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Economic Impacts of Irrigation Technologies in the Sevier River Basin

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ECONOMIC IMPACTS OF IRRIGATION TECHNOLOGIES IN THE SEVIER RIVER BASIN

by

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Theodore R. Frickel

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ABSTRACT

Economic Impacts of Irrigation Technologies
in the Sevier River Basin

by

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The economic well-being of the semi-arid intermountain area requires efficient use of available water supplies. Agriculture, the major water-consuming industry, depends on irrigation water. The adoption of sprinkler systems that increase irrigation "efficiencies" and increase water available for irrigation upstream may interfere with the "tenure" of downstream water rights. The farmers would like to use the water saved to irrigate additional acreages or crop to provide greater profits.

The problem in letting farmers expand their irrigated acreage is that the individual farmer increases his profits through increased consumptive use. The consequent reduction in return flows reduces the water available to the downstream irrigators and violates their proper rights. Water rights administrators have a responsibility to both groups. They need to protect downstream water rights. In doing so, the policies should not deny those who install new sprinkler systems the right to any water they really save from wasteful consumptive use (e.g., by weeds or evaporation).

A linear programing model was developed to determine to evaluate the effect of changes in irrigation technology on consumptive use and return flows for downstream users within the Sevier River Basin. The model was constructed in two sectors. The agriculture sector incorporated field slopes and soil types as represented by land classifications, consumptive use for nine crops, four on-farm irrigation systems: flood and sprinkler irrigation systems with lined and unlined ditches.

The hydrological flow integrated the return flows, outflows of one county with the inflows in the next downstream county. The water available within the county plus the inflow determine the water available for diversion. In addition, water diversions and available irrigated acreages were constrained to the limits imposed by the State Engineer's Office as a means of protecting property rights.

Modern systems would be adopted with the present acreage and diversion restrictions. Basin output would increase; however, downstream water rights will not be met. With the relaxation of acreage limitations, basin output again increases.

Maximization from a basinwide output indicates that society will gain by the adoption of new irrigation systems.

Again, water rights as presently held would not be met. The Federal and State cost sharing program could also aggravate the water rights problem if not properly handled.

Thereby by facilitating the transfer of water rights society stands to gain. Where the private incentive may differ from the basin's optimum, the study also provides sprinkler acreage limitations and recommendations which will allow the basin to achieve the optimum output.

Should the acreages be less than a basin optimum, subsidy programs would encourage the farmers to move to the optimum. (138 pages)

CHAPTER I

INTRODUCTION

The allocation of water rights among the various irrigators up and down the Sevier River evolved on the basis of an irrigation technology utilizing unlined distribution canals and field flooding. Recent advances in irrigation technology which involves conversions to lined canals and sprinklers results in greater productivity for the farmer and reduced downstream salinity. Farmers see visions of greater income by increasing acreages irrigated by their water allocation; and the federal government, specifically the Soil Conservation Service, sees visions of protecting stream water quality from soil salts leached by inefficient water use.

The resulting change in irrigation technology, however, has major economic and hydrologic effects. The optimal allocation of the available water among users changes as the technology advances, and the system changes associated with adopting the advanced technology cause major adjustments in the flow paths of water downstream. Both aspects need to be considered in formulating water rights policy during the period of technological change. This study used an economic model maximizing basinwide net farm income and deterministic estimates of the hydrologic effects of various irrigation technologies to explore how water rights transfers should be facilitated to achieve basinwide economic efficiency during the transition period.

The major problem in maintaining present property rights relating to water use relates to the downstream external effects of upgrading upstream irrigation technology. The upstream irrigator can increase his income by farming a greater acreage. In so doing, he helps downstream water quality by storing more salts in his soil. The result is that he decreases downstream flow. Increased upstream farm irrigation efficiency could deny downstream irrigators of their water right.

Evapotranspiration losses as flows move downstream, however, mean that all the water "saved" by upstream irrigators is not "lost" to those downstream. The upstream irrigators could be awarded any water they save from evapotranspiration in transit.

In cases where upstream advances in irrigation technology actually deprives downstream users of their water, economic criteria favor the use producing crops of the greater net value. The practical problems are that 1) fair compensation cannot be determined without some way of estimating those losses, and 2) upstream use changes cannot be regulated without some way of estimating how much they change the water available downstream. The goal of this study is to provide a model and results obtained with its application that can be used to resolve these issues.

The older technology results in substantially higher water losses to the individual irrigator because of overland runoff and seepage. It increases water loss to the total system by adding to stream evaporation, transpiration by phreatophytes, and deep percolation. The newer technologies moderate these losses by lining open canals with some form of impermeable material (clay, asphalt, concrete, etc) or enclosing the distribution system in pipes. Once the water reaches the farm, the older technology conveys the water to the field in an unlined ditch and then uses some form of flood irrigation, border, or furrow to take the water to the plant. The new technologies line the on-farm ditches, using some type of piping, and/or taking the water to the plants by some method such as sprinklers, trickle systems, or subsurface irrigation.

Statement of the Problem

Irrigation supplies water for plant growth. The crop consumptive use requirement is defined as the water transpired in plant growth and equals the amount of water entering plant roots and used to build plant tissue in that the weight of vegetative matter produced is proportional to plant transpiration. Plant transpiration is determined by soil moisture availability during the various stages of plant growth. If more than this amount of water is applied, it cannot be used productively and will either be passed on downstream or used by other vegetation. If less is applied, the plant suffers moisture stress and growth is reduced. The optimal irrigation strategy is to grow crops with an amount of stress determined by the marginal productivity of applied water equaling the ratio of the value of water applied to the value of crop produced.

All water diverted to arable land is not consumptively used by crops. Part of the water diverted is lost due to evaporation, transpiration by phreatophytes, and seepage which does not reappear downstream. The rest returns to the river through surface and groundwater flows, hereafter referred to as return flow (see Figure 1). Return flows are then rediverted downstream. Rediverted return flow accounts for a substantial part of the annual water supply being used for irrigation.

From an engineering point of view, water-use efficiency is increased by the adoption of modern irrigation methods. This increased "efficiency" or water savings results from reductions in seepage losses, return flows, losses through evaporation, consumptive use by aquatic plants and weeds and also, through more uniform application and better use of tailwater runoff.

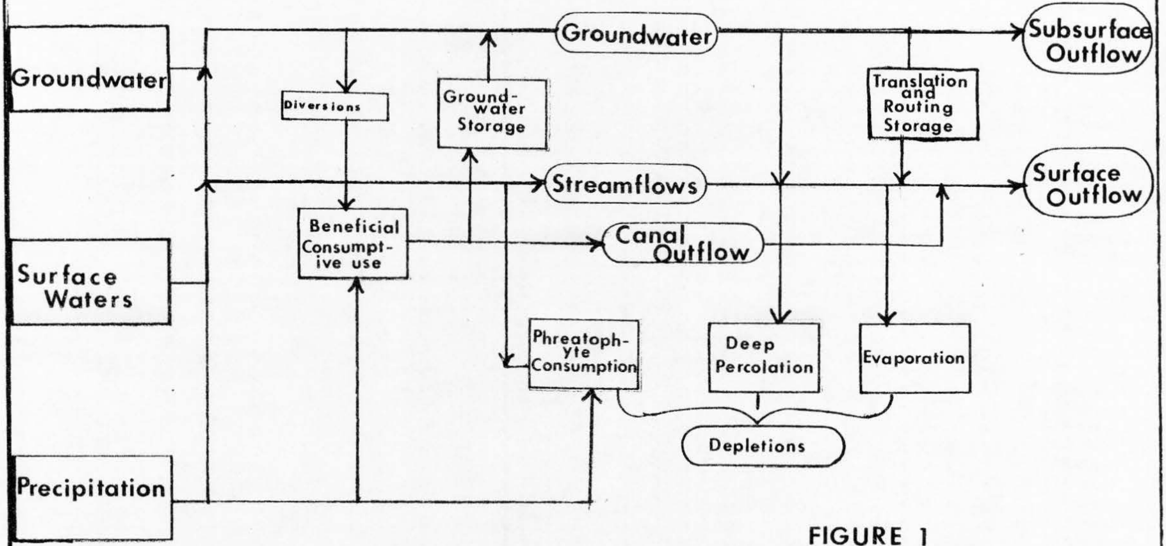


FIGURE 1
FLOWCHART OF A TYPICAL HYDROLOGICAL MODEL

Numerous studies claim that the adoption of modern capital intensive irrigation systems can generate surpluses of water (Mizue, 1968; Austin, 1970), which can be used to irrigate additional acreage (USDA, 1969a; Hiskey, 1972). For example, in the Sevier River Basin Study (USDA, 1969a), the conclusion was that the adoption of lined ditches, sprinklers, land leveling and reservoir construction would increase overall irrigation "efficiency" by 4 percent. These new systems would then provide an increased supply of water enabling the basin to increase in the acres of irrigable land.

In general, these studies tended to overlook the effect of the adoptions of new irrigation systems on the downstream user's water right. They often assumed that the "water saved" was the sum of the aforementioned reductions. However, increased irrigation efficiency may result in greater consumptive use on the farm through reductions in seepage losses and tailwater runoff, but the water saved by these means may constitute all or part of the downstream user's water supply.

The upper reaches of any river or stream often yield more water than is consumptively used (USDA, 1969a; USDA, 1973a). While the streamflow in the lower reaches yield less water than is consumptively used. The latter case demands critical study and analysis because much of the irrigation diversions in the lower reaches depend on return flow to the river for their supply. Therefore, any changes in the method of water application and irrigation practices that affect the "efficiency" may impact the allocation of water in the basin.

Study Area

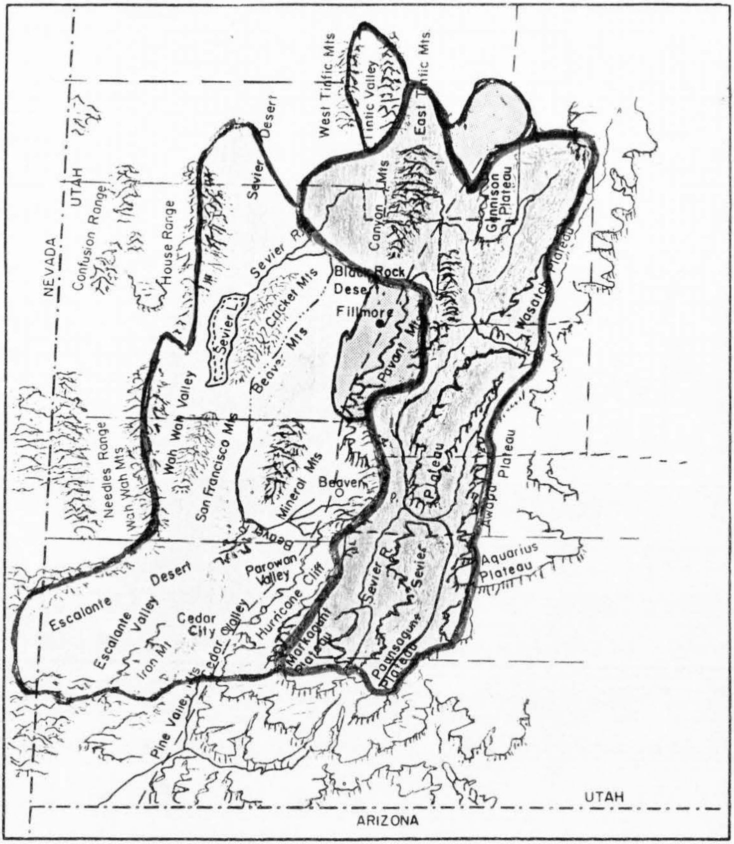
The Sevier River Basin was chosen for this study because it is essentially a closed system. The river's water are fully utilized within the basin. The present water users have rights to specific amounts of water. Any new irrigations or changes in farming methods could cause water to be reallocated. Thereby, violating these water rights and causing externalities upon the present users.

The basin is one of the most studied areas in the world and as a result there is a significant data base available to construct a model to determine the impact of the adoption of modern irrigation systems. This data includes: irrigated acreage by system, water diversions, consumptive uses, irrigation efficiencies, land classes, crop acreages, farming practices, types of farms, etc.

The Sevier Lake Basin is a major landlocked drainage system. (Figure 2) Its area includes over 17.7 million acres in a nine-county area. Within the Sevier Lake Basin, the Sevier River Basin covers about 12.5 million acres (USDA 1969a), while the Beaver River Basin covers about 5.2 million acres (USDA 1973a). The area to be studied includes the six counties (Garfield, Piute, Sevier, Sanpete, Juab and Millard) which make up the Sevier River Basin and that part of the Beaver River Basin located in Millard County.

The Sevier River Basin is characterized by high plateaus, narrow mountain valleys, and broad desert areas. The topographic features include table-topped mountains, lofty peaks, fertile valleys, steep cliffs and terraces, and dry desert lands. The altitudes vary from 4,500, at Sevier Lake on the desert floor to over 12,000 feet in the Tusher Mountains.

Fifty percent of the Sevier River Basin is mountainous and this area yields most of the water for irrigation. All perenial streams and rivers and most intermittent streams originate in the high mountains in the Southern portion of the basin. The undiverted portion of these



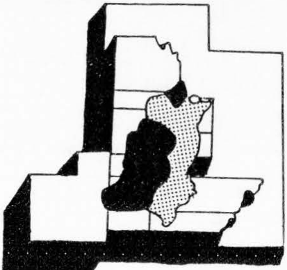


FIGURE 2
PHYSIOGRAPHIC FEATURES
SEVIER LAKE BASIN
UTAH

SEVIER RIVER BASIN

BEAVER RIVER BASIN

streams seldom leave these enclosed basins; they either evaporate or become part of the ground water reservoir as they infiltrate the valley floors.

The climate is semiarid with precipitation ranging from 6.4 to 13.0 inches in the valleys to over 40 inches in the highest mountains. Long winters reduce growing seasons to 98 to 178 days of mild summer weather.

Agricultural Basis

The irrigated agricultural lands are located in the relatively long and narrow valleys and in the desert area near Delta. The irrigated cropland and wet lands represent about 8% of the total land: 1,036,000 acres in the Sevier River Basin (USDA, 1969a), 196,000 acres in the Beaver River Basin (USDA, 1973a). Agricultural production in the Sevier River Basin represents about 25% of Utah's total agricultural production. Approximately 28.5% of the labor force in the basin is engaged in farming compared to about 6% for Utah. Alfalfa has been the leading crop accounting for 62% of all production, (Census of Agriculture, 1974). In addition, since 1955, crop production has been relatively stable, while livestock oriented enterprises have increased.

Agriculture in Sevier River Basin in essence is made up of two types of farm enterprises: (1) the livestock oriented farm with cropping patterns designed to meet livestock needs. Alfalfa, grass hay, pasture, corn for silage and feed grains are crops produced by these livestock-oriented enterprises. These enterprises were made up of dairy, range beef and general livestock farms, (2) the cash crop oriented farm is one whose crop is primarily sold for cash. These enterprises were made up of the cash crop-feeder farm and cash crop farm. Alfalfa, alfalfa seed, wheat, feed grains, potatoes, corn for grain were the principle crops produced by these enterprises.

The cash crop oriented farms accounted for 33.4% of the total farm enterprises within the basin. They accounted for 24% of the total acreage and 43% of all irrigated crops. Despite making up one third of the farms, cash crop oriented farms accounted for 55.5% of the net incomes for all agricultural enterprises in the Sevier River Basin.

A General Description of the Sevier Lake System

The main stream of the Sevier River arises on the slopes of the Markagunt Plateau east of Cedar Breaks National Monument. From this point the river flows about 320 miles. First, northward through agricultural areas alongside Utah Highway 80 and then in a westerly direction into the Sevier Desert to form the Sevier Lake.

About 60 miles downstream from head waters, the Sevier River is joined by the East Fork of the Sevier River near Kingston, Utah. This fork is formed by Otter Creek and the East Fork of the Sevier River. The main branch of the East Fork of the Sevier River drains the western slope of the Paunsaugunt Plateau. The eastern slope is greatly eroded and forms the beautiful Bryce Canyon National Park.

Downstream from its confluence with the East Fork, the Sevier River flows through intensive agricultural areas containing many feedlots and dairies. Several tributaries join the main stream through this region and many diversions of water for irrigation usage occur.

About 34 miles downstream of Kingston near the town of Sevier, Clear Creek joins the river and about 25 miles further downstream Vermillion Canal waters are diverted. The Vermillion Canal terminates adjacent to or into the Piute Canal. The City of Richfield is the largest city on the Sevier River and it is located near the Vermillion Canal diversion.

Just below the town of Vermillion is the Vermillion Canal Company Dam. The area above the Vermillion Canal Company Dam including Sevier, Piute and Garfield County have priority water rights over the Northern or Lower portions of the basin as a result of the Cox Decree of 1936.

The San Pitch River drains Sanpete Valley to the northeast of Gunnison and most of its flow is used for irrigated agriculture in the area. The San Pitch River has intermittent flow and is mostly stored in Gunnison Reservoir.

About six miles downstream from Gunnison, the backwaters of the Sevier Bridge Reservoir begin to develop. Yuba Dam, which creates the reservoir, marks the changeover from the verdant river valley south of Gunnison to the arid, sagebrush dominated area to the west. The Sevier River then loops out to the west and the agricultural area around Delta.

It is about a 67 mile journey from Yuba Dam to the backwaters of Gunnison Bend Reservoir just west of Delta. Most of the Sevier River flow is held in water rights by the farmers and ranchers in the Delta area and flows are controlled for their uses. Although flow occasionally continues out to Sevier Lake, the river essentially ceases to exist as an entity just west of Deseret, a small town three miles west of Delta.

The Sevier River has had a long history of development toward complete utilization of its water supply. Under natural conditions, waters of the river ultimately spill into Sevier Lake, which provided a large evaporative surface to dispose of the residual river flows. In time, man-made and natural depletions have steadily reduced the excess quantities finding their way into Sevier Lake. Today, about 10 percent or 13,690 acre-feet of the total water supply is discharged into the Sevier Lake drainage (USDA, 1969a), most of it in subsurface flows.

Within the Beaver River Basin, there are five basically independent irrigated agricultural areas (Figure 3). These areas are shown on the map as subbasins. Surface water seldom leave any of the subbasins. Surface waters are either diverted for irrigation or become part of the groundwater aquifer. This study is interested in those subbasins located within the Millard County boundry. The primary concern is the Fillmore subbasin as it is a heavily irrigated section within Millard County. The other subbasin within Millard county has negligible area being irrigated. Thus, the analysis of this river basin, except for Fillmore subbasin is not considered in detail in this report.

Water Rights

Doctrine of prior appropriation. The doctrine of prior appropriation basically says that a water right is acquired by diverting water from a water source for a beneficial use. Every appropriative water right is assigned a priority date based on the concept of "first in time, first in right." These water rights are enforced by the State Engineer's Office according to the priority date and state statutes.

The water diverted into a delivery system becomes the personal property of the right holder until it returns to the stream or escapes the appropriator's control. Upon returning to the stream, the water again becomes public property and is subject to the rights of appropriators thereon in order of priorities.

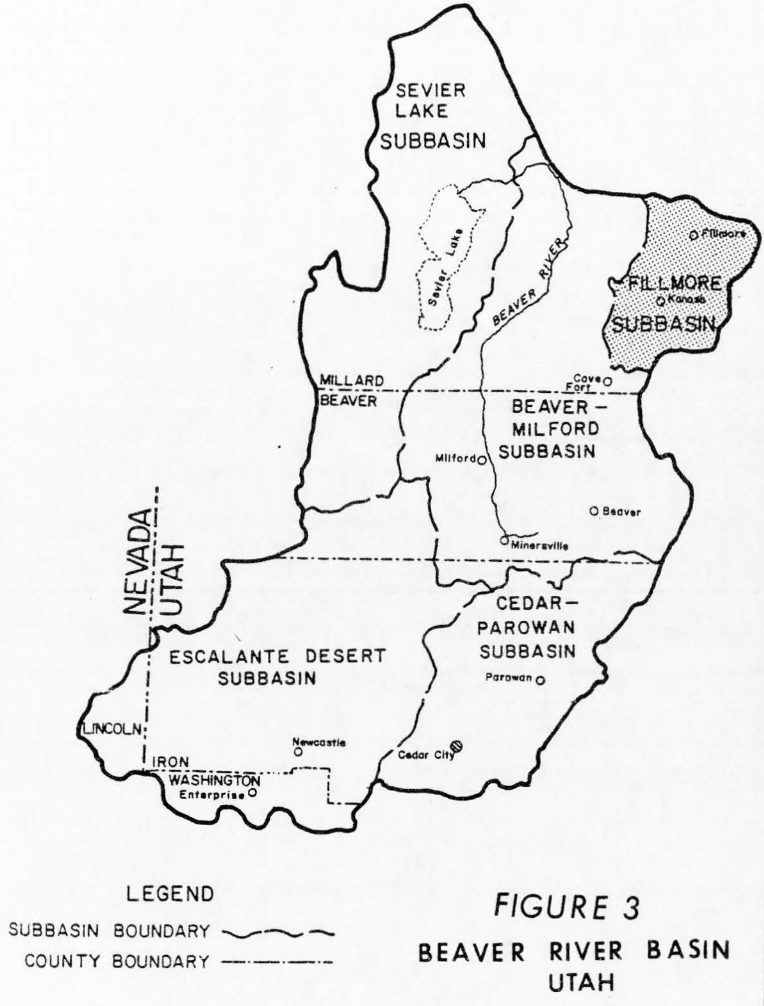


FIGURE 3

BEAVER RIVER BASIN
UTAH

By law, (although difficult to enforce), an appropriator cannot increase his historical consumptive use of diverted water because a change in the method of irrigation may adversely affect downstream users. Thus, while the irrigator has the private incentives for improving the "efficiency" of water delivery and expanding his irrigated acreages, he may be liable for any third-party effects that arise from the adoption of modern irrigation systems.

