ECONOMIC EVALUATION OF IDAHO'S WATER SUPPLY

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ECONOMIC EVALUATION OF IDAHO'S WATER SUPPLY

ABSTRACT

by

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This study examined the costs involved in making water available for use in Idaho. The difference between quantity of water and a supply of water was emphasized. To change a quantity of water into a supply of water requires that costs be incurred.

In examining the cost for making water available for use in Idaho, the water supply industry was segmented into three categories: municipal, industrial, and irrigation. Primary and secondary sources were used in the collection of data from these three categories.

When the data were assembled, regression analysis was performed on the data to determine the relationship between total, fixed and variable cost, and water output for each category. The results of the regression analysis showed there is a reasonably high correlation, 0.70 to 0.81, between cost and output. The economic interpretation of the regression results indicated the water industry in Idaho is in Stage I and subject to economies of scale.

Conclusions reached were the supply curves for the categories were either perfectly elastic or downward sloping and highly elastic. This indicated water availability in Idaho is sufficient to meet present and foreseeable needs.

CHAPTER 1

INTRODUCTION AND SCOPE

The value of water is a paradox. It is an indispensable requirement for life. However, when compared to certain items which are not requirements for life, such as diamonds, the price of water is quite low. This paradox of water is also apparent in that too much water, as with a flood, is as undesirable as too little water, as with a drought. The value of water then is concerned with having the proper amount in the right place at the right time. To achieve this goal, costs are incurred for capturing, transporting, and distributing water from its source to its place of use.

The Problem

By virtue of having 223,227,000 acre feet of water resources (see Table 1), Idaho potentially has a sufficient water quantity to meet its annual consumptive requirements of 5.3 million acre feet (see Table 2). However, when comparing Figure 1, showing annual mean precipitation in Idaho, with Figure 2, showing presently irrigated land in Idaho, it is apparent that water is not necessarily located where it can be used. Rainfall is more plentiful in the mountainous areas, while the irrigated lands are located in the more

TABLE 1

SUMMARY OF IDAHO'S WATER RESOURCES

Source of water	Quantity, in acre feet[a]
Groundwater	137,345,000
Stock (lakes, reservoirs, etc.)	18,350,000
Inflow from out-of-state (rivers)	29,951,000
Average annual water yield from precipitation	37,581,000
Total	223,227,000

[a] One acre foot equals 325,851 gallons of water

SOURCE: Water Resources Research Institute. *Idaho Water Resources Inventory*. Moscow: Univeristy of Idaho, 1968.

TABLE 2

ESTIMATED WATER USE IN IDAHO, 1970,
IN ACRE FEET

Use	Water withdrawn	Water consumed
Water used for public supplies	124,320	32,483
Water used for self-supplied industry	504,050	17,922
Water used for irrigation	16,916,491	5,264,526
Total	17,544,861	5,314,931

SOURCE: C. R. Murray and E. Bodette Reeves. Estimated Use of Water in the United States in 1970, Geological Survey Circular No. 676. Washington, D.C.: U.S. Government Printing Office, 1971.

