTHNRP .MINTNRP	.	.	+INF	-1042.933
OTHNRP .WHTNRP	.	.	+INF	-427.793
OTHNRP .BEANNRP	.	.	+INF	-1071.098
OTHNRP .CORNNRP	.	.	+INF	-739.583
OTHNRP .BERRYNRP	.	.	+INF	-7748.200
OTHNRP .NUTSNRP	.	.	+INF	-757.293
E40NRP .FPBPLNRP	.	.	+INF	-929.000
E40NRP .FPVPLNRP	.	.	+INF	-929.000
E40NRP .F245NRP	.	.	+INF	-1.207
E40NRP .F2HVNRP	.	.	+INF	-1.207
E40NRP .F2STNRP	.	.	+INF	-1.207
E40NRP .F2PLNRP	.	.	+INF	-634.207
E40NRP .AHAYNRP	.	.	+INF	-39.265
E40NRP .GHAYLNRP	.	3074.333	+INF	.
E40NRP .MINTNRP	.	.	+INF	EPS
E40NRP .WHTNRP	.	16.667	+INF	.
E40NRP .BEANNRP	.	.	+INF	EPS
E40NRP .CORNNRP	.	.	+INF	EPS
E40NRP .BERRYNRP	.	.	+INF	-279.407
E40NRP .NUTSNRP	.	.	+INF	EPS

---- VAR HERDRP herds on river land

	LOWER	LEVEL	UPPER	MARGINAL
F1PUBRP.COW1RP	.	.	+INF	.
F1PRIRP.COW1RP	.	.	+INF	.
F2RP .COW1RP	.	.	+INF	-571.450
RDEVRP .COW1RP	.	.	+INF	.
RRRP .COW1RP	.	.	+INF	-0.193
OTHRP .COW1RP	.	.	+INF	.
E40RP .COW1RP	.	1500.000	+INF	.

---- VAR HERDNRP herds on non river land

	LOWER	LEVEL	UPPER	MARGINAL
F1PUBNRP.COW1NRP	.	.	+INF	.
F1PRINRP.COW1NRP	.	.	+INF	.
F2NRP .COW1NRP	.	.	+INF	-594.386
RDEVNRP .COW1NRP	.	.	+INF	.

RRNRP .COW1NRP	.	.	+INF	-0.334
OTHNRP .COW1NRP	.	.	+INF	.
E40NRP .COW1NRP	.	.	+INF	-0.182

---- VAR REV1 total revenue on amenity river property

	LOWER	LEVEL	UPPER	MARGINAL
LOWRIV	-INF	7.4961E+5	+INF	.
MEDRIV	-INF	6.2405E+5	+INF	.
HIGHRIV	-INF	1.4512E+5	+INF	.

---- VAR REV2 total rev on amentity non river property

	LOWER	LEVEL	UPPER	MARGINAL
LOWNR	-INF	1.7912E+6	+INF	.
MEDNR	-INF	2.4917E+6	+INF	.
HIGHNR	-INF	2.7712E+6	+INF	.

---- VAR REV3 total revenue river production land

	LOWER	LEVEL	UPPER	MARGINAL
F1PUBRP	-INF	4.3661E+6	+INF	.
F1PRIRP	-INF	3.0008E+7	+INF	.
F2RP	-INF	2.7065E+5	+INF	.
RDEVRP	-INF	-1997.848	+INF	.
RRRP	-INF	-7.825E+4	+INF	.
OTHRP	-INF	.	+INF	.
E40RP	-INF	27576.948	+INF	.

---- VAR REV4 total revenue non river production

	LOWER	LEVEL	UPPER	MARGINAL
F1PUBNRP	-INF	4.8959E+5	+INF	.
F1PRINRP	-INF	3.3461E+6	+INF	.
F2NRP	-INF	2.9822E+6	+INF	.
RDEVNRP	-INF	-4.329E+4	+INF	.
RRNRP	-INF	-2.649E+5	+INF	.
OTHNRP	-INF	.	+INF	.
E40NRP	-INF	-1.284E+4	+INF	.

**** REPORT SUMMARY : 0 NONOPT
0 INFEASIBLE
0 UNBOUNDED

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G e n e r a l A l g e b r a i c M o d e l i n g S y s t e m
E x e c u t i o n

---- 860 VARIABLE ACRP.L acres of river properties

LOWRIV 744.000, MEDRIV 203.000, HIGHRIV 16.000

---- 860 VARIABLE ACNRP.L acres of non river properties

LOWNR 1933.000, MEDNR 740.000, HIGHNR 237.000

---- 860 VARIABLE PRODRP.L acres of production of various activities by river land type

	FPB67RP	FPBHVRP	FPBSTRP	FPV67RP	FPVHVRP	FPVSTRP
F1PUBRP	142.800	142.800	5489.400			
F1PRIRP				982.996	982.996	46499.690

+	F245RP	F2STRP	F2PLRP	GHAYLRP	MINTRP	BEANRP
F2RP	109.878	1585.296	109.878			
RDEVRP				10.327		
RRRP				531.383	50.000	
E40RP				1163.356		16.667

+	NUTSRP
RRRP	60.000

---- 860 VARIABLE PRODNRP.L acres of production of activities on nonriver land

	FPB56NRP	FPBSTNRP	FPBPLNRP	FPV56NRP	FPVSTNRP
F1PUBNRP	142.800	4649.400	142.800		
F1PRINRP				982.996	23293.008

+	FPVPLNRP	F2HVNRP	F2STNRP	GHAYLNRP	WHTNRP
F1PRINRP	982.996				
F2NRP		109.878	5227.122		
RDEVNRP				304.000	
RRNRP				1858.333	
E40NRP				3074.333	16.667

+	CORNNRP
RRNRP	16.667

---- 860 VARIABLE HERDRP.L herds on river land

	COW1RP
E40RP	1500.000

---- 860 VARIABLE HERDNRP.L herds on non river land

(ALL 0.000)

---- 860 VARIABLE REV1.L total revenue on amenity river property

LOWRIV 749605.457, MEDRIV 624047.750, HIGHRIV 145123.078

---- 860 VARIABLE REV2.L total rev on amentity non river property

LOWNR 1791236.341, MEDNR 2491655.595, HIGHNR 2771208.382

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----     860 VARIABLE  REV3.L        total revenue river production land

F1PUBRP 4366074.300,     F1PRIRP 3.000814E+7,     F2RP     270648.811
RDEVRP     -1997.848,    RRRP      -78253.948,    E40RP     27576.948


----     860 VARIABLE  REV4.L        total revenue non river production

F1PUBNRP  489589.800,    F1PRINRP 3346069.580,     F2NRP    2982215.638
RDEVNRP  -43285.585,     RRNRP     -264921.682,    E40NRP    -12840.308


EXECUTION TIME       =         0.100 SECONDS        VERID AXU-25-069


USER: University Computing Services                    B940912:1707AR-AXU
      Oregon State University

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