The "cox decree". In 1918, the Richlands Irrigation Company filed suit for the adjudication of all rights of the lower Sevier River system. A final decree on the Sevier River system was signed by Judge LeRoy Cox on November 30, 1936, and is known as the "Cox Decree." In the Cox Decree, the Sevier River system was divided into two distribution zones. Zone "A" (the upper Sevier River Basin) includes all rights from the Sevier River and its tributaries above and including the dam of the Vermillion Canal Company located in Sevier County. With Zone "A" (southern portion of the Sevier River Basin and includes Sevier, Piute and Garfield counties) water rights are primary to and have priority over the rights of Zone "B" (lower Sevier River Basin including Sanpete, Juab and Millard counties). Zone "B" includes all rights from the Sevier River and tributaries below the Vermillion Canal Company dam (Figure 4).

Water availability in Zone "B" is dependent upon the return flow from Zone "A". Problems inevitably arise when any rearrangement or redistribution of the water takes place through the adoption of more capital intensive irrigation methods, or through changes in management practices. The water users in Zone "B" have often objected to any

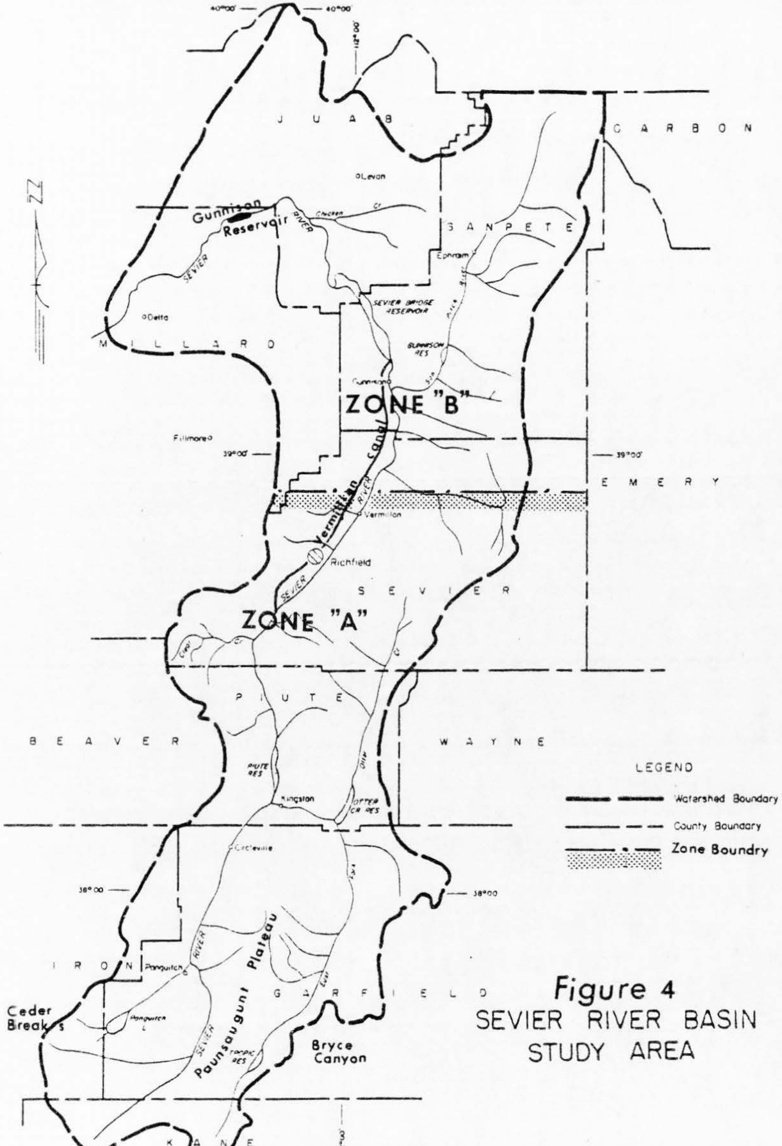


Figure 4
SEVIER RIVER BASIN
STUDY AREA

additional development in Zone "A" that would use more water and curtail the rate of return flow to the river. This does not mean that further redistribution or installation of capital intensives systems is impossible. It merely places emphasis on the need for capability to evaluate the effects of any proposed change. These effects should be identified and quantified so that equitable compensation or exchange procedure can be worked out where necessary.

Objectives of the Study

The objective of this study was to evaluate the tradeoffs between upgrading irrigation technology to increase farm productivity and external diseconomies caused by depleting the water supply available to those downstream. The method was to employ hydrologic input in an economic model of the basin's irrigated farm economy. The model was designed, 1) to incorporate various topographical factors such as soil types, land gradients and crop yield for various land classes, 2) incorporate institutional constraints such as fixed water rights and irrigated acreages limitations, and 3) to predict using slope, soil types and consumptive use, return flows, water losses and outflows for each of the six counties in the basin (Garfield, Piute, Sevier, Sanpete, Juab and Millard).

Since the water in the Sevier Basin system is completely utilized and the rights to the waters flowing in the streams and tributaries are fully apportioned by the State Engineer, any changes brought about by the adoption of more capital intensive irrigation methods must be accomplished subject to constraints imposed by the water rights structure, i.e.: diversions and fixed irrigation acreages. Thus, the impacts of the adoption of new modern irrigation systems will be easier to identify and study.

Specific objectives were:

a) To develop a method that could be used to estimate the magnitude of the impacts of the adoption of new modern irrigation systems; this method will determine if the adoption of modern irrigation methods would increase consumptive use and reduce return flows to cause third party effects on downstreams water rights under present acreage and water constraints.

b) To determine how much the Federal irrigation cost sharing programs would influence the magnitude of any third party effects.

c) To determine the basinwide impact of the relaxation of the various institutional constraints (acreage and diversion limitations).

d) To identify the various topographical features and crops where the adoption of the modern systems would most likely occur, so that appropriate tax mechanism may be devised to correct resource misallocations from any third party effects.

CHAPTER II

REVIEW OF LITERATURE

The study of third party effects go beyond the individuals and their immediate neighbors. This is particularly true in irrigation where seepages in one area may turn up as increased stream flows at some distant point downstream. Therefore, to take into account all impacts within a river basin some type of model was desired. This model would look at the water right and externality problem as a single manager or administrator would, or if a single unit were involved. Thus, a review of previous basin area and regional models was undertaken.

Since basin wide models have dealt with a wide range of topics dealing with water resources and irrigation, a further review was undertaken to determine the extent that irrigation systems have been used in previous studies. Therefore, the review of basin wide models and irrigation studies was useful for comparative purposes and techniques and methods used.

The adoption of newer irrigation systems can reduce seepages, evaporation and phreatophyte use. This has the impact of delivering more water to the individual irrigator. But in addition, with a more even application and better timing of water deliveries to the crop, one could expect crop yields to increase. Thus, the new systems do more than just "save water but also increase returns with higher yields." They provide the incentive for the irrigator to adopt modern technologies. Therefore, a review was undertaken to determine the yield impact associated with the adoption of the new irrigation methods.

Methods of Economic Modeling

Mathematical programming has become an increasingly useful tool in regional and river basin planning, design and management. Area wide modeling normally takes one of two forms, either simulation models or linear programming models.

In the simulation approach, a river basin or region is approximated on the computer with a mathematical model, then various scenarios are considered. While the simulation approach does not optimize, it does compare alternatives being evaluated and ranks them based on some criteria. Studies that have used simulation modeling in analyzing impacts in various river basins are: Nelson (1959), USDA (1970 VII), Mizue (1968), Austin (1970), and Keith et. al. (1978a).

Since the Second World War, Linear Programming has become one of the most widely used tools for identifying economically optimal decisions. It is being used extensively by resource and agricultural economists to optimize resource use, organization and product specialization as well as other related problems. Many applications have been made of the linear programming models in solving various problems in agricultural and water resources. Some of these LP studies are: Tolley and Hastings (1960), Moore and Hedges (1963), Hartman and Whittlesy (1961), Gisser (1970), Cummings and Gisser (1977), Condra et. al. (1975). Utah studies have included: Andersen (1971), King et. al. (1972), Keith et. al. (1973) and within the Sevier River Basin, Davis (1965, 1966), Davis and Johnson (1966), Milligan (1970) and Hiskey (1972).

The Role of Modern Irrigation Systems in Modeling

In most of the area and basin studies (particularly the earlier studies) modern irrigation practices were not utilized or considered.

The choice of irrigation methods in these models was usually limited to irrigated or non-irrigated systems without respect to any specific technology.

One of the first studies to incorporate modern technologies was done by Moore and Hedges (1963). However, they did not report the impact of the adoptions as the study focused on the demand for water. Gisser considered three different irrigation systems in estimating the demand function for water. He also reported that the model utilized these more efficient systems to maintain acreages as low salinity water declined, Gisser (1970). To evaluate the extent that the adoption of these technologies had in maintaining the irrigated agriculture in Estancea Valley in New Mexico, Cummings and Gisser (1977), used four different types of irrigation technologies: unlined ditches, pipelines, sprinklers, and trickle systems. Faced with reduced low salinity water allocations, they reported that the adoption of modern technology and greater "efficiencies" on agriculture, land retirements could be moderated.

Mizue (1968) and Austin (1970), parametrically took into account the impact of irrigation efficiencies in the Utah Lake drainage and Bear River Delta respectively. They did not examine the methods by which the increased efficiencies would be achieved. They both showed that if the present irrigation "efficiencies" were to be increased holding consumptive use constant, that (a) an annual water surplus would exist in the Utah Lake Basin, and (b) in the Bear River Delta the annual water available for export to other basins was increased.

USDA (1970 VIII) studied, through an analog model which simulated hydrological flows, irrigation efficiencies and basin farming practices of the Sevier River Basin, the various watersheds to evaluate the effect of the specific projects such as land leveling, canal and ditch lining, adoption of sprinklers and improved irrigation practices. From this model the Department of Agriculture USDA (1969a) reported that a 4% increase in efficiency would "save" enough water to irrigate an additional 70,000 acres.

In many of the Basin studies like the one above, the increased "efficiencies" or water savings not only includes reduction in evaporation and deep percolation losses and less phreatophyte consumption, but also classifies reduction in seepage and runoff losses as savings, while not considering them as part of the return flows. Although it is argued that, Committee on Research (1974), any seepage reduction is a savings because water lost by seepage must be "redeveloped" and that seepage degrades water quality, most studies seem to consider only the individual irrigators savings and not the redistributive effective within total basin. Thereby, ignoring possible third party effects.

A thorough analysis of the adoption of modern irrigation technologies was conducted by Strong (1962). His study identified the most feasible method of irrigation between unlined, graded pipe, lined ditches and sprinklers, for the factors which cause variations in costs and returns, i.e., slope and soil types. His results were based on the total cost of irrigation and decrease in output caused by the various factors. Strong only considered the adoption of modern technologies from the cost side. The study did not consider third party effects. Slopes and soil types are two of the factors which determine land classifications. As land class is moved from class I to IV the yields fall and his study did not consider this aspect.

Return Flows

The Committee on Research of the irrigation and drainage division in a paper presented in 1974 to the Proceeding of the American Society of Civil Engineers stated:

> The day is rapidly approaching when some irrigated regions will operate as an essentially closed system. Thus, all (or nearly all) return flows would be collected and recycled or treated. The social problems and institutional constraints associated with water planning and management, are complex and cannot be solved by only one discipline alone. It needs a multi-disciplinary approach, and a very close co-operation between physical and social scientists....It should be noted that in several recent system studies to facilitate water planning and management operations have completely neglected the whole complex role of institutions in policy planning and decision making... (Committee on Research, 1974, p. 153)

Bagley (1965) states that seepage and return flows saved are a bonafied loss to the farm but not the hydrologic system; but high seepage losses are not critical in terms of basin-wide development. The Committee of Research further states that little has been done to identify the social, economic, and institutional factor that have an important, if not overriding, influence on water management and policy particularly on a regional basis...that not only should the physical sciences adapt but that social and institutional changes are necessary to accomodate technological advances. In addition, the effect of methods of application on the quantity and quality of return flows, has not received detailed studies.

Of those studies which have considered return flows, Nelson (1959), Mizue (1968), Austin (1970), Hiskey (1972), Hurley (1968), Hall (1968), Sylvester (1963), Willardson (1972), only Hiskey apparently noted that return flows would be rediverted downstream and that the return flow was a function of the on-farm efficiencies and are affected by property rights.

Water Application--Yield Relationships

Studies on the impact of water application methods on crop yields has been reported by numerous authors. It is not clear whether the adoption of modern systems does and does not affect field crop yields.

The studies which report no evidence that field crops respond differently to different irrigation methods, fall into two types: controlled plot or actual observations. Some of the control plot studies include: Lewis (1949), Jacobson (1952), Somerholder (1958), Finkel (1959), Frost (1961), Kruse et. al., (1962), Pair (1962). These studies were conducted under optimum conditions to eliminate as many of the factors other than irrigation that affect yields, such as: climate, slope, water holding capacity of soils, and management practices. The controlled studies are usually made on simultaneously irrigated paired plots in which each system has been properly designed. In addition, these studies utilize sufficient management, labor, and hardware application such that the operational efficiency differences between the methods become neglible.

Under ordinary field condition and practices where total yields were unaffected, crops were grown with 7 to 40% less water being applied. [Israelson (1944), Hamilton and Schrank (1953), Proceedings (1962), Strong (1962) and Swarner and Hargood (1963).] Although total yields in all crops did not change, both Strong (1962), Swarner and Hargood (1963), found about 10% increases in alfalfa yields.

In addition, authors who have found or used increased yields with the adoption of sprinklers include: Price (1938), Ewing and Zerfoss (1942), Davis et. al. (1961), USDA (1969 XII), Cummings and Gisser (1977). The use of increased yields with the adoption of sprinklers in these studies was due to better uniformity both spatially and temporarily and better complimentary management techniques which occur when sprinkler irrigations are adopted.

Since the model is dealing with a basin in actual field conditions, those studies which used properly designed and managed conditions were disgarded. The choice of impact on yields was between water saved and increased yields. Increased yields were chosen primarily because of two studies: USDA (1969 XII), Cummings and Gisser (1977). The USDA study dealing with the Sevier River Basin reports that consumptive use and alfalfa yield data indicate that there is a significant relationship between the alfalfa yield level and the alfalfa yield-consumptive use ratio and that efficient use of irrigation is associated with higher alfalfa yields.

In the Cummings and Gisser study, the decision to use increasing yield for sprinkler was based in part on the belief that with the adoption of the newer system, the farmer usually receives additional training during the installation of the system as well as the fact that better uniformity in water application can be realized, Franklin (1979).

CHAPTER III

THEORETICAL APPROACH

Demand

In short run, the demand for water will depend on several factors: the relative price of the crops, the amount of land; the relative prices of other inputs used in the production of crops.

Given the crop yield relationships with respect to inputs, the demand for water for consumptive use by crops can be derived. With the adoption of a modern irrigation system, the marginal productivity of water increases through better uniformity of application (both spatially and temporarily). The more productive the resource becomes the greater the demand for it. As the demand for water for consumptive use increases, widespread use of modern irrigation systems which delivers the water to the crops will be observed.

In deciding whether to adopt a new irrigation system, the farmer looks at the increased private benefits he expects to receive and weighs them against the costs. With the same allocated water diversions, the farmer can increase in the total amount of water available for use by the crops. The irrigator views this additional water as a savings. A savings which should be available for his private use. However, part of the additional water available is from less seepages, lower runoffs which would normally return to the system via surface and subsurface flows and become part of the down stream water rights. As a result, the irrigator does not consider the impact of the adoption of modern irrigation system on the water rights of his neighbor.

Under the present system, a specified quantity of water is allotted for diversion to irrigate a specified parcel of land. New irrigation systems increase the water available for consumptive use without changing diversions. Yearly irrigated acreages can be increased as a farmer irrigates previously idle or fallow acreages more frequently. (These are included in the definition of irrigated land as long as it is irrigated at least once during any seven year period.) Secondly, the farmer can increase water use by growing more profitable and more water consuming crops. These can result in the upstream user by virtue of his location taking away part of the downstream water rights.

Initial Condition

Under the present water right allocations and prior to the adoption of the new technologies, one of three following states could exist within the basin: 1) no distortions exist where the value of the marginal product of Unit A (VMPa) is equal to the value of the marginal product of Unit B (VMPb) (a unit can be a farm, county or region), 2) the VMPa is greater than the VMPb, and 3) the VMPa is less than the VMPb. These three states are shown in Figure 5(a), 5(b) and 5(c).

When the values of the marginal products are unequal a distortion exists. This condition could exist due to several reasons that makes the water available to the units at a price which does not reflect the true "market" value. The shaded area in Figure 5b and 5c reflect the loss to society that occurs when the values of the marginal physical products are not equal. When the total water available for consumptive use is fixed and in the case where MPPa = MPPb, CUa and CUb would be the amount of water consumed by units A and B, if the VMP's were equal as in Figure 5a. However, when Unit B is able to obtain all the water

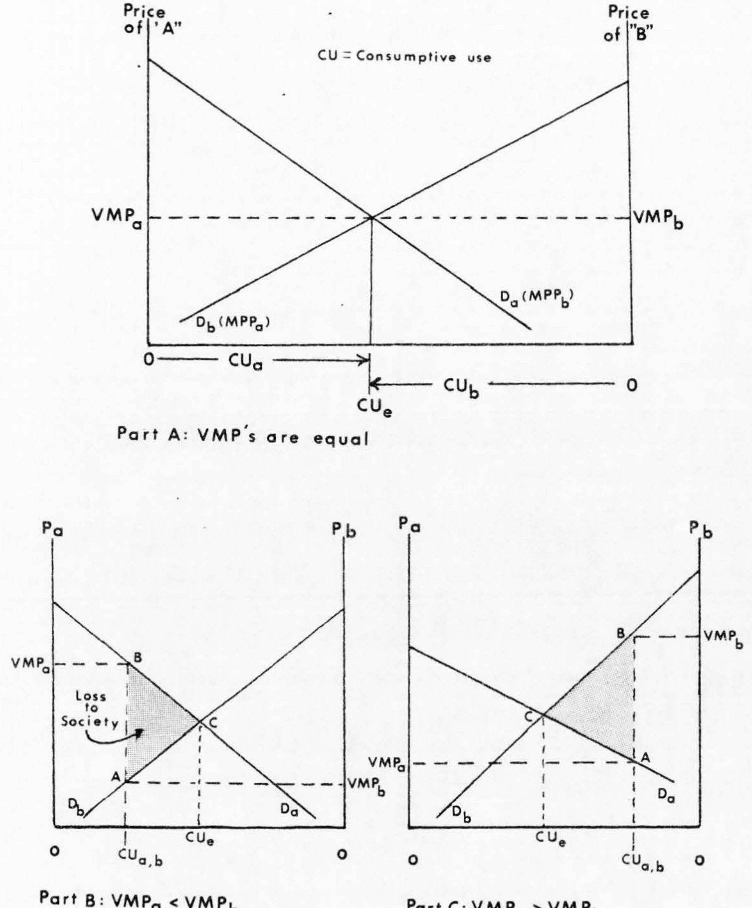


FIGURE 5
EXTERNALITY STATES PRIOR TO TECHNOLOGY ADOPTION

it demands by virtue of its location, then, Unit B would increase its consumptive use to CUa,b in Figure 5b. The net loss to society is BCA, the shaded area. The shaded area in Figure B shows the loss (externality) when VMPa > VMPb. In Figure C the area shows the loss when VMPa < VMPb.

After the Adoption of Modern Techniques

When the new technologies are adopted causing the marginal physical products of Units A and B to shift, one of several situations will result: 1) an externality will be created, 2) the initial distortion will be reduced or eliminated, 3) the welfare loss will be increased, or 4) the externalities will be imposed on the other unit.

Figure 6 shows the first situation where an externality is created. This occurs when the value of the marginal physical product is equal in the initial condition. The adoption of sprinklers causes the marginal products to increase. This is shown as a shift of the demand curves from Da to Da' and Db to Db'. When Unit A (the upstream user) expands his consumptive use to CUa from CUe where price equals the demand curve for a. Then assuming total supply of water is fixed, the water available for consumptive use by B falls to CUb, at this new quantity the value of the marginal product increases to VMPb'. As a result, an externality is imposed on B. The VMPa < VMPb' and a net loss to society occurs which is equal to the area BCD.

In the case where an externality exists, prior to the adoption, i.e. the VMPa ≠ VMPb, one of several impacts can occur. The externality can be reduced or eliminated, aggravated or switched to the other party. In the first two instances where the externality is reduced or eliminated, society will gain. For example, prior to the adoption, we assume the externality is on Unit A (VMPA > VMPb), as shown in Figure 7. Society's

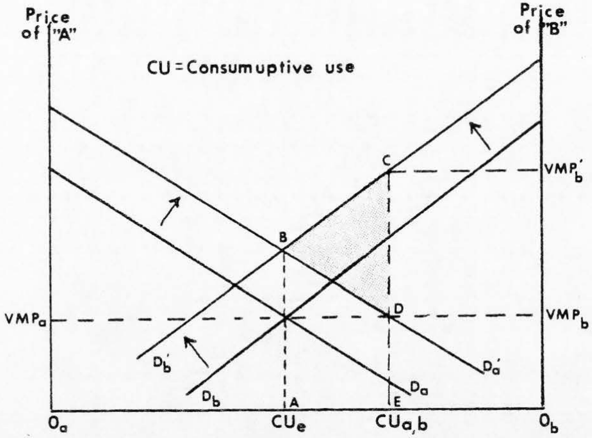


FIGURE 6: EXTERNALITY CREATED WITH THE ADOPTION OF TECHNOLOGY

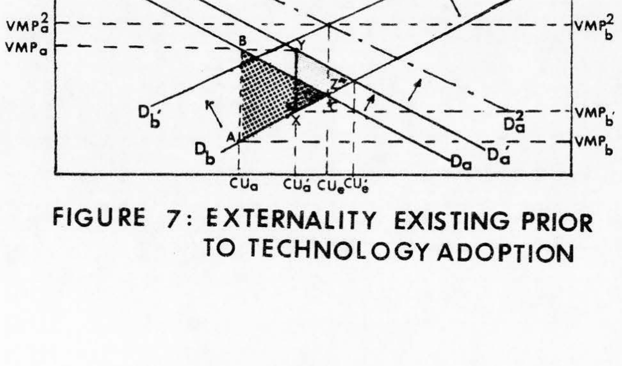


FIGURE 7: EXTERNALITY EXISTING PRIOR TO TECHNOLOGY ADOPTION

loss is equal to area ABC when Unit A consumes CUa. With the adoption of the newer technologies in Unit A only the demand curve shifts to Da'. However, for one reason or another (access to the resource due to locational advantage) Unit A is able to increase its consumptive use from CUa to CUa', where CUa' is still less than CUe', where no externality would exist. In this instance, the loss to society is area XYZ, and XYZ < ABC. The externality and loss to society has been reduced, yet an externality still exists. Had one or both of the demand curves shifted in a manner where CUe was attained or value of the marginal products were equal, VMPa = VMPb, then the externality would no longer exist. This occurs in this example when the demand for Unit A shifts to the D_a^2 curve and the demand for Unit B shifts to the Db' curve.

With the adoption of the newer technologies in Unit B, the demand curve shifts to Db'. Had Unit B been able to increase its consumptive use to CUb', as in Figure 8, then society's loss would have increased (area ABC < XYZ) as indicated by VMPa' > VMPa > VMPb. If Unit A adopted the newer technologies and maintained access to the resources by virtue of its location, then the loss to society will increase to area XY'Z' where the VMPa" > VMPa' > VMPa > VMPb.

In the instance where prior to the adoptions VMPa > VMPb and after the adoptions of the newer technologies in Unit B and not in Unit A, thereby increasing the demand in Unit B and not in A, there is a net increase in society's loss by area ABC (Figure 9) as the consumptive use is maintained at CUa. As Unit A increases the technology and CU to CUa', thereby reducing the consumptive use in Unit B, the VMP increase in Unit B to VMPb' and reduces the externality in A and reduces the loss to society (area XYZ). If the VMPb increases even greater than VMPb' in Unit B,

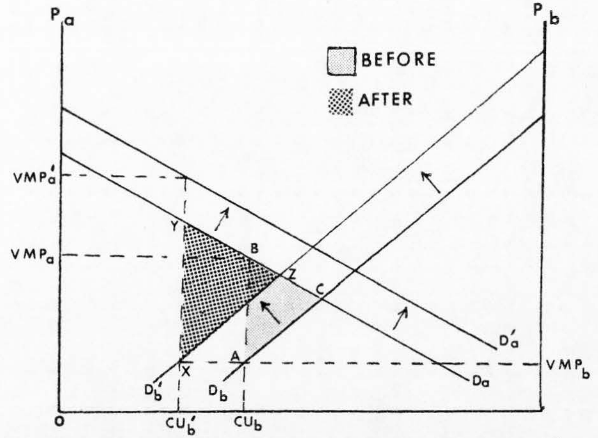


FIGURE 8: TECHNOLOGIAL ADOPTION AGRAVATING AN EXTERNALITY

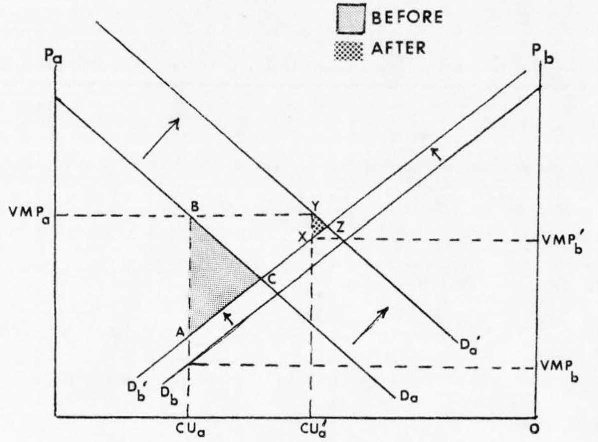


FIGURE 9: EXTERNALITY REVERSAL WITH TECHNOLOGICAL ADOPTION

the externality will be reversed, i.e., VMPa < VMPb from Unit A to Unit B. If the social loss after the adoption is less, although reversed, society gains. If the social loss is greater then society is worse off.

Adoption of Technology without Violation of Water Rights

In the above instances, the water available for consumptive use remained constant. However, when the new systems are adopted the total water available for consumptive use could increase as the improved irrigation can save water by reducing evaporation, deep percolation, phreatophyte consumption and/or withdrawing water from wetlands (assuming no environmental benefits are foregone). In this instance, it would be possible to increase consumptive use by one or more units without causing or increasing externalities and without violating water rights.

Figure 10 shows this condition where a previous externality exists. Prior to the adoption of the new system the following conditions hold: VMPa > VMPb; water rights of both units are OCUa for Unit A, and OCUb for Unit B; the total water available is CUt and CUt = OCUa + OCUb. After the adoption, total water available for consumptive use increases by δCUt. Unit A and Unit B increase their consumption by δCU'a and δCU'b respectively. In addition, the sum of the individual increases is less than or equal to the total increase in water available for consumption, CUa' + CUb' $\leq$ CUt'. In this instance total consumption by each unit increases and all units can maintain their water rights.

Even if the private incentive for the adoption of these modern systems results in property right violations, this study is aimed at identifying the losers and gainers. Assuming basin wide output increases,

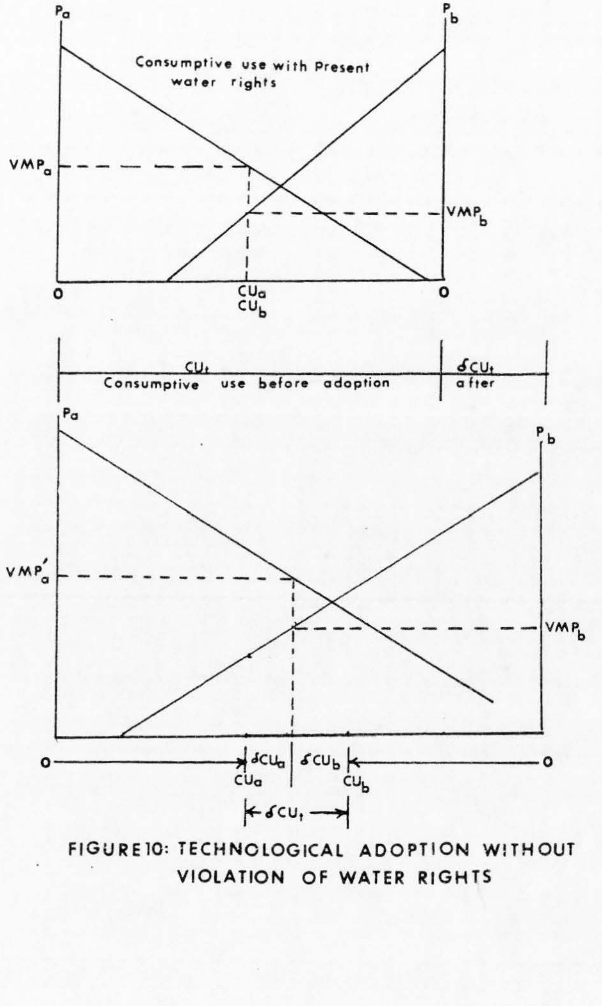


FIGURE 10: TECHNOLOGICAL ADOPTION WITHOUT VIOLATION OF WATER RIGHTS

this would be a desirable situation by facilitating appropriate water transfers.

When the adoption of sprinklers and other systems results in increased basin output, and although diversion rights may not be met, government intervention through enforcement of diversions and acreage limitation and the use of taxes and subsidies may only serve to reduce basin output (social output). For example, should acreage limitation prevent the use of high yielding lands, it may be desirable from a social point to irrigate this land even if water rights elsewhere are not met because the social gain exceeds the loss.

Supply

In the discussion so far, the cost aspect has been neglected. In addition, to the irrigator being a demander of water for consumptive use, the irrigator is also the supplier of water to be consumptively used by the crops. The extent of adoption of modern systems depends on their cost. Associated with the new irrigation system, the supply curve of water change. The introduction of a capital intensive system (lined ditch, pipe, drainage systems and/or sprinklers) generally causes the supply curve to shift to the left. This shift due to increased costs for supplying water determines whether in fact, the consumptive use increases or not.

The degree of shift in the cost and the profitability of the new system being adopted depends also on the class of land to be irrigated. Land classification therefore is related to the two factors which affect the adoption of these modern systems. They are yields and irrigation costs.

Land classes are defined with respect to four qualities. These are wetland, climate, erosion and soil qualities. When water retention or flooding is the primary problem, the soil is classified as "w", if climate is the primary problem in growing crops the soil has a "c" subclassification. Erosion or slope problems are given a subclassification of "e". For shallow soil, or salt-alkali problems a subclass of "s" is used. The primary classification of land with respect to yield and ability to grow crops, range from a high of Class I to low of Class VII. Agricultural lands range from Class I to Class IV. For the higher quality lands in the Sevier Basin (Classes IIw, IIc, IIe and IIIe), the annual costs are higher for spinkler and/or lined ditches than for any surface flood irrigation system. While there is an increase in output (revenues) associated with the adoption of more "efficient" systems it may not be sufficient to close the cost differential between the system.

However, investment and annual cost of surface irrigation systems are inversely related to the lengths of irrigation runs; i.e. as irrigation runs are shortened, costs per acre increase. Lands with steeper slopes and course soil require shorter run and require more frequent irrigations and consequently, more irrigation structures and equipment to convey and distribute water. Thus, the cost gap between sprinklers and surface irrigation methods is decreased for the poorer quality lands, IIIe, IVw, IVs, IVc. However, total crop productions for the poor quality lands is significantly less where shorter runs are required. In this instance the relative gain in yield may not be sufficient to warrant its adoption.

For the medium quality land (IIe, IIIw, IIIe, IIs), the investment and annual costs of surface irrigation systems are rising while sprinkler systems costs remain relatively constant. This combined with increasing yields could result in the medium quality land being relatively more profitable for sprinkler adoption.

Then considerations are to be incorporated to evaluate how private incentives for the adoption of sprinklers and improved conveyance systems would affect third parties. Further, if there is a welfare loss as a result of private decisions, through government intervention, policies need to devised by which basin-wide output should be maximized. To examine various policy implications and manage water resources basin-wide, a centralized planning approach will be used. Alternative policy effects can be simulated using this framework and optimal irrigation systems adoption can be determined.

CHAPTER IV

EMPIRICAL MODEL

The Programing Model

Water rights are generally assigned in terms of the quantity that an individual farmer is allowed to divert and irrigate over specified parcel of land. Any changes in economic, technological and physical factors affecting water consumptive use will create externalities. Therfore, enforcement of water laws and protection of property rights should entail monitoring the actual quantity of water consumptively used. But the measurement costs are prohibitively high and as a consequence, alternate procedures are needed to determine impacts of changes in water consumptive use.

Specifically, to examine the impact of the adoption of modern irrigation systems on third-parties and to facilitate water transfers that are consistent with basin-wide output maximization, a mathematical programming model will be used. The model formulated in this study uses data have been observed for the Sevier basin. The policy conclusions derived based on this model will be directly applicable to the Sevier basin area.

One of the key factors of the model was the inclusion of the various soil types and slope features as they affect the various methods of irrigation associated "efficiencies" and crop yields. Soil types and slope data have been appropriately weighted by percentage of land types so that these characteristics are reflected in the various land classifications.

The model was designed to maximize the Sevier River Basin's agricultural net returns subject to various constraints. Important model features are shown in Figure 11 which includes the agricultural and the hydrologic submodels. The basin was divided into six counties, with the following factors being considered: slope, soil types and yields as reflected by land class; crop consumptive use for nine crops (alfalfa, alfalfa seed, barley as a nurse crop, wheat, pasture, potatoes, corn for silage and corn for grain); crop rotation patterns; various on and off-farm irrigation systems and efficiencies; water diversions and acreages limitations which took into account the legal constraints administered by the state engineer. Table 1 lists the basic data sources.

The mathematical structure for the LP Model was constructed as follows: the objective function is given by:

$$\text{Max } Z = \sum_{i=1}^{L} \sum_{j=1}^{M} \sum_{r=1}^{N} b_{ij}^{r} X_{ij}^{r} \quad - \sum_{r=1}^{N} \theta GW^{r}$$

(net crop revenue) (groundwater diversion costs)

$$- \sum_{q=1}^{S} \sum_{r=1}^{N} \phi_{q}^{r} Wd^{r} \quad + \sum_{h=1}^{t} \sum_{r=1}^{N} \delta \Gamma_{h}^{r} Td_{h}^{r} \quad - \sum_{h=1}^{t} \sum_{r=1}^{N} \eta \Gamma_{h}^{r} Td_{h}^{r} \qquad (1)$$

(cost of off-farm) conveyance system (cost sharing) (tax on system)

Subject to the following constraints:

$$\text{Land:} \quad \sum_{j=1}^{M} X_{ij}^{r} \leq PIL_{i}^{r} \qquad i=1,\ldots,L \qquad (2)$$

(presented irrigated land) $r=I,\ldots,N$

$$\sum_{j=1}^{M} X_{ij}^{r} \leq PDL_{i}^{r} \qquad i=1,\ldots,L \qquad (3)$$

(Potentially irrigated land) $r=1,\ldots,N$

$$\text{Crop Rotations:} \quad \sum_{h=1}^{t} \sum_{i=1}^{L} \sum_{j=1}^{M} \left(\varepsilon_{j} X_{ijh}^{r} \pm \sum_{\substack{J_1=1 \\ J_1 \neq j}}^{Q} \sigma_{J_1} X_{iJ_1 h}^{r}\right) \gtrless 0 \quad r=1,\ldots N (4)$$

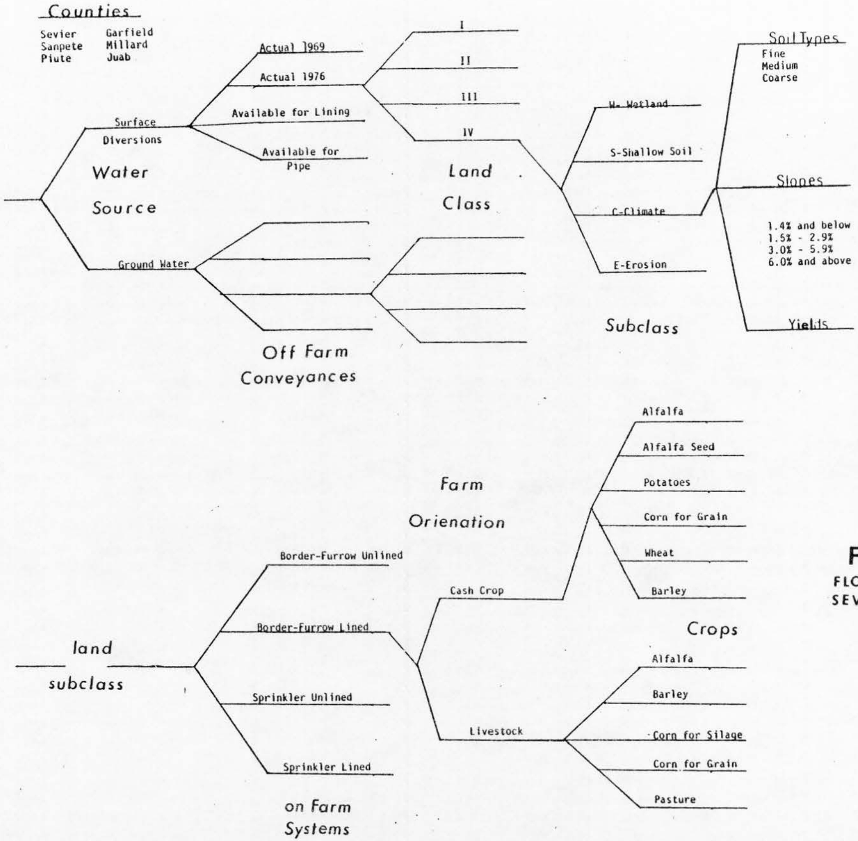


FIGURE 11
FLOW DIAGRAM OF THE SEVIER RIVER BASIN

TABLE 1

SOURCES OF DATA

Data	Source
Agricultural prices	Utah Agricultural Statistics (1970-1977)
Pasture prices	Nebraska Formula Davis (1979)
Crop productivities by	
land class	Utah and Idaho Soil Surveys (1968-1979) Soil conservation Service
for nurse crop	Richards (1979)
Basic farm budget	
general	Utah Agricultural Statistics (1975-1977) and Christenson (1973)
Sevier Lake basin	USDA (1969x)
Cropping practices	
Sevier River Basin	USDA (1969x)
Alfalfa seed production	Ogden (1979)
Costs	
Labor	Utah Agricultural Statistics (1976)
Machinery, depreciations and insurance rates	Franklin (1979) and Cummings (1977)
Land evaluations	Christenson (1973)
Sprinkler	Franklin (1979)
Groundwater mining	Oklahoma (1978), USDA (1973a)
Off-farm systems	Tuttle (1979) UWRL (1975)
Power and fuel costs	UWRL (1975), Inter-agency task force (1978), Franklin (1979)
Potato cost by farm size	Davis (1974)
Land clearing costs	Snyder (1979)
Drainage costs	Hancey (1979)
Leaching costs	USDA (1969a)
Land Classification	
Soil and slope relationships	Utah Soil Surveys (1968-1979) Soil Conservation Services
Irrigation Efficiencies	
For slope and soil type	Strong (1972)
For off-farm systems--unlined	USDA (1969a), Mizue (1968)
County total system	USDA (1969)
Length of raw requirements	Utah Soil Surveys (1968-1979) Soil Conservation Service, Strong (1972)

Table 1, Continued

Data	Source
Rotation Practices and Acreage Limitations	
Maximum acreages--wheat, potatoes and alfalfa seed	Agricultural Census data (1959-1979), Davis (1974)
General constraints	Stewart (1979), McAllaster (1979), Hiskey (1972), Ogden (1979), Andersen (1979)
Corn irrigation by sprinkler	Finkel (1960), Ogden (1979), McAllaster (1979)
Consumptive Use Requirements	USDA (1969 IV), Irrigation Operator's Workshop (1966), and Criddle (1962)
Acreages by Land Class	USDA (1970), USDA (1969 IV)
Water Losses	
Deep percolations	Mizue (1968), Keith (1973)
Evaporation	Snyder (1979)
Phreatophyte consumption	Blaney (1961)
Form Classifications	USDA (1969a)

Surface water for agricultural diversion;

$$\sum_{r=1}^{N} IF_r + A_r^* \geq TD_r \tag{5}$$

Inflows:

$$\sum_{\substack{r=1 \\ r_1 \neq r_2}}^{N} OFr_1r_2 = IF_{r2} \qquad r_2=1,\ldots,N \tag{6}$$

Groundwater availability

$$\sum_{r=1}^{N} GW^r \leq \sum_{r=1}^{N} GW^{r*} \tag{7}$$

Total water available for diversions

$$TD_{r_1} + OF_{r_1} - RF_{r_1} - \sum_{r_2=1}^{N} IF_{r_1r_2} = Ar_1^* \quad r_1=1,\ldots,N \tag{8}$$

Diversions

$$\sum_{h=1}^{t} \frac{1}{\gamma_h} \left(\sum_{i=1}^{L} \sum_{j=1}^{M} CU_{ij}^r \right) = WA^r \tag{9}$$

On-farm availability

$$GW^r + \sum_{q=1}^{S} \lambda_q^r \, Wd_q^r = WA^r \qquad r=1,\ldots,N \tag{10}$$

(total water conveyed to the farm)

Total stream diversions

$$\sum_{q=1}^{S} Wd_q^r = TD^r \qquad r=1,\ldots,N \tag{11}$$

Return flow constraint

$$WA^r - \sum_{i=1}^{L} \sum_{j=1}^{M} CU_{ij}^r - \sum_{q=1}^{S} \beta_q^r (1-\lambda) Wd_q^r + \sum_{q=1}^{S} \left| (1-\beta)(1-\lambda) \right| \cdot$$

$$Wd_q^r - w \sum_{h=1}^{t} Wd_h^r = RF^r \qquad r=1,\ldots,N \tag{12}$$

Total conveyance losses

$$\sum_{q=1}^{S} \beta_q^r (1-\lambda) Wd_q^r \quad (13)$$

Definition of Variables and Terms

i	Class of land (IIw, s, c, E, IIIw, S...etc.)
j	Type of crop grown
r,k	County
h	On-farm irrigation system
q	Off-farm conveyance system
b_{ij}^r	Net revenue associated with one acre of the jth crop grown in the ith class of land in the rth county
X_{ij}^r	jth crop acreage grown in ith land class in county r
θ	the cost of pumping one acre inch of groundwater
GW^r	the amount of groundwater for the rth region (acre inches)
ϕ_q^r	the cost of diverting water by qth off-farm method for the rth county
Wd^r	the amount of water diverted from surface flows to the rth county
PIL_i^r	potential land for irrigation of the ith class in the rth county
δ	percent of the irrigation system costs paid by cost sharing
η	percentage tax rate based on system cost
Γ_h^r	per acre cost of the hth on-farm irrigation system in the rth county
Td_h^r	total water diverted by the hth on-farm irrigation system in the rth county
β_q^r	percentage of waters lost to deep percolation, evaporation and phreatophyte consumptive use for the qth off-farm conveyance system in the rth county

w percentage of water percolated beyond groundwater recovery

γ_h efficiency of the hth on-farm system

CU_{ij} consumptive use of the jth crop on the ith land class

TCL^r total conveyance losses to the system due to evaporation, deep percolation and phreatophyte losses in the rth county

X_k^r the amount kth crop acreage allowed in the rth county

k crops, potatoes, alfalfa seed and wheat

$\varepsilon_j, \sigma_{j_2}$ the rotational coefficient of the jth and j_1st crop on the ith land class using the hth type of on-farm irrigation system in the rth county

WA^r water conveyed to the farm available for delivery to the crops by an on-farm system

IF_r water flows into the rth county

A_r^* surface water flows available from within the rth county

TD_r total surface water diverted from the stream in the rth counties

OF_r water flows out of the rth county

GW^r groundwater diversions in the rth county

GW^{r*} total groundwater diversions allowed in the county

λ_h off-farm efficiency for the hth irrigation system in the rth county

RF_r water not consumed and returned as stream and groundwater

CU_{ij}^r beneficial consumptive use requirement by the jth crop on the ith class of land in the rth county

Objective Function Coefficients

Total Revenue

In order to maximize net revenue for the basin, both total revenue and total cost had to be determined for each crop for the 11 land classes. In determining revenues, an average was used to eliminate the year to year variability of agricultural prices. An eight year price average was determined for each crop, except for pasture lands and an establishment (nurse) crop which are not reported, Utah Agricultural Statistics (1970-1977). The price of pasture land was determined using the Nebraska formula which linked the price of pasture land to price of alfalfa, Davis (1979). Establishment or nurse crop price was a weighted price determined by taking the price of alfalfa times the expected yield for one alfalfa cutting (USDA, 1969 IX) plus the expected yield of barley as a nurse crop (Richards, 1979) times its price.

Crop yields for the 11 land classifications found in the basin were determined by averaging estimated yields for each land class per acre as found in the various soil surveys of Utah, published by the Department of Agriculture Soil Conservation Service. For corn and potatoes data for several Idaho counties were used. Total revenue by land class was then determined by multiplying the yield by the average prices (Table 2).

Ten percent higher yields were used for sprinkler irrigations based primarily on Cummings (1977) and USDA (1969 XII) indicating that yields increased as water application efficiency increased.

Farm Budgets and Costs

Separate farm budgets were developed for each of the 11 land classes: for 4 on-farm irrigation systems; lined and unlined flood, lined

TABLE 2

TOTAL REVENUE FOR AGRICULTURAL PRODUCTION BY LAND CLASSES FOR FLOOD IRRIGATION

Crops / Land Classes / Price	Alfalfa (August) $41.75 (ton)	Alfalfa seed $74.84 (CWT)	Establishment Crop* (b)	Potatoes 3.07(CWT)	Corn for Grain 2.45 (bu)	Corn for Silage 14.18 (ton)	Wheat 2.67 (bu)	Barley 1.84 (ton)	Pasture* 8.35 (AUM)
	TR	TR	TR	TR	TR	TR	TR	TR	TR
Class IIW	221	304	129	875	256	341	193	172	96
IIS	221	304	122	893	284	231	187	160	84
IIC	234	308	129	936	a	330	222	170	92
IIE	255	316	124	921	229	281	199	153	88
Class IIIW	205	300	110	801	212	279	180	143	84
IIIS	196	296	106	783	180	220	160	138	71
IIIC	167	246	97	a	a	a	134	131	63
IIIE	209	300	105	866	189	271	160	135	75
Class IVW	180	250	89	642	135	260	153	112	67
IVS	171	246	97	660	116	242	134	129	63
IVE	200	296	105	672	162	212	a	134	75

[a]Not enough acreages of the crop grown on this class to determine on average.

[b]Calculated on the basis of a one ton alfalfa yield and 50% of the barley yield for that class of land.

*Estimated price

and unlined ditch with sprinklers systems: for 9 crops and 6 counties. Table 3 lists the farm characteristics while Tables 4 and 5 shows a sample budget for alfalfa. The basic farm budget for each crop was developed from the Utah Agricultural Statistics (1975, 1976, 1977), USDA (1969X) and Christensen (1973). USDA (1969X) was used to determine frequency of use, and general cropping practices within the basin, i.e., whether alfalfa was grown strictly for seed or as alfalfa for hay and seed.

At the time the model was developed the most comprehensive data available was for the year 1976. Thus, the model used 1976 as the base year to calculate farm budgets. Wage rates and labor costs were taken from Utah Agricultural Statistics (1976). Machine costs, depreciation and insurance rates were determined from Franklin (1979) and Cummings (1977), with machine time from Christensen (1973). Land evaluations by class were updated from Christensen (1973) for incorporating tax costs.

Irrigation costs were developed as follows: The initial step was to develop a land class profile which reflected soil types and slopes, USDA-SCS soil surveys were used to determine the percentages for the soil types; the soil types are classified as fine, medium and coarse. Slopes classified are: less than 1.4%, 1.5 to 2.9%, 3.0 to 5.9% and 6.0% and over, for each of the 11 land classifications.

Strong (1962), was used in determining irrigation efficiencies for the 11 land classes for each irrigation system, as well as identifying machine time and labor requirements based on soil types and slopes. The soil surveys were used to determine recommended irrigation timings and length of run for the land classifications and irrigation systems. The

TABLE 3

FARM CHARACTERISTICS USED IN THE SEVIER RIVER BASIN MODEL

Land Classes:

Class 2: High Yielding Land
Subclass
- W = water problem
- S = soil salts and alkaline problem
- C = climate problem
- E = erosion and slope problems

Class 3:
Subclass
- W
- S
- C
- E

Class 4: Low Yielding Land
Subclass
- W
- S
- E

Crops:

Alfalfa	Corn for Grain	Wheat
Alfalfa seed	Corn for Silage	Barley
Nurse crop	Potatoes	Pasture

Geographic Area:

Garfield County	Sanpete County
Piute County	Juab County
Sevier County	Millard County

Irrigation Systems:

On-farm:
- surface flooding unlined ditch
- surface flooding lined ditch
- sprinkler with unlined ditch
- sprinkler with lined ditch

Off-farm
- unlined channel
- lined channel
- covered pipe

TABLE 4

FARM BUDGET FOR ALFALFA BASIC BUDGET

Basic Variable Costs	Number of Times (e)	Man Hours (e)	Labor Costs at 2.38/hr	Machine Time (e)	Power and Fuel (b)	Depreciation & Insurance	Materials (a)	Total Flood Unlined	Total Flood Lined	Total Sprinkler Unlined	Total Sprinkler Lined
Fertilizing 45 lbs/acre	1	.4	.95	.3	1.38	1.09	6.90	$ 10.32			
Spraying	1	.4	.95	.1	.31	.28	4.20	5.74			
Swathing	3(a)	1.3(a)	3.09		4.32	5.22		12.63			
Bailing	3(a)	1.7(a)	4.05		6.06	4.13	3.75(b)	17.99			
Loading & hauling	3(a)	7.4(a)	17.61		6.66	2.94		27.21			
Taxes $88 assessment at 60 miles								5.25(a,e)			
Subtotal								$ 79.14	$ 79.14	$ 79.14	$ 79.14
Irrigation Costs											
Land planning (c)								5.20	5.20		
Ditching-corregating	1.8(a)	.3(c)	.71	.25(c)	1.51	.47		2.69	2.69		
Renovating system	1(d)	1.5(d)	3.57	1.4(d)	3.92	3.46		10.95	4.94	10.95	4.94
Preirrigation setup (d)	1	.3	.76	.1	.14	.13				1.03	1.03
Irrigating											
Flood 2A/hr	4.5	2.25	5.22					5.22	5.22		
Sprinkler	6x.94	5.64	13.42	5.7	5.77	15.61				34.80	34.80
Down Time 10%								3.62	3.62	2.62	2.62
Subtotals								27.68	21.67	49.40	43.39
Interest variable cost 6%								6.09	6.45	7.40	7.40
Interest other								7.17	7.17	7.17	7.17
Interest ditches									9.77		9.77
sprinkler										7.17	7.17
Depreciation ditches									7.98		7.98
sprinklers										9.77	9.77
Subtotals								13.26	31.37	31.51	49.26
								$120.08	$132.18	$160.15	$171.79

(a) Utah Agricultural Statistics
(b) Franklin (1976)
(c) USDA (1969X)
(d) Strong (1962)
(e) Christensen (1973)

TABLE 5

FARM BUDGET BY LAND CLASS FOR ALFALFA

Land Classes	2W/2C	2S	2E	3W	3S	3C	3E	4W	4S	4E
					Cost Index					
Ditching & renovation	100	117	129	100	127	151	156	112	173	168 [f]
Irrigating costs, downtime and interest	100	100	111	100	111	135	136	107	148	151 [g]
					Budgets for Alfalfa - Flood Unlined					
Basic (flood-unlined) cost	79.14									
Plus other interest	7.17									
	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31
Ditching & renovation	13.64	15.96	17.60	13.64	17.32	20.60	21.28	15.28	23.60	22.92
Irrigation & downtime	8.84	8.84	9.81	8.84	9.81	11.93	12.02	9.46	13.08	13.35
Subtotals	108.79	111.11	113.72	108.79	113.44	118.84	119.61	111.05	122.99	122.58
Interest v.c. 6%	6.09	6.67	6.82	6.53	6.81	7.13	7.18	6.66	7.38	7.35
Land planning	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20
Total costs	120.08	122.98	125.74	120.52	125.45	131.17	131.99	123.91	135.47	135.03
					Alfalfa - Flood-lined					
Base \ Land Class	2W/2C	2S	2E	3W	3S	3C	3E	4W	4S	4E
Basic costs	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31
Ditching & renovation	7.63	7.63	8.64	7.63	8.64	10.30	10.38	8.16	11.29	11.52
Irrigation & dep....etc.	16.82	18.50	20.52	16.82	20.52	26.74	24.22	18.84	26.74	26.74
Interest system	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77
Interest v.c. 6%	6.45	6.63	6.81	6.53	6.81	7.28	7.14	6.78	7.28	7.63
Lane planning	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20
Subtotals	45.87	47.73	50.94	45.95	50.94	59.29	55.71	48.75	60.28	60.86
Totals	132.18	134.04	137.25	132.26	137.25	145.60	143.02	135.06	146.59	147.17

Table 5, Continued

-continued-

	Alfalfa - Sprinkler-unlined									
	2W/2C	2S	2E	3W	3S	3C	3E	4W	4S	4E
Basic cost	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31
Renovation	10.95	12.81	14.13	10.95	13.90	16.53	17.08	12.26	18.94	18.40
Irrigation, preirrigation interest, depreciation, downtime	62.89	62.89	69.81	62.89	69.81	84.90	85.53	67.29	89.93	94.96
Total Cost	160.15	162.01	170.25	160.15	170.02	187.74	188.92	165.86	195.18	199.67

	Alfalfa - Sprinkler-lined									
	2W/2C	2S	2E	3W	3S	3C	3E	4W	4S	4E
Basic cost	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31	86.31
Renovation	4.94	5.78	6.37	4.94	6.27	7.45	7.71	5.53	8.55	8.30
Irrigation; preirrigation; interest, system, v.c.; downtime	80.54	80.54	89.40	80.54	89.40	108.73	109.53	86.18	119.20	121.62
Total Cost	171.79	172.53	182.08	171.79	181.98	202.49	203.55	178.03	214.06	216.23

f/ - adjusted for length of runs

g/ - irrigation time, soil & slope adjustment irrigation timings and lengths of run were then used to weight the labor and machine times to reflect the differences (Appendix B describes this calculation). Power and fuel costs, depreciation, insurance, interest on irrigation capital were calculated using UWRL (1975), Inter-Agency Task Force (1978), Franklin (1979). Oklahoma State University (1978) and then adjusted for each land type and system using the above weights.

The farm budgets for alfalfa seed production were based on the cropping practices in Millard County as over 85% of the total seed output was grown in this county. The budget reflected that 66% of the seed grown included, at least one hay cutting, while 33% was straight seed production.

Potato production costs were adjusted to reflect farm size. A cost index by farm size was used and acreages were determined using Census of Agricultural data; Davis (1974), Census (1974, 1979).

Land development costs were calculated and added to the basic farm budgets. It was assumed that all land required clearing prior to use. The costs reported by Snyder (1979) were used. Due to high water tables and salinity problems, all wetlands class 2W, 3W, and 4W would require draining in order to maintain yields over time, Irrigation Operators Workshop (1970). Drainage costs were estimated from Hancey (1979).

Other Costs

For sprinkler irrigation in Millard County an additional cost was added to the farm budgets to reflect the labor and ditch maintenance necessary to provide for a flood irrigation leaching, Irrigation Operators Workshop (1970) and USDA (1969a). The cost of mining groundwater at \$1.27 per acre inch was determined from USDA (1973a) and Oklahoma State University (1978) for up to a 300 foot deep well.

The cost of converting to the various off-farm irrigation systems was determined from UWRL (1975) and Tuttle (1979). The costs were weighted by irrigation conveyance system condition percentages from USDA (1969a), in which it was assumed that the poor quality system would require the highest costs.

$$C_i^r = \frac{\sum_{i=1}^{a} \sum_{j=1}^{b} \gamma_{ij} \alpha_j^r}{\beta} \qquad r=1,\ldots,N \tag{14}$$

i type of off-farm system, lined ditch or covered pipe

C_i^r cost per acre of the ith system in the rth county

γ_{ij} cost of the ith system for the jths conveyance condition per mile

α_j percentage for the jth conveyance condition in the rth county per mile

β acres per mile

Constraints

Agriculture

Rotational constraints were used to reflect cropping practices used to maximize yields (alfalfa) to limit decreases (potatoes) or weed and insect problems (seed and wheat).

Rotational constraints for all crops were developed from Stewart (1979), McAllaster (1979), Hiskey (1972) and Ogden (1979). The rotational constraints are listed in Table 6.

Alfalfa and alfalfa seed constraint were established from Hiskey (1972), at those levels which would maximize yields. Ogden (1979) indicated that the average farmer in Millard County, harvested a seed crop every 3rd year of alfalfa growth, as this generally produced the

TABLE 6

ROTATIONAL CONSTRAINTS FOR SELECTED CROPS IN THE SEVIER RIVER BASIN

1) Alfalfa = 4 Alfalfa Establishment [except in Millard County]

2) Alfalfa seed $\leq$ 8 Alfalfa Establishment [except in Millard County]

3) .33 Alfalfa $\geq$ Alfalfa seed [Millard County only]

4) .25 Alfalfa + 1.67 Alfalfa seed $\leq$ Alfalfa Establishment [Millard County only]

5) Alfalfa + Alfalfa seed $\leq$ 8 corn for silage [except in Piute County]

7) Potatoes $\leq$ 4 alfalfa

8) Potatoes $\leq$ 4 wheat + 4 corn for grain

9) Wheat $\leq$ 4 Barley

10) Wheat $\leq$ 5 Alfalfa Establishment

best yields. The alternative according to Ogden (1979) and McAllaster (1979) would be to have the former concentrate on to seed production, this is something not generally done in the basin. The potato and grain constraints were established in order to minimize the problems of weeds and diseases (Richards (1979), Ogden (1979), Andersen (1979)).

Corn was not grown in Garfield County because of the weather, short growing seasons and attitudes; corn was not generally considered as being a crop irrigated with sprinklers as stated by Finkel (1960):

> Those crops which grow fairly tall such as corn cannot be easily irrigated by sprinklers because the crop interferes with uniformity of distributions unless the sprinkler heads are mounted in very high standards. Portable pipe is also seriously hindered by tall plants. Furrow irrigation in general is the advantage for all plants. (pg. 93)

In all counties except Millard, the general methods of sprinkler irrigation was portable pipe or big wheel methods. However, in Millard, the Center piviot is used and often mounted in high stands for potato irrigation. Thus, corn for grain irrigated by sprinkler incorporated with potatoes was considered feasible.

Crop Water Requirements

The data for consumptive use of water by crops was obtained from UDSA (1969 III), and verified for reasonableness using Irrigation Operator's Workshop (1966) and Criddle (1962). Where the crop irrigation water requirement per acre (CU_j) for the jth crop was defined as total consumptive use (TCU_j) of the jth crop per acre, less total precipitation (P) on irrigated lands, total direct use from ground water (G) and Total Root Zone availability (RZ) per acre for the growing season from May 1st to October 30th.

$$CU_J = TCuj - \left(\frac{P + G + RZ}{Total\ Acres}\right) \qquad J=1,\ldots,M \tag{15}$$

Diversion Requirement

The diversion requirement was defined as the amount of water which has to be taken out of the system and to be diverted via the on-farm irrigation system to meet crop consumptive use need.

$$DR_h = \frac{1}{\eta_h^r} CU_j^r \qquad \begin{array}{l} h=1,\ldots,E \\ j=1,\ldots,M \\ r=1,\ldots,N \end{array} \tag{16}$$

DR on-farm diversion requirement for the hth on-farm system

η_h^r the efficiency of the hth on-farm delivery system in rth county

CU_j^r consumptive use requirement for the jth crop in the rth county

Conveyance and Delivery System Efficiencies

Total system efficiencies were by watershed as reported in USDA (1969 IV) and interpelated by county. Total miles and type of off-farm conveyances in pipe and lined ditch was given in USDA (1970). The milage and condition of unlined canals by subbasin was available from USDA (1969a). Mizue (1968) listed an estimated range of conveyance efficiencies for the various conveyances (Table 7). Inter-agency Task Force (1979) also gave efficiencies in this range. For unlined ditch the range was between 20 and 60%. It was assumed that an unlined canal in poor condition would be 20% efficient and a canal in good condition was 60% efficient. A fair conditioned canal efficiency was taken as a mid-point between the high and low.

The average efficiency of an unlined canal in each county was calculated as follows:

$$\Omega^r = \sum_{s=1}^{\gamma} \eta_s^r \theta_s^r \qquad r=1,\ldots N \tag{17}$$

TABLE 7

ESTIMATED RANGE OF LOSSES AND EFFICIENCIES OF CONVEYANCE

Conveyance	Loss, Percent of Diversion		Efficiency, Percent
	Seepage	Operational Waste	
Closed pipeline	0	0-5	95-100
Exposed hard surface	5-15	3-8	77-92
Unlined	15-45	5-15	40-80

Source: Mizue, Hiro, 1968, Irrigation demand in the Utah Lake Drainage Area: The Role of Irrigation Efficiency, Unpublished Dissertation, Department of Civil Engineering, Utah State University, Logan, Utah.

where Ω^r is the weighted unlined canal efficiency for the rth county which is equal to the weighted sums of the efficiency (η_s^r) of the Sth condition of unlined ditch times the percentage (θ_s^r) of that condition for the total unlined conveyance system in the rth county. Then, the total off-farm system efficiency for each county was calculated as follows:

$$\varepsilon^r = \sum_{h=1}^{S} \Omega_h \Phi_h \qquad r=1,\ldots,N \tag{18}$$

Where the off-farm efficiency (ε^r) for the rth county is equal to the sum of the qth conveyance system efficiency (Ω) times the percentage (Φ) of the total system for the hth conveyance system.

On-farm unlined ditch efficiencies (γ) for the rth county were then calculated as:

$$\gamma^r = \frac{\chi^r C}{\varepsilon^r} \qquad r=1,\ldots,N \tag{19}$$

Where C is the consumptive use requirement and assumed to be 1. χ^r was the total system efficiency for the rth county and ε^r was the off-farm efficiency for the rth county.

The estimated attainable field application efficiencies for the four alternative irrigation systems for various physical land situations were produced from the land class profiles previously developed. (Appendix A). Acreages and percentage of land by each class were determined from the Conservation Needs Inventory for Utah, USDA (1970). An overall county wide on-farm efficiency was calculated (a weighted average based on land acreages) using the above acreages and efficiencies for each land class. A ratio of the tabulated on-farm efficiency developed from Strong and the calculated efficiencies from the Sevier Basin budgets USDA

(1969 IV) was used as an adjustment factor. Thereby, expected efficiencies (γ_s^r) for each on-farm system(s) were calculated. Then, the diversion requirement for each system was developed using formula (15).

Water Diversions

Total surface water diversions could not exceed the stream flow entering the county from upstream counties plus the stream flow originating locally within the county. Locally originating water was assumed to consist of small streams, springs and snow melt run-off from basins totally within the boundaries of the rth county.

Total water originating within the county for diversion was calculated by summing the total diversion from all sources for each crop for each land class and on-farm irrigation system. Plus the outflow for the county. From this value one subtracts the return flows and the sum of the inflows into the county. On-farm water availability was made up of mined groundwater and the sum of the water diverted by the various off-farm conveyance systems, formula (9). The water requirement for the jth crop on the ith class of land in the rth county utilizing the hth on-farm system was determined to be:

$$\sum_{h=1}^{t} k\left(\sum_{i=1}^{L} \sum_{j=1}^{M} CU_{ij}^{r}\right) \qquad r=1,\ldots,N$$

$$\text{where } k = 1/\gamma_h$$

where γ_h is the efficiency of the hth on-farm delivery system.

The return flow constraint was made up of several sections and completed the model. Return flow was equal to the water available on the farm (WA^r) less that water which was consumed ($\sum_{i=1}^{L} \sum_{j=1}^{M} CU_{ij}^{r}$) and

and was lost to the system through deep percolation ($w \sum_{h=1}^{t} Wd_h^r$); plus the seepages which were not lost to the system from the off-farm conveyance systems $[\sum_{q=1}^{S} (1-\beta)(1-\tau)_q \, Wd_q^r]$ see page 42 for definition of symbols.

Water losses to the system available neither for plant growth or return flow were made up of three types: deep percolations, evaporation and consumptive use by phreatophytes. Deep percolation was estimated as 5% of the water diverted in unlined conveyance systems and 5% of the return flow from field Mizue (1968), Keith (1973) and ranged from 7 1/2 to 10% of the total waters available. Evaporation was considered to be equal to 10% of the water diverted (wd), (Snyder, 1979). The phreatophyte consumption was 15 acre-feet per mile for poor condition unlined canals, 10 acre-feet/mile for a fair condition canal and 5 acre-feet/mile for good condition canals (Blaney, 1961). Therefore, the percentage of off-farm conveyance losses was equal to:

$$\frac{D_p + E_v + P_c}{\tau_q Wd_q^r} = \beta_q^r \qquad \begin{matrix} r=1,\ldots,N \\ q=1,\ldots,S \end{matrix} \qquad (20)$$

where D_p is deep perculation, E_v is evaporation, and P_c is phreatophyte consumptive use divided by total losses of the qth irrigation system.

RHS (Right Hand Side) Constant Values

Water Resources

Since the total diversions allowed in each county by the State Engineer's Office was not available, Ryan (1979); water budget data on diversions USDA (1969 IV) was used to determine the water rights and available surface allocations. Groundwater availability and rights were determined by interpolating the five year average withdrawal of water from wells reported in UWRL (1974). These availabilities were calculated for the six month growing season, May 1st thru October 30th. Groundwater was generally only piped during the growing season, USDA (1969 IV).

Agricultural Resources

The amount of land available for agriculture in the eleven land classes and subclasses (Table 8) was obtained from USDA (1970) and USDA (1969 IV). Land was categorized into two types: presently irrigated and potentially irrigated. Potentially irrigated land excluded forest acreages found in the 11 land classes. The definitions of the various land classes are defined in (Table 9). Acres of present and potential agricultural land are shown in Table 8.

In a totally unconstrained model three cash crops (potatoes, alfalfa seed and wheat) would be the only crops produced except for other crops which were introduced through rotational constraints. This is a result of two factors, 1) the grain crops tend to be non-water intensive. Thus two acreas irrigated with sprinklers of a grain crop use almost as much water a one acre of alfalfa and the net output of two acres of a grain are equal to or greater than the net return to alfalfa, 2) for both potatoes and alfalfa for seed the net returns are generally greater than those of the other crops. However, this would not be a realistic solution for the basin as the cropping patterns over the past century have been livestock oriented. There are 155,000 acres of alfalfa, 24,200 acres of irrigated wetlands and 106,090 of wetlands supporting this industry which makes up over half of the 540,360 acres in the Sevier River

TABLE 8

LAND AVAILABLE FOR AGRICULTURE AND IRRIGATION BY LAND CLASS

Land Class	Garfield		Piute		Sevier		Sanpete		Juab		Millard	
	Presently Irrigated (I)	Potentially Irrigated (p)	I	P	I	P	I	P	I	P	I	P
Total acreage	32,272	18,863	23,905	4,448	65,303	28,696	72,930	24,706	28,306	35,214	136,600	59,524
2W	-0-	-0-	837	210	916	1,449	-0-	-0-	1,814	-0-	26,432	26,920
2S	567	-0-	572	-0-	3,163	2,131	-0-	-0-	102	-0-	36,153	2,061
2C	178	-0-	4,641	-0-	15,542	2,834	2,559	1,456	5,419	1,205	29,677	885
2E	4,005	-0-	1,861	-0-	16,390	5,587	37,456	3,433	2,992	573	6,919	1,073
3W	3,440	697	7,757	2,045	11,349	2,766	10,702	892	1,261	1,929	8,472	8,846
3S	4,579	-0-	1,774	769	2,462	1,924	1,485	-0-	8,285	3,634	3,965	4,470
3C	2,548	290	1,425	-0-	-0-	-0-	3,316	3,628	3,476	17,525	20,653	-0-
3E	13,733	-0-	3,095	633	6,950	1,831	11,463	3,525	4,070	1,784	2,842	-0-
4W	2,683	2,117	-0-	-0-	-0-	-0-	381	-0-	-0-	-0-	-0-	-0-
4S	539	8,282	1,590	791	521	188	3,754	4,558	463	8,664	732	6,528
4E	-0-	7,377	353	-0-	7,510	7,259	1,521	7,214	424	-0-	695	8,741

TABLE 9

LAND CLASS DESCRIPTIONS, IRRIGATED ACREAGES, UTAH

Irrigated Land Class	Description
Class 2	
Subclass:	
W	Drainage: Excessively to poorly drained. No standing water table within 40 inches of surface after drainage. Overflow or flooding: May occur 1 year in 10.
S	Soil: More than 30 inches deep, surface light, sandy loam to light silty clay. Up to 50 percent gravel. Moderately slow to rapid permeability. Crops affected some by salt or alkali.
C	Climate: Suitable for wide choice of field, small grain, and forage crops. Growing season--100 to 149 days.
E	Slope: 6 percent or less for low erodible soils and 2 percent or less for highly erodible soils. Erosion hazard none to moderate.
Class 3	
W	Drainage: Excessively to poorly drained. No standing water table within 30 inches of surface. Overflow or flooding: May occur 1 year in 5.
S	Soil: More than 20 inches deep, surface heavy, loamy sand to slays and may be peaty. May be gravelly or stony. Stones are 30 feet or more apart. Moderately low water-holding capacity. Permeability slow to rapid. Moderate amount of salt or alkali.
C	Climate: Limited to production of small grains and frose tolerant forage. Growing season--70 to 99 days.

Table 9, Continued

Irrigated Land Class	Description
Class 3	
E	Slope: 10 percent or less for low erodible soils and 5 percent or less for highly erodible soils. Erosion hazard may by severe.
Class 4	
W	Drainage: Excessively to poorly drained. No standing water table within 40 inches of surface. Overflow or flooding: May occur 1 year in 5.
S	Soil: Shallow to 10 inches, (20 inches if over saline shales). Surface sandy to heavy clay and may be peaty. May be gravelly, cobbly, or stony. Stones are 5 feet to 30 feet or more apart and are less than 3 percent of surface. Low water-holding capacity. Permeability slow to rapid. Crops affected some by salt or alkali.
E	Slope: 25 percent or less for low erodible soils and 10 percent or less for highly erodible soils. Erosion hazard may be severe.

water budget area, USDA (1969a). In addition, the cash crop farms were generally concentrated in the Millard County area. All other counties were normally livestock oriented (Table 10).

Hence, acreage limitations were placed on potatoes, wheat and alfalfa seed production. Potatoes were restricted to the highest acreage for the 24 year period from 1950 to 1974 or the maximum recommended acreages proposed by Davis (1974). Alfalfa seed in Millard County was only constrained to a rotational limitation, while limited to the highest acreages reported in the Census of Agriculture (1954, 1964, 1969, 1974). Irrigated wheat was also limited to its maximum acreages for the same period. However, with potential lands for development dry land acreages were also considered for irrigation.

For the Northern Juab subbasin located in Utah County and for the Fillmore subbasin located in Beaver County. The diversions and outflows were fixed, as the stream flows and return flows do not enter into the Sevier River. They are included in the model in order to approximate the total counties agricultural output.

The inflow in the Juab County from the Yuba Dam was fixed at the 1969 levels (USDA, 1969 IV), in all but scenarios 4 and 7. In 1969, the releases at the dam were approximately 1.15 times the inflows into the reservoir and adjoining wetlands. In scenarios 4 and 7, the releases were tied to the inflows at the above ratio as a means of regulating the reservoir.

TABLE 10

FARM TYPES WITHIN THE SEVIER LAKE BASIN EXCLUDING THE FILLMORE SUBBASIN

Type	Dairy	Range Beef	General Livestock	Cash Crop Feeder	Large Cash Crop	Small Cash Crop	Total
Number of farms	554	972	210	461	300	150	2,647
Percent to total	20.9%	36.7%	7.9%	17.4%	11.3%	5.7%	100%
Total acreages	37,874	702,468	67,500	109,049	120,000	11,250	1,048,141
% of total acreages	3.6%	67.0%	6.4%	10.4%	11.4%	1.1%	100%
Income (000)	3,984	7,091	3,209	13,797	3,678	335	32,127
% of income	12.4%	22.0%	10.0%	42.9%	11.5%	1.0%	
Irrigated acres	26,326	129,992	32,025	79,862	59,100	5,550	332,855
% of total irrigated acres	10.9%	39.0%	9.6%	24.0%	17.8%	1.7%	31.8%
% irrigated within farm type	69.5%	18.6%	47.4%	73.2%	49.2%	49.3%	

CHAPTER V

RESULTS OF THE ANALYSIS

The Sevier Lake Basin model was applied to a series of scenarios to measure and predict the impacts of different management alternatives on the adoption of modern irrigation technology. These scenarios are outlined in Table 11. The left hand column in the table represents the parameters that were adjusted to produce the various scenarios. A "Δ" indicates that a particular parameter was changed or introduced during the scenario under which it is listed. An "X" represents the parameter condition during the scenario.

The first scenario represents the 1969 situation within the basin. At that time, the use of sprinklers and on-farm lined ditches was only minimal and thus, could be ignored. The off-farm conveyance systems efficiencies reflected those that existed within the basin at that time USDA (1969a), USDA-SCS (1970).

Scenarios 2 and 3 were designed to represent the basin in the long run. These scenarios allowed the adoption of both off-farm and on-farm technologies. Water diversions, irrigated acreages and the Sevier Bridge Reservoir releases were fixed at the 1969 solution levels. Scenario 2 measured the impact of the modern technologies while holding cropping patterns constant. This allowed the impact of the technological changes to be measured, without interference from cropping pattern changes.

Scenario 3 was the actual long run solution and allowed the cash crop cropping patterns to reach their maximums. Thereby, total gains that would occur with the adoption of new technologies and cash cropping pattern shifts would be measured.

TABLE 11

ALTERNATIVE SCENARIOS FOR APPLICATION OF THE SEVIER LAKE BASIN MODEL

Item \ Scenario's	1969 Base Years	New Technology	Long-run Solution	Sevier Bridge--Yuba Dam Management Long-run Solution	1976 Off-farm Improvement	Open Land	Open Land with Sevier Bridge--Yuba Dam Management	Open Land and Water Diversions	Cost Sharing Analysis	Ecology-Outflow Analysis
	1	2	3	4	5	6	7	8	9	10
Irrigation Technology										
a) Base (no sprinklers)	X									
b) New technology		Δ	X	X	X	X	X	X	X	X
Cropping Patterns										
a) Base	X	X								
b) Maximums			Δ	X	X	X	X	X	X	X
Water Diversions										
a) Fixed	X	X	X	X	X	X	X		X	X
b) Open								Δ		
Acreage for Irrigation										
a) Fixed	X	X	X	X	X					
b) Open						Δ	X	X	X	X

Table 11, continued

Item \ Scenario's	1	2	3	4	5	6	7	8	9	10
Sevier Bridge Reservoir										
a) Fixed release	X	X	X		X	X		X	X	X
b) Regulated release				Δ			Δ			
Off Farm Improvement										
a) Base	X	X	X	X		X	X	X	X	X
b) 1976 status					Δ					
Basin Analysis										
a) Total basin	X	X	X	X	X	X	X	X		
b) Upper section									Δ	X
Out Flow Analysis										
a) Free	X	X	X	X	X	X	X	X	X	
b) Minimum levels										Δ
Cost Sharing Analysis									Δ	

X = Status
Δ = Major Parameter Changed

The fourth scenario was the same as the third scenario except for the release of water from Yuba Dam for use in Juab and Millard Counties. The release of water in this scenario depended on the inflow into the Sevier Bridge Reservoir (outflows of Sanpete County). Thus, if inflows decreased due to the adoption of new technologies, releases would also be decreased. Previous scenario's fixed the releases at Yuba Dam at 1969 levels under the assumption that this level was necessary to maintain downstream diversion.

Scenario 5 looked at the impact of the off-farm water resource projects undertaken by the Board of Water Resources in Utah, between 1966 and 1979. The off-farm efficiencies in the model were upgraded to reflect the improvements implemented by the Board. These improvements included lining of channels and installation of conveyance pipelines.

Scenarios 6 to 8 were used to determine the impact on the long run solution with the relaxation of the various institutional constraints (acreage and diversion limitations). Scenario 6, held water diversions to the 1969 level, but allowed all irrigated and potentially irrigable land to enter the solution. In scenario 7, the Yuba Dam releases were determined by the inflows into Sevier Bridge Reservoir. Diversions were fixed at 1969 levels with no restrictions on irrigated acreages. This scenario would indicate what adjustments would be necessary with an unrestricted policy for land expansion with reservoir management. Scenario 8, dropped the water diversion requirements (water rights) and allowed both land and diversions to be developed in a manner that would maximize basin output and would approximate a "free" market solution.

The ninth scenario was made up of two parts. The first part dealt with the impact of the Federal Cost Sharing Programs by varying parametrically the price of sprinklers from a 0 to 80% subsidy. Diversions were restricted to 1969 levels but acreages were allowed to expand. The second part of the scenario dealt with the use of taxes to offset the impacts of sprinkler adoptions. In this scenario the cost of sprinklers were increased parametrically from 0 to 100% of their cost.

The last scenario was designed to determine the impact of maintaining various stream flows to meet possible ecological and environmental goals, particularly in the upper basin (Garfield, Piute, Sevier and Sanpete Counties). This scenario parametrically increased outflows as a means of maintaining stream flows, using the long run--open acreage solution as a base. Outflows were increased by 10% till a 50% increase was achieved.

It should also be noted, that if the model was run with the cash crops unconstrained in any of the scenarios, then the optimum combination of crops would include only the cash crops, except for small amounts of other crops brought into the solution by rotational constraints. This would be similar to the results found by Giles, at Utah State University and reported in USDA (1974 IV). However, cropping practices throughout most of the basin are livestock oriented with over half of the acres in the basin supporting this industry (USDA 1969a). This condition that has persisted over the past century. The reliance on alfalfa is also due to alfalfa being drought tollerant and less risky. Therefore, cash-crop acreages were constrained to a level that would allow other crops for the livestock industry. In all the scenarios, potatoes, alfalfa seed and generally wheat entered the solutions at the maximum levels allowed because of their higher profitablity rates.

Discussion of Results

Analysis of the results of the first scenario in which the 1969 situation was modeled are shown in Table 12 and Exhibit 12. The total irrigated acreages were somewhat smaller than what actually existed within the basin. This is probably due in part to the use of water for leaching in Millard County. Another reason is that the model used only full water supply to the crops and did not take into account partial irrigations through reduced water applications. Beneficial consumptive use for the basin was somewhat larger than that reported which is due to a larger percentage of land in alfalfa, which has a high consumptive use requirement. Even though consumptive use was higher, total diversions were lower. This was due to ground water in Sanpete County not entering the solution. In the base solution outflows compared quite well to those reported in USDA (1969 IV). Table 13 shows the acreages and crops distributions for the 1969 solution.

In general, all crops entered the solution. However, barley as a cash crop (not as an establishment crop) entered the solution in only Garfield and Millard Counties. Corn for grain did not appear in this solution. Irrigated pasture and meadows failed to enter in any of the counties or scenarios throughout the study.

The results of scenarios 2 and 3 represented the basis in the long run. The results are shown in Tables 14 and 15. Scenario 2, which dealt with the impact of new technologies while holding cropping patterns at the 1969 levels. The adoption of the on-farm technologies increased net output of the basin by $855,000; while off-farm technologies did not enter into the solution in any of the first 8 scenarios. When cropping patterns were allowed to adjust to their maximums (scenario 3)

TABLE 12

INITIAL SOLUTION COMPARISONS TO 1969 ACTUAL CONDITIONS

	Actual	Base Year
Profits		
Basin	NA[a]	$21,667,000
Garfield	NA	1,774,000
Piute	NA	1,732,000
Sevier	NA	5,206,000
Sanpete	NA	5,435,000
Juab	NA	1,422,000
Millard	NA	6,102,000
Presently Irrigated Land		
Basin	335,794	270,717
Garfield	32,272	26,665
Piute	23,905	22,315
Sevier	65,303	61,401
Sanpete	72,903	64,832
Juab	28,306	27,780
Millard	113,105	91,724
Diversions (acre feet)		
Surface water Basin	697,268	697,268
Garfield	36,860	36,860
Piute	63,150	63,150
Sevier	194,030	194,030
Sanpete	225,890	225,890
Juab	30,350	30,350
Millard	146,988	146,988
Groundwater		
Basin[c]	269,865	246,272
Garfield	5,827	5,227
Piute	11,580	2,929
Sevier	5,650	5,650
Sanpete	23,593	0
Juab	40,125	40,125
Millard	183,690	183,690
Consumptive Use (acre feet)		
Basin	360,394[b]	397,592
Garfield	17,350	16,613
Piute	31,685	29,644
Sevier	81,150	78,723
Sanpete	98,170	92,993
Juab	28,983	42,778
Millard	103,056	136,841

Table 12, continued

	Actual	Base Year
Return Flows (acre feet)		
Basin	NA	
Garfield	NA	17,186
Piute	NA	25,796
Sevier	NA	111,623
Sanpete	NA	120,557
Juab	NA	20,994
Millard	NA	---
Outflows (acre feet)		
Garfield to Piute	78,380	78,712
Piute to Sevier	123,590	117,745
Sevier to Sanpete	123,890	133,785
Sanpete to Sevier Bridge	122,730	123,254
Sevier Bridge to Juab	1,616,160	1,616,160
Juab to Millard	134,680	142,764
Millard to Sevier Lake and wetlands	172,258	171,272

a) Data not available--Crops grown but not sold are not figured into basin total for reporting.

b) Estimated

c) Source: UWRL, 1974, Planning for Water Quality in the Sevier River System, in the State of Utah, PRWG-142-3, Utah Water Research Laboratory, Logan, Utah.

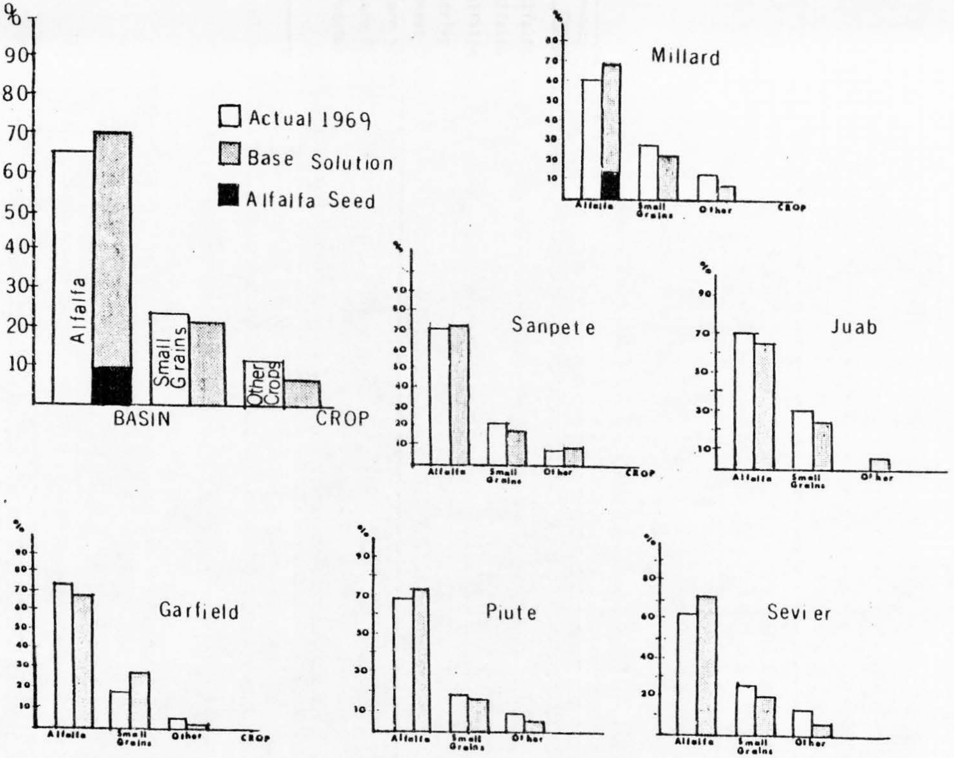


FIGURE 12 : CROP DISTRIBUTION PERCENTAGES
BASIC SOLUTION VS ACTUAL

TABLE 13

BASE SOLUTIONS ACREAGES AND CROPS

Crop \ County	GR	PI	SU	SP	JB	MI	Total
Alfalfa	18,571	16,629	44,411	47,124	18,393	47,437	192,565
Alfalfa Seed	--	--	135	95	1,071	14,453	15,754
Alfalfa Establishment Crop	4,665	4,158	11,035	11,799	4,776	14,274	50,707
Barley	3,034	--	--	--	--	1,494	4,528
Wheat	306	91	1,453	--	2,348	5,975	10,171
Corn Silage	--	1,259	4,304	5,705	1,213	7,736	20,218
Corn Grain	--	--	--	--	--	--	--
Potatoes	100	176	63	108	10	358	815
							294,780

TABLE 14

SCENARIO SOLUTIONS FOR THE SEVIER LAKE BASIN MODEL

Scenario	Actual 1969	1969 Base Year	Adoption of Technology	Long Run Solution	Sevier Bridge Management	1976 Off Farm Improvements	Open Land	Open land with Sevier Bridge Mgmt	"Free" Market
Profits (thousands)	NA	21,667	22,229	23,702	22,596	24,450	26,761	24,631	27,257
Acreages									
Available for Irrigation	335,794	294,710	318,709	321,734	305,635	310,862	277,659	275,805	281,001
Potentially Irrigated	186,724	--	--	--	--	--	93,114	55,305	104,133
Total acreage	522,516	294,710	318,709	321,734	305,635	310,862	370,773	331,110	384,298
Technological adoption (acres)									
Lined ditch	--	--	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Sprinkler with unlined ditch	--	--	110,870	94,614	92,468	91,076	98,265	102,932	79,836
Sprinkler with lined ditch	--	--	34,030	33,684	17,956	35,883	58,990	35,883	62,445
Diversions (acre feet)									
Surface flows	697,268	697,268	694,905	690,709	628,252	669,500	687,633	668,723	705,951
Groundwater	269,865	237,586	236,238	235,868	264,061	220,071	243,394	269,865	246,272
Consumptive Use (acre ft)	374,189	397,592	428,706	428,310	404,719	435,875	473,048	423,718	483,048
Outflows (acre feet)									
Sevier Bridge-Yuba Dam	122,730	124,754	82,640	82,274	110,485	61,265	47,139	126,894	36,725
Wetland and Sevier Lake	172,258	171,272	167,967	176,722	142,606	125,193	166,412	134,468	157,381

TABLE 15

SCENARIO SOLUTION BY COUNTIES

Scenario	Actual 1969	1969 Base Year	Adoption of Technology	Long Run Solution	Sevier Bridge Management	1976 Off Farm Improvements	Open Land	Open land with Sevier Bridge Mgmt	"Free" Market
Garfield Profits (000)		1,774	1,850	2,208	2,208	2,167	2,262	2,244	2,811
Acreages	32,272	26,658	27,731	29,325	29,325	29,185	31,793	29,799	42,752
Potential	18,863								
Sprinkler with unlined ditch		--	2,178	4,075	4,075	9,736	17,733	4,635	4,635
Diversions--surface flow	36,860	36,860	36,860	36,860	36,860	36,860	36,860	36,860	62,196
groundwater	5,527	5,527	5,527	5,527	5,527	5,527	5,527	5,527	5,527
Consumptive Use	17,350	16,613	19,010	19,513	19,513	19,421	20,926	19,535	28,624
Piute Profits (000)		1,732	1,755	1,908	1,886	1,912	2,017	1,963	1,933
Acreage Irrigated	23,905	22,315	22,781	22,406	23,905	22,406	26,060	26,362	24,544
Potential	4,448								
Sprinkler with unlined ditch	--	--	5,047	5,047	696	5,047	5,680	547	486
Diversions--surface	63,150	63,150	63,150	63,150	63,150	63,150	63,150	63,150	56,983
groundwater	11,580	2,929	1,636	1,176	6,429	860	8,702	11,580	11,580
Consumptive Use	31,685	29,644	29,973	29,667	31,506	29,667	34,570	34,767	32,237
Profits Sevier (000)	--	5,206	5,339	5,339	5,334	5,420	6,047	5,944	6,259
Acreage	65,303	61,401	64,765	64,782	64,782	64,782	69,729	74,782	73,716
Potential	20,382								
Sprinkler with lined ditch	--	--	27,758	27,758	25,883	18,079	37,117	34,702	37,117

Table 15, continued

Diversions--surface	194,030	194,030	194,030	194,030	194,030	194,030	194,030	194,030	205,325
groundwater	5,650	5,650	5,650	5,650	5,650	4,202	5,650	5,650	5,650
Consumptive Use	81,150	78,723	84,164	84,164	83,243	84,164	86,205	85,788	90,664
Profits Sanpete (000)	--	5,435	5,874	5,999	5,769	5,966	7,018	6,488	6,968
Acreage	72,930	64,832	72,930	72,930	72,930	72,930	97,635	84,101	97,635
Potential	24,706								
Sprinkler with unlined ditch	--	--	26,636	26,562	40,728	23,805	10,903	35,037	10,903
Sprinkler with lined ditch	--	--	14,092	14,116	0	16,923	43,979	11,915	47,434
Diversions--surface	225,89	225,890	220,791	220,057	224,130	223,848	218,880	223,196	206,752
groundwater	23,593	23,593	-0-	-0-	-0-	22,940	-0-	-0-	-0-
Consumptive Use	98.170	92,993	104,098	103,927	103,927	103,927	137,905	100,955	138,041
Juab Profits(000)	--	1,422	1,459	1,459	1,459	1,565	1,802	1,663	1,802
Acreages	28,306	27,780	28,213	28,213	28,213	24,830	33,955	31,330	24,830
Potential	35,314								
Sprinkler with unlined ditch	--	--	3,131	3,131	3,131	15,449	11,683	9,630	11,683
Diversions--surface	30,350	30,350	30,350	30,350	30,350	30,350	28,678	24,171	28,678
groundwater	40,125	40,125	40,125	40,125	40,125	27,084	40,125	40,125	40,125
Consumptive Use	28,983	42,778	43,539	43,539	43,539	38,067	43,990	41,770	43,990
Milford Profits (000)	--	6,108	5,237	6,788	5,940	7,469	7,614	6,336	7,638
Acreages	113,105	102,779	102,779	104,076	86,480	96,729	112,532	90,425	112,806
Potential	83,029								
Sprinkler with unlined ditch	--	--	26,918	26,497	17,955	18,960	15,012	18,381	15,012

Table 15, continued

Sprinkler with lined ditch	--	--	19,938	19,518	17,956	18,960	10,012	18,381	15,012
Diversions--surface	146,988	146,988	146,988	146,262	79,723	146,262	146,066	70,486	146,066
groundwater	2,204,280	2,204,280	2,204,280	2,204,280	2,204,280	2,204,280	2,204,280	2,204,280	2,204,280
Consumptive Use	103,056	136,841	147,923	147,500	125,963	160,638	149,316	127,316	149,316

an additional net basin wide output of $1,177,000 resulted. Garfield County gained the most with a 24% increase in output with the adoption of the modern technologies. Sanpete and Millard Counties also gained with the adoption of modern technologies.

In these 2 scenarios, the three technologies available were ditch-flooding, lined and unlined ditch with sprinklers; only sprinklers with unlined ditches were adopted. Lined ditch for flood irrigation did not enter the solution in any of the first eight scenarios.

With the adoption of sprinkler irrigation in over 125,000 acres, return flow to Sevier Bridge-Yuba Dam complex decreased by over 40,000 acre-feet compared to the 1969 levels, with Sanpete County diversions not being met.

The adoption of on-farm technologies resulted in an increase of an additional 24,000 acres over the 1969 solution (scenario 2). This was primarily accomplished by reducing inflows into the Sevier Bridge Reservoir. In scenario 3, the shift in cropping patterns to less water intensive crops accounted for an additional 3,000 acres of land being irrigated. Forty four percent of the 8,277 acre-foot reduction from 1969 levels in surface and ground water diversions (scenario 3) was due to the more "efficient" system being adopted. The remaining 56% of the reduction was a result of shifts to crops using less water.

The combined impacts of crop adjustments and technology adoptions caused total crop consumptive use of water to increase by over 31,000 acre-feet. As a consequence of the increased acreages and aggregate consumptive use with adoption of the modern systems, surface diversion rights could no longer be met in Millard and Sanpete Counties where return flows equalled the total outflows in both counties. Groundwater rights went unused in Sanpete County. Furthermore, outflows to Sevier Lake, Sevier Bridge-Yuba Dam and wetland areas declined by over 44,000 acre-feet. The reduced inflow to Sevier Bridge Reservoir for this scenario was 66% below the average figure reported for 1969. With this reduction it would be doubtful that the 1969 level water releases from Yuba Dam to meet diversion requirement in Juab and Millard Counties could be maintained. In 1969, the water released into Juab and Millard Counties from Yuba Dam was 1.15 times greater than the inflow into the reservoir.

Scenario 1, scenario 2 and scenario 3 outflow at Yuba Dam into Juab County was fixed at the 1969 levels. Scenario 4, was constructed so that the release of water for irrigation in Juab and Millard Counties would be determined by the outflow in Sanpete County (inflow to the Sevier Bridge Reservoir).

When the water released at Yuba Dam were tied to the inflows, net basin output fell by over $1,106,000. Except for Garfield and Juab all output in the basin declined. Millard's output dropped by $848,000. This can be in part explained by the high diversion requirement and costs for flood leaching. The results are shown in Figure 13.

The management of releases at Yuba Dam would require a net decrease of about 16,500 irrigated acres. In addition, the basin would require numerous cropping pattern adjustments as well as the shifts in the use of sprinkler-irrigation system between counties. Total irrigated acreages (all methods) dropped by over 18,000 acres in Millard County but increased in Piute County. Unlined sprinkler acreages declined in all counties except Sanpete. Millard and Piute Counties had the highest sprinkler acreage losses with about 6,000 and 4,000 acres respectively. The total basin acreages in unlined sprinklers declined by 2,100 acres. Lined

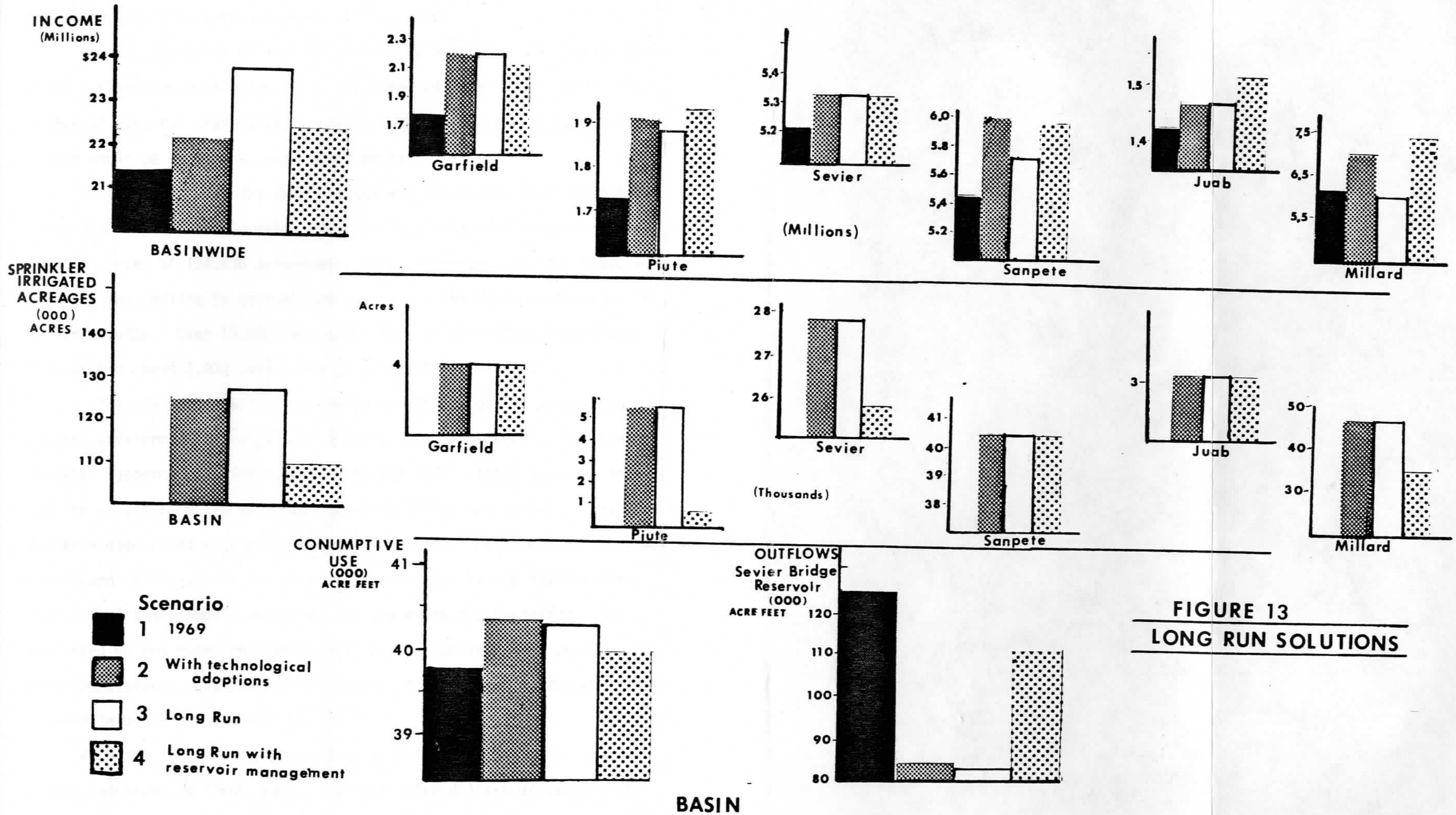


FIGURE 13
LONG RUN SOLUTIONS

sprinkler systems within the basin declined by over 15,700 acres with the major impact in Sanpete County (14,000 acres).

Over 11,300 acres of alfalfa previously irrigated with sprinkler-ditch combination would have to be irrigated with sprinkler only. The output of corn for grain grown in Millard County, under the combination system would be reduced by over 3,500 acres.

Furthermore, when the variable release management for Yuba Dam was used, Juab and Millard Counties received less water for diversions than the 1969 level of 134,630 acre-feet. As a consequence 91.3% (21,536 acre-feet) of the decline in consumptive use within the basin would occur in Millard County. Over 10,000 less acres were in sprinklers with lined ditches and about 2,000 less acres were in unlined ditches.

Analysis of scenario 5, explored the impact of the program to upgrade off-farm water conveyance facilities administered by the Board of Water Resources in Utah between 1966 and 1979. Table 16 shows the amounts of off-farm improvements installed during the period. This scenario used fixed acreages and water diversions; maximum crop adjustments and modern technology in the model. In addition, it was assumed that the cost of these improvements was not placed on the irrigator. This was based on the model results that if the irrigator was to pay for off-farm improvements (options in this model), no off-farm improvements entered into any of the solutions.

With the installation of the various projects, basin agricultural output increased by three quarters of a million dollars annually. The largest gain would be in Millard County $6,000,000 while Sevier and Juab Counties would also gain ($80,000 and $55,000 respectively). Sanpete and Garfield lost about $30,000 each while Piute County showed no change.

TABLE 16

IRRIGATION PROJECTS INSTALLED

DIVISION OF WATER RESOURCES

County	Ditch Lining and Pipeline (Miles) 1966-1979
Piute	4.3
Sanpete	75,6
Garfield	8.3
Juab	6.9
Millard	23.6
Sevier	39.2
TOTAL	(158.0)

Source: Division of Water Resources, State of Utah, 1979.

Consumptive use of surface water increased by 7,500 acre-feet while about a 50% reduction occured in groundwater use. This reduction could be attributed to the estimated $1.27 per acre inch pumping cost for groundwater. Resources and time did not allow further development of these off-farm impacts such as what might happen if the irrigator absorbed part of the costs. The decrease in diversions and increased consumptive use would also influence the basin's ability to meet downstream water requirements. A further outcome of the installation of the off-farm improvement was the decline of outflows into Sevier Bridge Reservoir and Sevier Lake drainages and wetlands by about 52,000 and 48,000 acre-feet respectively, making it more difficult to maintain the Yuba Dam release at 1969 levels.

The off-farm adoptions have very little impact on the total adoptions of on-farm systems with only about 2,000 acres being converted from straight sprinkler to sprinkler-lined ditch. Although the total impact was small, considerable changes occured in the lower basin (Juab and Millard Counties). Juab, would adopt over 12,000 additional acres in sprinklers while reducing its ground water diversions by over 14,000 acre-feet and consumptive use by 5,500 acre-feet. In Millard, the major impact was a 7% reduction in acreage and a reduction in sprinkler and sprinkler-ditch of about 8,000 acres. The reduction in sprinkler acreages occured due to a shift out of corn for silage (14,000 acres to less than 1,000 acres). There was also an increase in wheat-barley production from straight sprinkler to sprinkler-lined ditch irrigation of about 6,000 acres.

The next three scenarios were used to determine the impact of relaxing various institutional constraints (acreage and diversion limitations). Table 5 shows how much land was presently irrigated and potentially suitable for irrigation. It should be noted that presently irrigated lands in the Sevier Lake Basin are lands that are being irrigated at least once over a seven year period. This category included irrigated cropland, fallow land, idle land and land in conservation. Even without allowing potential land to enter into the solutions, acreages within the basin increased from 294,710 acres to 321,734 irrigated acres with the introduction of modern technology. This increase would be brought about by several factors including the use of additional water "saved" and the irrigation of fallow and idle lands, which were part of the overall lands considered irrigated (USDA-SCS, 1970). Yet, despite the increase in acreage there was no potentially irrigable land entered in the solution.

The results of scenarios 6 and 7 opened all land in the basin to development, while holding the diversion rights constant. It was assumed that the integration of potential land for irrigation would not require any major conveyance system development. Development cost did include drainage of wetlands (subclass W), land clearing and irrigation systems purchases and installations costs. The results of this analysis are shown in Table 14 and Figure 14.

With the development of higher yielding lands basin output increased from $23,702,000 to 26,761,000. However, the increase was only to $24,631,000 if the inflows and releases at Yuba Dam were taken into account.

In scenario 6, with the release of acreage restriction holding Yuba Dam release at 1969 levels, all counties would gain. Sanpete's gain would be about $1,000,000 with Millard and Sevier gaining about

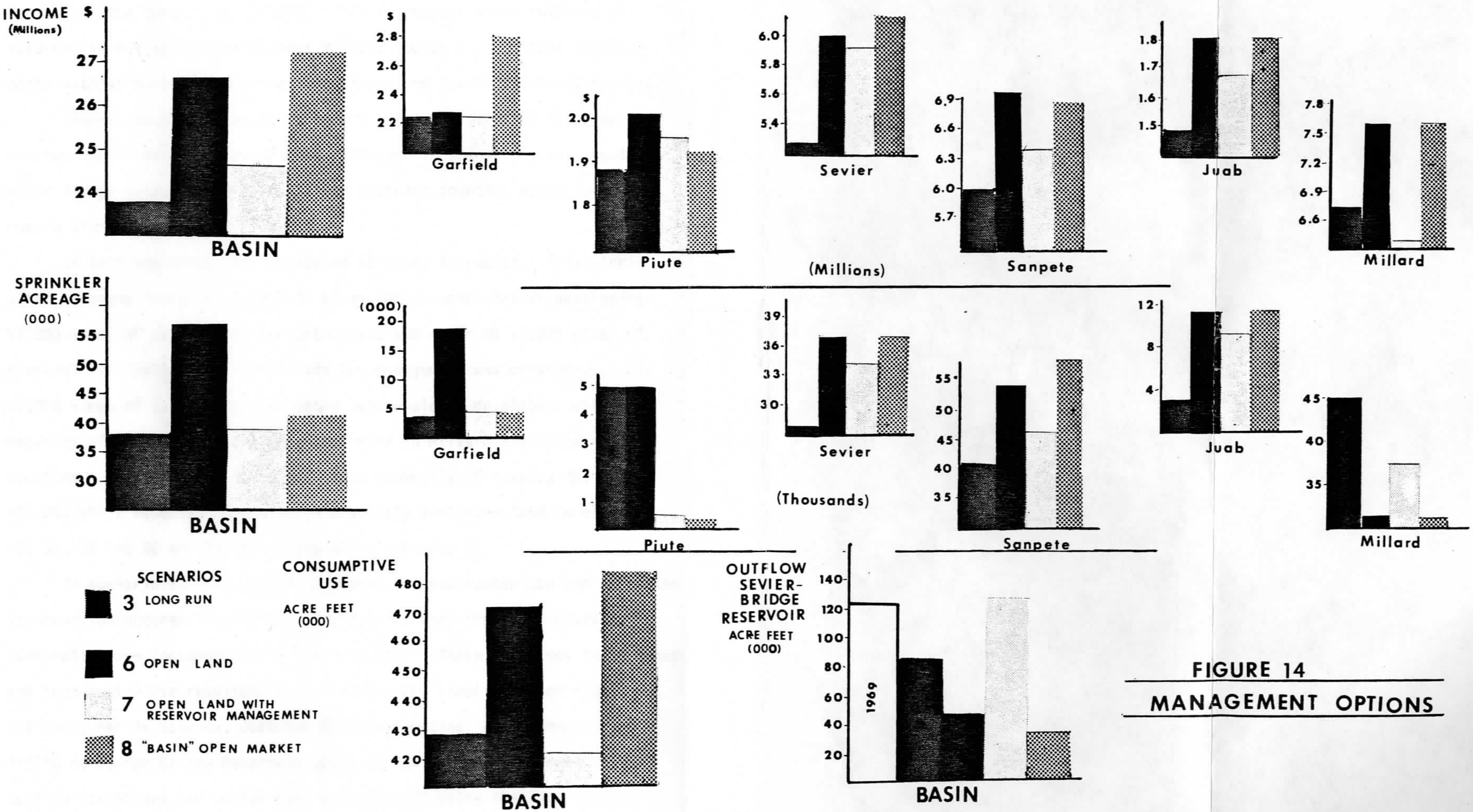


FIGURE 14
MANAGEMENT OPTIONS

$800,000 and $7,000,000 respectively. However, if the releases of water at Yuba Dam were to be regulated based on inflows at the Sevier Bridge Reservoir, Millard County would bear the brunt of the output decline to the tune of $1,200,000. This is because water released at Yuba Dam is not sufficient to meet Millard County's diversions requirements without further reductions in Sanpete and Sevier County diversions.

Sanpete would require to forego an output of $500,000 in order to increase outflows to the reservoir. Although in scenario 7 all counties would forego output, none of the other upstream counties would suffer such a severe reduction.

In both scenarios, the irrigated acreages increased. Total irrigated acreages increased by 59,000 acres, which consisted of developing 93,000 acres of potentially irrigated land and retiring 34,000 acres of presently irrigated land. When Yuba Dam management was considered, only 55,000 acres of potentially irrigated land would be developed, with the majority of the 38,000 acre reduction being in Millard and Sanpete Counties. The newly developed land were generally of classes 2W, 3W, 2E, 3E, while reductions occured in presently irrigated land in classes 4E, 3C, 3S and 2C an classes 4W and 4S in scenario 7.

In scenario 6, only slight increases in groundwater use and decreases in diversion occured when acreage limitations were dropped. However, consumptive use increased by 44,000 acre feet. These increases in acreages and consumptive use resulted in full diversions (implied water rights) not being met in Sanpete, Juab and Millard Counties. Furthermore, the inflow to Sevier Bridge Reservoir would be 38% of the 1969 levels. The outflow to wetland and Sevier Lake would be 32% below the 1969 level.

Numerous adjustments were necessary when the Sevier Bridge-Yuba Dam was taken into account. Over 18,000 less acres would be in lined and unlined sprinkler systems. All counties but Sanpete and Garfield (13,000 acres), would reduce acreages in sprinklers. While Sanpete County would have 31,000 less acres in lined sprinklers, it would have an additional 25,000 acres in unlined sprinklers systems. This is the only time in all scenarios that total groundwater diversions were used by the model. However, surface diversions were not met in Sanpete, Juab and Millard Counties. In this solution, inflow into Sevier-Bridge Reservoir increased to 110,485 acre-feet or 80% of the 1969 level.

Analysis of scenario 8, the "basin wide" market solution produced the greatest net value of agricultural output of $27,258,000 with irrigated acreage of 384,198 acres, total diversions amounting to 952,223 acre-feet and consumptive use of 483,048 acre-feet. This also produced the lowest inflow levels at Sevier Bridge-Yuba Dam of 36,726 acre-feet which is only 29.4% of 1969 levels. When acreages and diversions were allowed to seek their own levels, a maximum of 80,000 acres in unlined sprinklers and 62,500 acres of lined sprinklers were adopted. All the additional acres were in lined sprinklers in Sanpete County on class 2E and 3E land.

A basin wide market solution produced the largest percentage output gain in output in Garfield and Juab, 27% and 24% respectively ($600,000 and $350,000). The total dollar gains occur in Sevier, Sanpete and Millard Counties with about $900,000 in additional outputs produced (17, 16 and 12% gains). The solution set for Piute County was basically unchanged from the long run solution.

Cost Sharing and Tax Policy

In 1978-79, Federal (SCS) cost sharing programs would pay 80-85% of the capital costs of installing various irrigation improvements. The improvements include installation of sprinklers, lined ditches, canal lining...etc. serving presently irrigated lands. The first part of the ninth scenario dealt with the impact of these Federal cost sharing programs.

In this segment of scenario 9, the price of sprinklers was varied parametrically from a zero to 80% subsidy at 20% increments. Since the lower section results depend on the Yuba Dam management policy and on the outflows from upstream users, the program emphasized only the upper basin. In this scenario, diversions were restricted but the acreages were not.

The major impact of the governments subsidy policy is shown in Table 17 and 18. The general results of the Federal subsidy policy would be to cause an increase in basin output with an associated social welfare loss for all subsidy levels.

The largest social loss $100,000 annually occured with the 80% subsidy. This was also a $59,000 increase in the social losses over a 60% policy. The 80% subsidy would cost the government over 3.5 million dollars or $389,000 on an annual basis. This is the cost of adding more acres over and above what the model indicates that the irrigator would install on his own. The model indicates that without the subsidy the irrigator would install over 115,000 acres in sprinklers. The subsidy policy would result in a total of 150,000 acres being irrigated by sprinklers (83.3% of total acreage), an increase of 35,000 acres.

TABLE 17

IMPACT OF FEDERAL COST SHARING PROGRAMS ON THE UPPER SEVIER RIVER BASIN (AREA SOUTH OF THE SEVIER BRIDGE-YUBA DAM COMPLEX)

	Subsidy				
	Long Run	20% Subsidy	40% Subsidy	60% Subsidy	80% Subsidy
Upper Basin Profits	17,344	17,331	17,330	17,274	17,244
Garfield	2,262,347	2,257,763	2,257,763	2,257,196	2,229,532
Piute	2,016,846	2,016,846	2,016,894	2,016,894	2,016,894
Sevier	6,047,356	6,047,356	6,046,601	6,040,638	6,040,638
Sanpete	7,017,967	7,009,535	7,009,084	6,988,878	6,957,342
Yearly Subsidy (000)	0	152	184	302	389
Total Subsidy Paid (000)	0	1,388	1,680	2,757	3,551
Acreage Irrigated					
Garfield	29,185	29,185	29,185	29,185	29,185
Piute	22,406	22,406	22,406	22,406	22,406
Sevier	55,033	55,033	55,033	55,033	55,033
Sanpete	72,930	72,930	72,930	72,930	72,930
Sprinkler Acreages with Unlined Ditch					
Garfield	17,733	24,730	24,730	24,877	30,166
Piute	5,680	6,033	6,033	6,033	6,033
Sevier	37,117	37,117	37,630	39,498	39,498
Sanpete	10,904	20,500	20,462	27,601	33,993
Lined Ditch					
Sanpete	43,979	42,848	42,885	41,628	40,498
Total Both	115,413	131,258	131,740	139,637	150,182
Consumptive Use	279,741	280,926	281,039	281,399	281,901
Garfield	20,926	21,679	21,679	21,679	22,181
Piute	34,569	34,570	34,570	34,570	34,570
Sevier	86,205	86,205	86,318	86,678	86,678
Sanpete	138,041	138,472	138,472	138,472	138,472
Outflow to Sevier Bridge	47,139	45,955	45,860	45,549	45,130

TABLE 18

SOCIAL COSTS AND GAINS FROM SUBSIDY POLICY

	Subsidy		
Rate of Tax or Subsidy	Fiscal (cost) or Revenue	Private gain or (loss)	Social (Cost)
80% (Basin)	(389)	289	100,000
Garfield	(139.1)	106.3	(32,815)
Piute	(3.9)	3.9	48
Sevier	(26.6)	19.9	(6,718)
Sanpete	(219.4)	158.8	(60,625)
60% (Basin)	(302)	262	40,000
Garfield	(89.1)	84.0	(5,151)
Piute	(4.4)	4.4	48
Sevier	(29.7)	23.0	(6,718)
Sanpete	(778.8)	149.7	(29,089)
40% (Basin)	(184)	170	14,000
Garfield	(78.8)	74.3	(4,584)
Piute	(4.0)	4.0	48
Sevier	(5.8)	5.0	(755)
Sanpete	(95.4)	86.5	(8,883)
20% (Basin)	(152)	139	13,000
Garfield	(67.3)	62.7	(4,584)
Piute	(3.4)	3.4	48
Sevier	(0)	0	0
Sanpete	(81.3)	7.29	(8,432)

In addition, the third party impacts would be severe as the additional acreage decrease the inflows into the Sevier Bridge-Yuba Dam Reservoir to 37% of the 1969 inflow. Therefore, with Federal subsidies the management of the lower basins releases and water rights will become critical as releases of water at the dam may not be maintainable.

Although the major impacts were reduced in outflows and the net social losses, Garfield and Sanpete were the counties impacted the most. With an 80% subsidy $93,000 of the $100,000 social loss occured in these two counties. The only county to achieve a social gain was Piute. A 20% subsidy increased irrigated acreages by 353 acres and increased output (with subsidy) by $48. Sevier County was only moderately impacted with a 40 and 60% subsidy. The impact in Garfield County occured because of its location at the headwaters. Thus, in this and other scenarios what happens in Garfield has a significant impact on the downstream counties. In Sanpete County, the high social loss was due to the models attempting to maintain high yield as inflows decerased as upper basin counties adoptions increased. The adoptions enabled Sanpete County to reduce outflows into the Sevier Bridge Reservoir-Yuba Dam complex in order to maintain output.

With reduced inflow to the Sevier Bridge Reservoir as modern irrigation techniques are being adopted, some water right problem will exist. In an attempt to alleviate the problem a policy option would be to place a tax on sprinklers, thereby increasing the costs to the irrigator. The ninth scenario Part b, dealt with taxing sprinkler users.

In the results of scenario 9b the cost of sprinklers was increased by varying parametrically the tax on sprinklers from 0 to a 100% of the capital cost in 20% increments. Table 19 and 20 show the impact of

TABLE 19

IMPACT OF A TAX ON SPRINKLERS FOR THE UPPER SEVIER RIVER BASIN

		Tax				
	Long Run	20%	40%	60%	80%	100%
Upper Basin Profits (000)	17,344	17,332	17,313	17,279	17,177	17,094
Garfield	2,262,347	2,249,698	2,248,897	2,248,897	2,234,762	2,231,150
Piute	2,016,846	2,009,431	2,004,208	2,004,208	2,004,208	2,003,721
Sevier	6,047,356	6,047,356	6,029,347	6,016,478	5,920,397	5,864,529
Sanpete	7,017,967	7,025,462	7,029,939	7,009,137	7,017,389	6,994,620
Yearly Tax Revenues (000)		151	244	328	496	588
Total Tax Revenues (000)		1,378	2,227	2,994	4,528	5,368
Acreages						
Garfield	29,185	29,185	29,130	29,130	28,990	29,954
Piute	22,406	22,406	22,406	22,406	22,406	22,315
Sevier	55,033	55,033	52,260	52,014	50,400	50,480
Sanpete	72,930	72,930	72,930	72,930	72,930	72,930
Acreage Lined Ditch						
Garfield		2,798	2,798	2,798	2,798	3,209
Sanpete						3,316
Sprinkler Acreages unlined						
Garfield	17,733	4,955	4,635	4,635	1,975	1,426
Piute	5,680	1,952	486	486	486	395
Sevier	37,117	37,117	30,657	27,423	13,460	5,446
Sanpete	10,904	8,423	8,423	8,423	8,423	8,423
Sanpete Lined	43,979	43,629	43,323	37,456	36,026	33,126
Total Both	115,413	96,076	87,524	78,772	60,370	48,816
Consumptive Use	279,741	278,083	277,408	269,909	266,132	264,031
Garfield	20,926	19,593	19,555	19,555	19,457	19,432
Piute	34,569	34,389	34,318	34,318	34,318	34,197
Sevier	86,205	86,205	85,654	85,324	82,365	80,538
Sanpete	138,041	137,896	137,881	130,712	129,992	129,844
Outflow Sever-Bridge	47,139	49,467	50,391	57,839	61,145	63,081

TABLE 20

SOCIAL COSTS AND GAINS FROM A TAX POLICY

	Tax		
Rate of Tax	Fiscal (cost) or Revenue	Private loss	Social (Cost)
100% (Basin)	588	(838)	(250)
Garfield	17.1	(48.3)	(31,197)
Piute	4.8	(17.9)	(13,125)
Sevier	65.6	(248.4)	(182,827)
Sanpete	500.5	(523.8)	(23,347)
80% (Basin)	496	(663)	(167)
Garfield	16.2	(43.8)	(27,585)
Piute	4.0	(16.6)	(12,638)
Sevier	110.6	(237.5)	(126,959)
Sanpete	365.2	(365.7)	(578)
60% (Basin)	328	(393)	(65)
Garfield	19.3	(32.7)	(13,450)
Piute	2.0	(14.6)	(12,638)
Sevier	114.1	(145.0)	(30,878)
Sanpete	192.0	(199.8)	(8,830)
40% (Basin)	244	(275)	(31)
Garfield	12.9	(26.4)	(13,450)
Piute	1.3	(13.9)	(12,638)
Sevier	85.5	(103.5)	(18,009)
Sanpete	144.3	(132.3)	11,972
20% (Basin)	151	(163)	(12)
Garfield	7.8	(20.4)	(12,649)
Piute	3.0	(10.4)	(7,415)
Sevier	58.0	(58.0)	0
Sanpete	81.7	(74.2)	7,495

taxes on sprinkler adoptions, output and outflows within the basin. Figure 15 shows the impact of a tax and subsidy on output.

Net basin outputs declined with higher tax and subsidy. This is a result of divergences between marginal social values for irrigation systems and marginal costs of these systems. The following changes were observed in the solution: one, the shifting from sprinklers with lined ditch to an unlined ditch sprinkler systems in Sanpete County. Two, in Garfield County, lined ditch for flood irrigation was adopted. And three, the switching of large acreages of low consumptive cash-crops to less acres of a more water intensive crop, alfalfa. This was to be expected as the net return for water intensive crops are higher when flood irrigation was used. At the higher tax rates, the consumptive use declined and outflows increased more rapidly.

The impact of taxes varied in each county. Sevier County had the largest social losses of about $183,000 with a 100% tax rate. At this rates, Sevier would remove about 32,000 acres from sprinkler systems. Sanpete would retire the lowest percentage of acres and would pay 85% of the total tax revenue at a 100% tax rate. This can be attributed to the high productivity of the land available under sprinklers in this county.

The major impact in Garfield occurs at a 20% tax rate with a 72% reduction in sprinkler irrigated acreages. The primary impact of this reduction is to reduce consumptive use and increase outflows; thereby, increasing water available downstream particularly in Sanpete where the higher productive land is located.

Outflows to the Sevier Bridge Yuba Dam complex increased by 33.8% to 63,081 acre feet. This was approximately 51% of the 1969 levels.

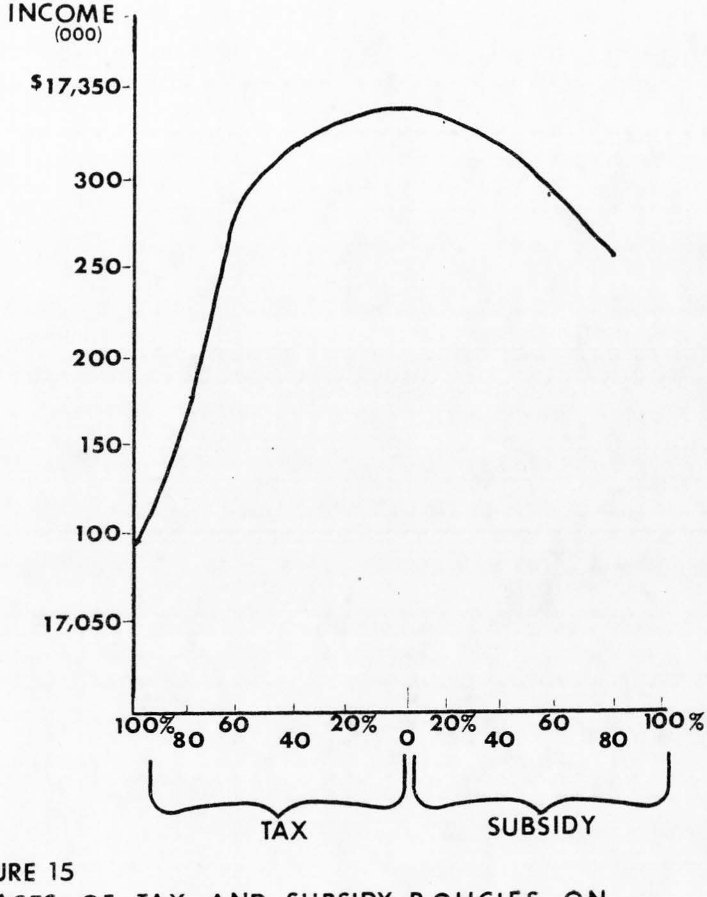


FIGURE 15
IMPACTS OF TAX AND SUBSIDY POLICIES ON SPRINKLER ADOPTIONS

This indicates that a larger tax may be necessary to increase outflows. As an alternative some other policy measure involving taxes would have to be adopted in order to increase flow into the Sevier Bridge Reservoir to the 1969 levels.

Ecological Considerations

Analysis of scenario 10 was designed to determine the impact of maintaining minimum stream flows for environmental reasons. In many of the previous solutions, Sanpete County's total stream flows were totally diverted to crop use when modern irrigation systems were adopted. The diversion of all (environmental and recreational) waters from the stream eliminates all instream flow uses of that water and also reduces ground cover along stream bank, thus, reducing wildlife habitats. In this scenario outflows were parametrically increased as a means of maintaining stream flows at various levels. The long run open acreage solution was used. Outflows were increased at 10% increments until a 50% increase was achieved. For example, outflow from Garfield was at 74,000 acre-feet in the base solution. The first run increased this outflow by 10% or 7,400 acre-feet to 81,400 acre-feet. This procedure was followed for all counties.

The results as summarized in Table 21 and Figure 16 showed that it becomes more costly in terms of reduced agricultural productivity as instream flow requirements are increased. A 10% increase reduced basin output by $210,000. The increase of 10% to 50% of base level outflow over the long run would cause a $704,000 decrease in basin outputs. This can be attributed to the land with the least value being removed from production.

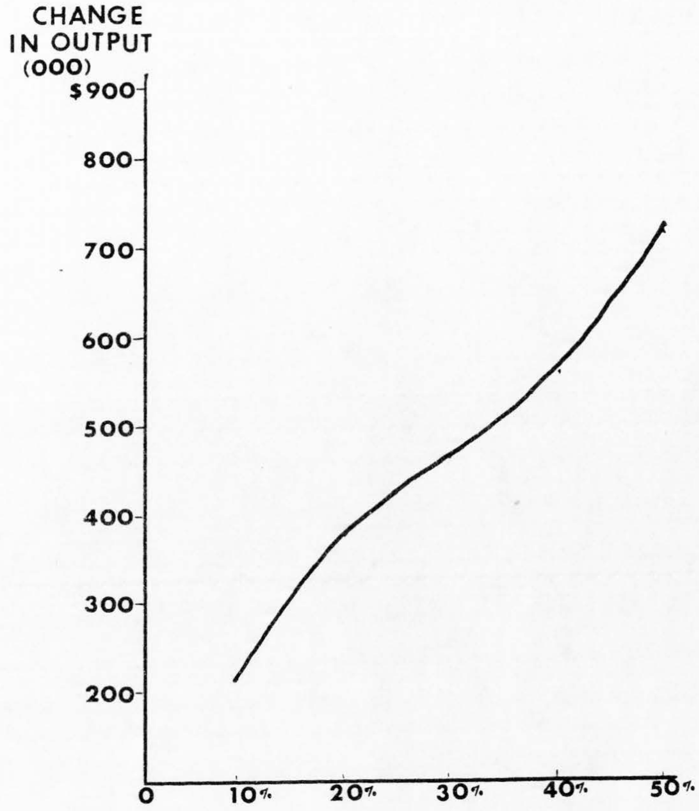


FIGURE 16
STREAM FLOW IMPACT CURVE

TABLE 21

THE IMPACT OF INCREASED OUTFLOWS TO MEET MINIMUM STREAM FLOWS FOR ECOLOGICAL PURPOSES--UPPER BASIN

	Long Run Open Acreages	10% Increase in Outflow	20% Increase in Flow	30% Increase in Flow	40% Increase in Flow	50% Increase in Flow	1969 Base
Total Profits Upper Basin (000)	17,367	17,157	16,785	16,343	15,792	15,088	
Change in Output Basin		-210	-372	-442	-551	-704	
Change in Output							
Garfield	2,262	-22	-61	-63	-139	-532	
Piute	2,009	-170	-292	-350	-348	-143	
Sevier	6,047	-17	-20	-28	-28	-28	
Sanpete	7,047	-1	--	--	--	--	
Acreage Irrigated							
Garfield	31,793	30,071	32,572	33,807	29,745	26,502	
Piute	26,060	24,632	23,116	20,513	13,277	6,673	
Sevier	69,731	69.731	69,025	68,497	67,869	67,443	
Sanpete	97,635	98,342	98,342	98,342	98,342	98,342	
Upper Basin Totals	225,219	222,776	223,053	221,159	209.233	198,960	
Sprinkler Acreages							
Garfield	17,733	4,635	4,635	4,635	4,635	4,635	
Piute	5,680	486	486	1,333	1,333	1,333	
Sevier	37,117	33,178	30,076	26,012	21,957	17,903	
Sanpete	10,904	10,904	10,904	10,904	10,904	10,904	
Total Upper Basin	71,433	49,203	46,092	42,884	38,829	34,775	
Land in Lined Ditch and Sprinkler--Sanpete	47,434	41,968	41,968	41,968	41,968	41,968	
Inflow Sever Bridge-Yuba Dam	82,274	58,413	70,668	82,923	95,178	107,432	122,730
Outflow							
Garfield						74,400	75,813
Piute						113,990	113,157
Sevier						122,548	123,756
Sanpete						107,432	122,730

Piute and Garfield Counties would suffer the greatest losses. Sanpete County's output remained constant throughout. The key to in-stream flow maintainance appears to be in the upper and head water counties (Garfield and Piute), where increases in these counties resulted in outflow volumes being met.

The lower flow requirements were essentially met holding total acreage constant by reducing the amount of sprinkler irrigated acreages. The 10% increase in outflow had the largest impact on technologies with a 23,000 acre reduction in sprinkler systems occuring. The breakdown of the 23,000 acre reduction entailed a 13,000 acre reduction in Garfield County and 5,000 acre reductions in both Piute and Sevier Counties. A 5,500 acre reduction in lined sprinklers and conversion to unlined sprinklers was necessary in Sanpete County.

As the outflow requirement increased, the only way to meet these requirements was to retire the less productive land. Less productive land was mostly found in Piute County. Only for the 40% and 50% increases did acreages drop in Garfield County. The increased stream flows were generally brought about with about 4,000 acre reduction in unlined sprinklers in Sevier County.

After the initial 10% outflow the model was able to increase Garfield and, in part, other counties outflows by converting all of the off-farm conveyance systems to pipe in Garfield. One of the benefits of requiring higher stream flows was that inflows into the Sevier Bridge Reservoir increased by 24, 21, 17, 15, 13% respectively with the final outflows approximately equal to that of the 1969 outflows as shown in Table 22.

TABLE 22

PERCENTAGE BY LAND CLASSIFICATION OF SPRINKLER WITH LINED AND UNLINED DITCHES

Scenario	2W	2W	2C	2E	3W	3W	3C	3E	4W	4S	4E
3-1974	44.9%*	58.0%	0.0%	80.0%	8%	4%	0.0%	21.0%	0%	86.0%	1.0%
6-Open Acreages	17.0%	79.8%	7.6%	88.2%	16%	21%	17.6%	47.4%	0%	41.9%	20.0%
8-"Free" Market	17.0%	79.8%	7.6%	88.8%	14%	19%	38.9%	48.5%	0%	41.9%	16.9%

*Primarily corn for grain grown in Millard County

Generalizations on the Adoptions of Modern Irrigation Systems

Sprinklers

Table 22 shows that sprinklers are the most profitable for farmers to class 2E land where optimal adoption rates ranged between 80% to 89%. Class 2E land is characterized by medium soil textures (85%) with slopes of 1.5 to 2.9% (66%) and 3.0 to 5.9% (27%). Class 2S, also, had a high rate of adoption and this class of land was generally in small grains when irrigated with sprinklers. If it was irrigated with the border-furrow option, the main crop in this land was alfalfa. The high adoption rate under scenario 3 of Class 4S is due to the small amount of acreage cultivated in that class of land. Land classes 3C, 4S, and 4E did enter into the solutions only for growing either small grains, or alfalfa seed. Also the potential land (for the same classes) had to be sprinkler irrigated before they entered the solution.

The least likely land classes to be sprinkler irrigated were Class 2C and the wetlands; 2W, 3W, 4W. The exception was the long run solution in which Millard County went to 13,000 acres of 2W land sprinkler-lined ditches for irrigating corn for grain.

In general, the systems for irrigating cash crops (potatoes, alfalfa seed and wheat) were the first to be converted to sprinklers. The first adoptions in all counties occured with potatoes. In all counties except Millard, alfalfa seed was second crop to be converted. Alfalfa irrigated by sprinkler was primarily grown on Class 2E and 3E land, and occasionally on 4E and 3S land. In Garfield County Class 3W land was used. For most scenarios in Millard County alfalfa seed was predominantly irrigated by an unlined flooding system. As diversion limitation and/or acreages constraints were relaxed, the amount of seed acreages under irrigated sprinkler continued to decrease within Millard County.

Lined Ditch and Sprinklers

Sprinklers using lined ditches entered into the solution in only two counties, Sanpete and Millard. Any time corn for grain was grown in Millard as a cash crop usually on Class 2W and 2C land, this combination was used. Alfalfa grown on Class 2E and 3E land utilized this combination in Sanpete County, while wheat and barley were irrigated in Millard County on Class 2E land.

Lined ditch. In most instances, lined ditches for flood-border irrigation were not adopted by the model. The only time lined ditches were adopted was when a tax was applied on sprinklers. In Garfield County, 2,800 acres were adopted for alfalfa on Class 3W land when a 20% tax was applied and it reached a maximum of up to 3,200 acres with the 100% tax. In Sanpete County a 100% tax resulted in only 3,200 acres being converted on Class 3C land for alfalfa growth. Maximum lined ditch acreage was less than 2% of the total lands irrigated.

Crops and Sprinklers

Table 23 shows the extent of adoption of sprinkler based systems by crop.

The results of the model indicate that a cash crop and cash-feeder farms would always be sprinkler irrigated except in Millard County where alfalfa seed is grown extensively as a cash crop by unlined flood irrigation method. As previously indicated, alfalfa grown on Class 2E and 3E land makes up the majority of sprinkler irrigated alfalfa.

TABLE 23

PERCENTAGES BY CROPS USING SPRINKLERS WITH LINED AND UNLINED DITCH

Scenario	Alfalfa	Alfalfa Seed	Potatoes	Small Grains[a]	Corn for Grain	Corn for Silage
3-1974	33.7%	31.7%	100%	100%	100%	NA
6-Open acreage	38.0%	27.6%	100%	100%	100%	NA
8-"Free Market"	30.9%	27.6%	100%	96%	100%	NA

[a] - excludes barley grown as an establishment crop

NA - not irrigated by modern systems

Counties and Sprinklers

Throughout the analysis, Garfield was the only county to adopt any form of off-farm conveyance (pipe in scenario 10). It was one of the few counties (Millard being the other) to grow barley as a non-establishment crop (scenario 1). The development of potentially irrigated land was small in Garfield, but occured on Class 3W and 4E land and was done only with sprinkler irrigated cash crops.

Piute was the least sensitive county for the adoption of sprinklers. A maximum of 6,000 acres were being irrigated by sprinkler in Piute County. Potential land development occured in the Class 3 lands both by sprinkler and conventional methods.

Cash crop production was very sensitive to taxes on sprinklers in Sevier County. However, the use of subsidy had very little impact within this county. The amount of acres of sprinklers adopted was highly variable depending on the assumption underlying the various scenarios.

Sanpete County was least sensitive to changes of all the counties. The only changes that normally occured were the conversion between lined sprinkler and unlined sprinkler with the relaxation of diversion and acreage limitations.

In addition, extensive potential land development occured in both Sevier and Sanpete Counties when acreage limitations are released. This is primarily due to the large amounts of better class lands being available. Generally all of Class 2, and 3W and 3E lands are considered better class land.

Juab is little affected by the scenarios, primarily because there is no direct access to Sevier River from most of the agricultural lands. The major impact in this county is drastic shifts of cropping patterns.

For example, as the scenarios go from 1 to 6, irrigated wheat goes from highly productive land classes 2E and 3E to poor quality land Classes 4E, 4S and 3S.

Millard County has the largest amount of and potential land in the basin. However, because of it leaching requirements and higher cost and cash crop orientation, it often reacted differently than the other counties. For example, all other counties, alfalfa seed, wheat and barley were irrigated by sprinklers. But these crops were not generally irrigated by sprinklers in Millard County.

CHAPTER VI

SUMMARY

Objectives of the Study

The primary objective of this study was to determine what impact the adoption of modern capital intensive irrigation systems would have on water rights, streamflows, water quality, cropping patterns and incomes within the Sevier River Basin and what impact fixed water rights would have on the adoption of technology. The second objective was to assess the third party effects and to indicate how federal cost sharing and tax policies would aggravate or alleviate the problems. A final objective was to identify those characteristics, soils, crops, counties and topography that would be most likely affected by the adoption of sprinkler systems.

Results of the Study

The majority of the water diverted and not consumed by crops returns to the river. The rediversion of these return flows accounts for a large part of the downstream water supply for irrigation. In order to protect irrigators' water rights, under the doctrine of prior appropriation, the State Engineer limits water diversions and irrigated acreage as proxies for holding consumptive use at some fixed level.

With the development of newer and more "efficient" irrigation systems, the irrigator is given an incentive to expand his acreages and consumptive use of water due to potential increases in supply of water. In an attempt to improve downstream water quality by encouraging farmers to convert to irrigation methods that wash less salts into the stream, Federal and State agencies have encouraged the accelerated adoption of these new technologies through subsidies and other programs. Initially, the general results of these programs have increased the farmers incomes and basin wide outputs. However, the adoption of these systems have not only changed the method of application but also the consumptive use patterns which affect the amount of water going to the downstream water right holders.

To study the impact of these technological adoptions, an empirical model (a LP model), was designed for the Sevier River Basin which incorporated various topographical features. These topographical features are soil types, slopes, crops and crop yields. Irrigation technologies: sprinklers, lined ditch, pipelines; institutional constraints; acreage limitations and diversion requirements were also included in the LP model. The model was used to evaluate the impact of newer technology systems on output, outflows and diversions which may conflict with established water rights.

The empirical model was divided into six counties each to include 11 SCS land classifications, eight crops and four irrigation systems. Surface and groundwater diversion requirements and irrigated acreage limitations were established for each county. Each crops consumptive use requirement by county, for the growing season from May to October, were determined.

Findings

A limitation of the model is that the results are not forecasts of what will or has to happen. These findings are a tool for estimating the cost to the agricultural economy of various water rights violation form policies other programs, etc. In addition, the results are on indication of the direction the Basin is headed. The model and study only indicate where change may occur. No attempt is made to identify any specific farm, group or type of forms or geographic area outside of a general county classification in which the various changes would occur.

The findings of this study are:

1. Increased adoption of modern technologies under the present institutional water and acreage constraints will occur because of increased benefits to the farmer adopting them without any assistance from governmental agencies or units. Given present land allocation and water diversion, the adoption of sprinkler systems would result in an increased output by almost two million dollars. $800,000 is a direct result of adopting sprinkler systems and the remainder would result from shifts in cropping patterns. Under the institutional constraints, over 94,500 acres would be irrigated with a combined unlined ditch-sprinkler system. In addition, sprinkler with lined ditch accounted for over 30,000 acres. The largest areas of adoptions occuring in Sanpete, Sevier and Millard Counties.
2. Increased adoption of modern irrigation systems also caused the outflows to decline within the basin. In fact, diversion requirements in Sanpete and often Sevier and Millard Counties would not be met on an annual basis.

   Furthermore, inflows into the Sevier Bridge-Yuba Dam dividing Sanpete and Juab Counties declined to the point where water released to meet diversion requirements for Juab and Millard Counties would not be met. When water releases at Yuba Dam were based on the inflows to the reservoir, the value of Basin output declined over a million dollars, where the largest decline occured in Millard County due to a water requirement for leaching, and diversions (water rights) would still not be met in Juab and Millard Counties.

3. When acreage restrictions were relaxed, output, consumptive use and sprinkler irrigated acreages increased. Even with a reservoir-dam management policy considered, output would still increase by a million dollars, with over 55,000 potentially irrigated acres of land being converted to irrigated acreages. The largest gains occured in Millard and Sevier Counties. However, despite a reservoir dam management policy, the 1969 diversion levels were not met in Sanpete, Juab and Millard Counties.

4. When institutional restrictions were relaxed, the "Basin wide" solution produced the highest output of over $27,000,000 which is over 5.5 million dollars more than the 1969 solution. The largest output gains occured in Sevier, Sanpete and Millard Counties. However, this solution did not consider a reservoir-dam management policy. As such, the inflows into the Sevier Bridge Reservoir-Yuba Dam Complex were at their lowest point of 36,726 acre-feet or 86,000 acre-feet below the 1969 level of 122,730 acre-feet.

5. Since 1969, the State of Utah Department of Water Resources has sponsored programs which have installed in 158 miles of

canal linings and pipelines to assist the basin farmers. These installations increased annual outputs by over $700,000 and decreased the reliance on the more expensive mining of groundwaters, due to the increase in water delivered to the farmers by these projects. However, a major impact of these state sponsored programs was the decline of inflows at the Sevier Bridge Reservoir by over 20,000 acre-feet below the long run solution to 61,000 acre-feet or 50% of the 1969 solution.

6. Government subsidy programs to assist the irrigator have had similar results to the state programs. Output consumptive use sprinkler acreages all increased but inflow into the reservoir decreases. In part, there is some indication that at the onset of the development of sprinkler systems the farmers have delayed those adoptions (despite being profitable) in order to have the government pick up the cost through the subsidity program. (1974 Census of Agriculture showed that the adopted acreages to be below what a long-run solution would indicate).

   If carried to its end point, and 80% subsidy would eventually increase sprinkler acreages above the long-run solution by as much as 30,000 acres. Furthermore, outflows into the reservoir declined, indicating that the Federal Subsidy program would aggravate any third party effects.

7. One method of offsetting the decreased inflows into the Sevier Bridge Reservoir would be to place a tax on sprinklers, i.e., an annualized 100% of capital cost tax, that would cause

inflows into the reservoir to increase by 33%. However, it would require a larger tax to return the outflow to the 1969 levels.

8. With reduction in outflows occuring as a result of the adoption of sprinkler systems, various ecological factors such as the maintenance of wild life habitat become important considerations. One method of overcoming ecological damage and maintaining stream flows to meet diversion requirement would be to regulate outflows at a minimum level. If, for example, the level fell below a minimum rate, diversions to all areas above the point would be curtailed. The regulation of outflows to various levels can bring the flows to levels similar to the 1969 levels (50% increase in outflows from the long-run solution). However, increasing outflows to maintain 1969 levels would reduce the upper basins, Garfield, Piute, Sevier and Sanpete Counties, output by over two million dollars annually. Figure 16 shows the trade offs between output and increased flows. It is important to note that increasing outflows to 1969 levels will not return the basin to similar cropping or technological patterns. This regulation of outflows would require cropping pattern changes retiring poorer quality land increased productivity on and better quality land. This would result in a redistribution of incomes.

10. Modern sprinkler irrigation systems were adopted more extensively on Class 2E, 2S, 3E, 3S, and 3C lands. These land classes are generally the mid to high yield lands that have moderately sloping features or soil problems, i.e., sandy soil

or shallow soils. The sprinkler systems were least likely to be adopted on 2W, 3W, 4W class land where drainage and salinity are problems and on Class 4S, 4E lands where soil and slopes are a major factor.

Sprinklers with lined ditch were adopted extensively in Millard and Sanpete Counties where diversion were often not met but productivity was high. These two counties have the highest outputs of all six areas.

Lined ditches for flood irrigation and off-farm systems did not generally enter into the solutions, except in the case of outflow regulation where Garfield County adopted this system.

11. Alfalfa seed and potatoes were the first cash-crops to adopt sprinklers. Alfalfa irrigated by sprinklers was usually limited to Class 2E and WE acreages although other classes did appear in the solutions. In general, all cash crops would be sprinkler irrigated.

12. County wide impacts were as follows:

Garfield County: The rate of adoption and change within this county was highly variable depending on the assumptions of the scenarios and when policies which restricted adoptions were in effect such as tax, outflow or reservoir management. Garfield was the first county that adjustments were made in. This came about because Garfield is located at the headwater for the system, thus whatever happens here is felt throughout the basin.

Piute County: This county was the least sensitive and changeable of all the areas. This is primarily due to the lower acreages of high producing acres. Thus, only 6,000 acres of land were converted to sprinklers.

Sevier County: The amount of sprinkler acreage within Sevier County varied throughout the different scenarios. The primary reason being the relative large acreages of Class 2 and Class 3 quality lands. There was also little cash crop acreages. Thus, when conditions changed it was sprinkler acreages that were adjusted.

Sanpete County: This county was not sensitive to changes. The predominant changes was the shifting of sprinkler acreages between lined and unlined ditch. However, Sanpete was the first county to adopt sprinklers in the different land classes.

Potential land development occured in Sanpete and Sevier Counties due to the extensive area of Class 2 and 3 land.

Juab County: There is a lack of direct access of irrigated land along the Sevier River. The impacts of new irrigation technology did not affect Juab County for the most part.

Millard County: Irrigated and crop acreages fluctuated more than in any other county due to the availability of water and the higher costs associated with leaching requirements incorporated within the model. The larger amount of cash crop acreages within the county also allowed more adjustments to be made, e.g., switching from water intensive crops to/from water extensive crops...etc. In addition, the large acreages in sprinklers enabled more options for switching between land classes technologies and crops.

13. The cash crops, potatoes, alfalfa seed, wheat and barley, were most likely to be irrigated with sprinklers. Sprinkler irrigated alfalfa was normally done on Class 2 and 3E land. Corn for gain was irrigated in conjunction with potatoes on high center pivot systems in Millard County. Irrigated pasture land was not economically feasible in any scenario.
14. With the exception of regulated outflows in Garfield County, off-farm systems did not enter into the solutions. Pipelines become feasible when outflows were increased by 20% or more in the last scenario.

Conclusions and Implications

The adoption of modern irrigation systems (sprinklers) would increase total consumptive use and reduce return flows to cause externalities (water right violations) for downstream users. Under constraints of fixed water diversions and irrigated acreage limitations imposed by the State Engineer, stream flows are altered so that externalities result. Any relaxation of acreage and diversion constraints would aggravate the externalities, i.e., farmers can be expected to increase consumptive use and reduce outflows.

Recommendations for Further Study

This study is not an exhaustive and complete analysis of the economic impacts of technological change in the Sevier River Basin, therefore, the results are only indicative of the scope problems involved. The model has several major limitations which should be noted when making policy and administrative decisions. The limitation and recommendations are:

1. The model did not take into account the timing of water deliveries and irrigations during the growing season. Further research would be recommended to determine the availability of water at critical times. For example, water is critical in the latter stages of potato growth. For maximum production, impact of sprinkler irrigation on lag times for return flows must be considered.

2. The adoptions of various technologies was justified primarily on the basis of "efficiency." However, sprinkler technologies may impact the amounts of dissolved solids during irrigation. Thus, water quality may be an additional benefit and thus further research is needed in this area.

3. The model assumed full water requirement for each crop was being met. The model did not take into account the option of partial water supplies.

4. The model accounted for a homogeneous land classification for each farm. Additional study is needed to determine the desirability of adoption of irrigation systems on farms of mixed land classes.

5. Further study by the SCS is needed to update and determine the actual land classification within the basin. The majority of SCS studies are 70-80 years old.

6. The model assumed access to potential lands did not require any major off-farm systems. The potential lands for development does not include an estimate of off-farm systems development costs.

7. Much of the data used was general dated, therefore, additional information of yields by land class, subclass and soil type and land gradient is needed.

8. This study does not include a differentiation between the cash-crop farmer and the livestock oriented farmer. Further studies should take into account start up costs, salvage costs and conversion costs between the two types of farmers. This could indicate the optimum mix of farms and desirability of concentrating in one type of farm or another, e.g., more cash-crop and less livestock or vice versa.

Federal cost sharing programs which aid the individual farmer and state programs which increase the conveyance efficiency of canals to the farms encourage faster adoptions of modern irrigation technology and aggravate these effects. In addition, Federal and State programs which act independently aggravate the difficulties in controlling third party impacts.

Management policies that consider outflows, consumptive use and irrigated acreage impacts on land classifications, acreage locations, cropping patterns, timing and salinity can increase the basins overall output. Table 24 reviews the results of several policy options that can be used to assist the basin in achieving an optimal output. The first policy option is the 1969 level before the adoption of the new technologies.

The long run solution indicates that the present irrigation limitation imposed by the State Engineer results in a private incentive to adopt new technologies as output increases by over $2,000,000. In addition, the present policies will not prevent third party effects and water right violations. Tax policies, used to offset the impacts of newer technologies, would occur on lands and in areas other than where irrigation technology systems were adopted. However, the basin gains in total output with the adoptions of sprinkler systems. By providing or

TABLE 24

SUMMARY OF SCENARIO'S FOR POLICY OPTIONS

	Output (1000's)				Sprinkler Acreages				Actual	Changes in Consumption			Diversion Requirements				Outflows Sevier Bridge and Sevier Lake			
	1969	Long Run	Long Run with Management	Open Land with Management	1969	Long Run	Long Run with Mgmt	Open Land with Management	1969	LR	LR with Mgmt	Open Land Mgmt	1969	LR	LR with Mgmt	Open Land with Mgmt	1969	LR	LR with Mgmt	Open Land with Mgmt
Basin	21,667	23,702	22,596	24,631	-0-	144,113	133,634	159,043	397,592	30,718	7,127	26,126								
Garfield	1,774	2,208	2,208	2,244	-0-	4,075	4,075	4,635	16,613	2,900	2,900	2,922	Y	Y	Y	Y				
Piute	1,732	1,908	1,886	1,963	-0-	5,047	696	547	29,644	23	1,862	5,623	Y	Y	Y	Y				
Sevier	5,206	5,339	5,334	5,944	-0-	27,758	25,883	34,702	78,723	5,441	4,250	7,065	Y	Y	Y	Y				
Sanpete	5,435	5,999	5,769	6,488	-0-	40,728	40,728	46,952	92,993	10,934	10,934	7,962	Y	N	N	N	124,754	82,274	110,485	126,894
Juab	1,422	1,459	1,459	1,663	-0-	3,131	3,131	9,630	42,778	761	761	(1008)	Y	Y	Y	N				
Millard	6,103	6,788	5,940	6,336	-0-	46,015	35,912	36,762	136,841	10,659	10,878	9,525	Y	N	N	N	171,272	176,722	142,606	134,468

encouraging inter-county transfers of water rights and encouraging selective adoptions of sprinklers and new higher productive lands, the gain in output would be realized.

The last two options on Table 24 show possible acreage limitations on sprinklers and lined ditches that can be used to optimize basin and society's output. The long run solution, which regulates the outflows from Yuba Dam based on reservoir levels (inflows to the reservoir), provides a minimum of water right violations. However, by allowing open acreages, basin output can be further increased, as shown in the "open land with reservoir management" option. In this option, sprinkler acreage and consumptive use are maximized, although water right violations do occur. The free transfer of water rights would eliminate water right violations in that those who value the resource more will pay for the right.

In order to maximize output, the maximum acreages indicated by the model are:

Garfield	4,635 acres	Piute	547 acres
Sevier	34,702 acres	Sanpete	46,952 acres
Juab	9,630 acres	Millard	36,762 acres

Private incentives may not produce this desired result if left to the individual irrigator as indicated by the long run solution for Piute County. Thus, subsidies in areas below the optimum levels in each county may be desirable.

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APPENDIX A

CALCULATION OF IRRIGATION EFFICIENCIES BY LAND CLASS

The following soils are classified into three categories based on the definition of the USDA SCS National Engineering handbook.

Fine	Medium	Course
Clay	Sandy loam	Sands
Clay loam	Loams	Loamy sands
Silly clay loam	Silt Loams	
Silly clay		

Soil Profile

Following Soil Profiles were derived from USDA-SCS soil profiles in Utah.

TABLE A-1

PERCENTAGE OF LAND BY SOIL AND SLOPE CHARACTERISTICS FOR EACH LAND CLASS

Land Class	2W	2S	2C	2E	3W	3S	3C	3E	4W	4S	4E
Soils											
Fine	39.6	54.8	2.9	15.7	79.0	14.9	--	28.1	36.7	8.2	35.8
Medium	60.4	34.1	97.1	84.3	19.5	71.2	--	66.5	63.3	58.0	55.5
Course		11.1			1.5	13.9	--	5.4	--	33.8	8.7
Slope											
less than 1.4%	68.8		67.3	7.0	77.4	9.3	--	4.2	45.0	6.7	14.2
1.5-2.9%	31.2	100.0	32.7	65.7	21.0	71.0	--	29.2	39.4	20.7	51.8
3.0-5.9%	--			27.3	1.6	17.9	--	51.4	10.2	22.2	34.0
6.0% & up	--					1.8	--	15.2	5.4	50.4	--

All data in percent.

TABLE A-2

ATTAINABLE FIELD APPLICATION EFFICIENCY

Estimated attainable field application efficiencies for alternative methods of irrigation and various physical land situations.

Soil Texture	Method of Irrigation	Land gradient (percent)			
		Less than 1.4	1.5 to 2.9	3.0 to 5.9	Over 6.0
		percent	percent	percent	percent
Medium	Surface systems:				
	a) unlined ditches	65	60	55	50
	b) lined ditches	70	65	60	55
	Sprinkler systems:	75	70	65	60
Fine	Surface systems:				
	a) unlined ditches	60	55	50	45
	b) lined ditches	65	60	55	50
	Sprinkler systems:	70	65	60	60
Coarse	Surface systems:				
	a) unlined ditches	55	50	45	40
	b) lined ditches	60	55	50	45
	Sprinkler systems:	75	75	75	70

Source: Strong (1972)

Calculation of the attainable field applications efficiencies by land class is as follows:

$$\sum_{h=1}^{S} \sum_{i=1}^{R} \sum_{j=1}^{P} A_{hij}(B_{ik} + C_{jk}) \qquad i=1\ldots3 \quad k=1\ldots11 \quad j=1\ldots4 \quad h=1\ldots4$$

a = is the attainable efficiency for the h^{th} irrigation system for the i^{th} soil type and j^{th} slope from Table B-2.

b = is the percentage of the k^{th} land class for the i^{th} soil type.

c = is the percentage of the k^{th} land class for the j^{th} slope type.

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