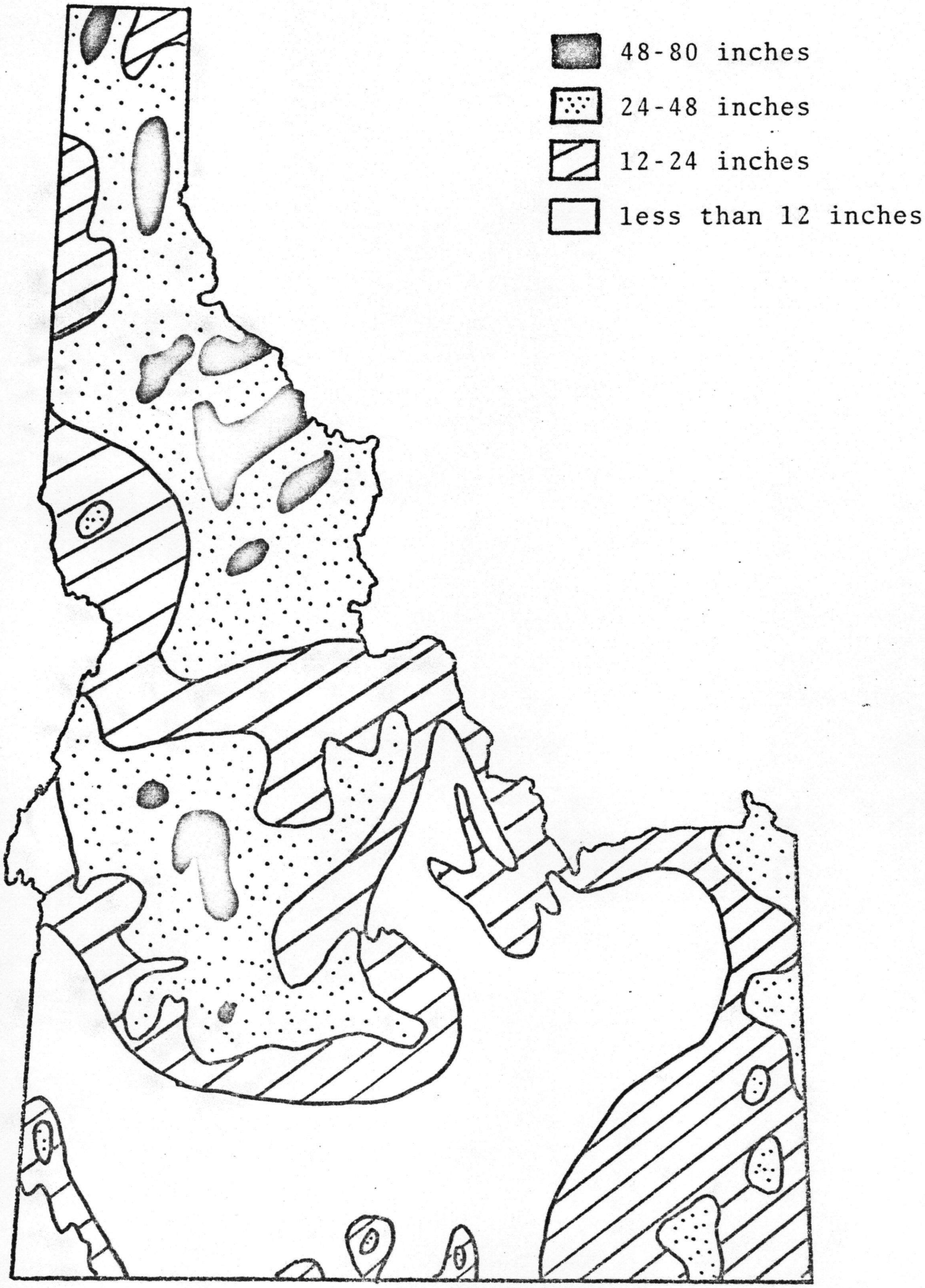


Figure 1. Mean annual precipitation in Idaho, 1900-1967. SOURCE: Idaho Water Resource Board. Interim State Water Plan. Boise: State of Idaho, 1972.

Figure 2. Irrigated land in Idaho, 1970. SOURCE: Water Resources Research Institute. _Idaho Water Resources Inventory_. Moscow: University of Idaho, 1968.

arid regions of the state. Irrigation of farmlands accounts for over 90 percent of Idaho's water use requirements. Southern Idaho, though, with the preponderance of irrigated and potentially irrigable land, has an average annual rainfall of less than 12 inches, while northern Idaho, with the smallest amount of irrigated and potentially irrigable land, has an average rainfall of 38.9 inches and the largest quantity of water in the state (10:92). (See Figures 2 and 3.) Consequently, there exists a problem of making water supplies available to the areas in which they are demanded.

To make Idaho's water resources available for various uses requires that costs be incurred for capturing, transporting, and distributing the water from existing sources. The problem of this thesis will be to study the quantity of water provided from groundwater and surface sources and to evaluate the nature of their associated costs. By placing these relationships into an economic context, the relative scarcity or abundance of water resources can be better evaluated for each source and each use in Idaho. Such an understanding is desirable for policy makers. This study proposes to construct and evaluate the production functions and associated costs involved with making water available to users in Idaho on a state-wide basis.

Justification for Research

J. M. Milliman, in the April, 1956, issue of the Southern Economic Journal, commented "because basic economic

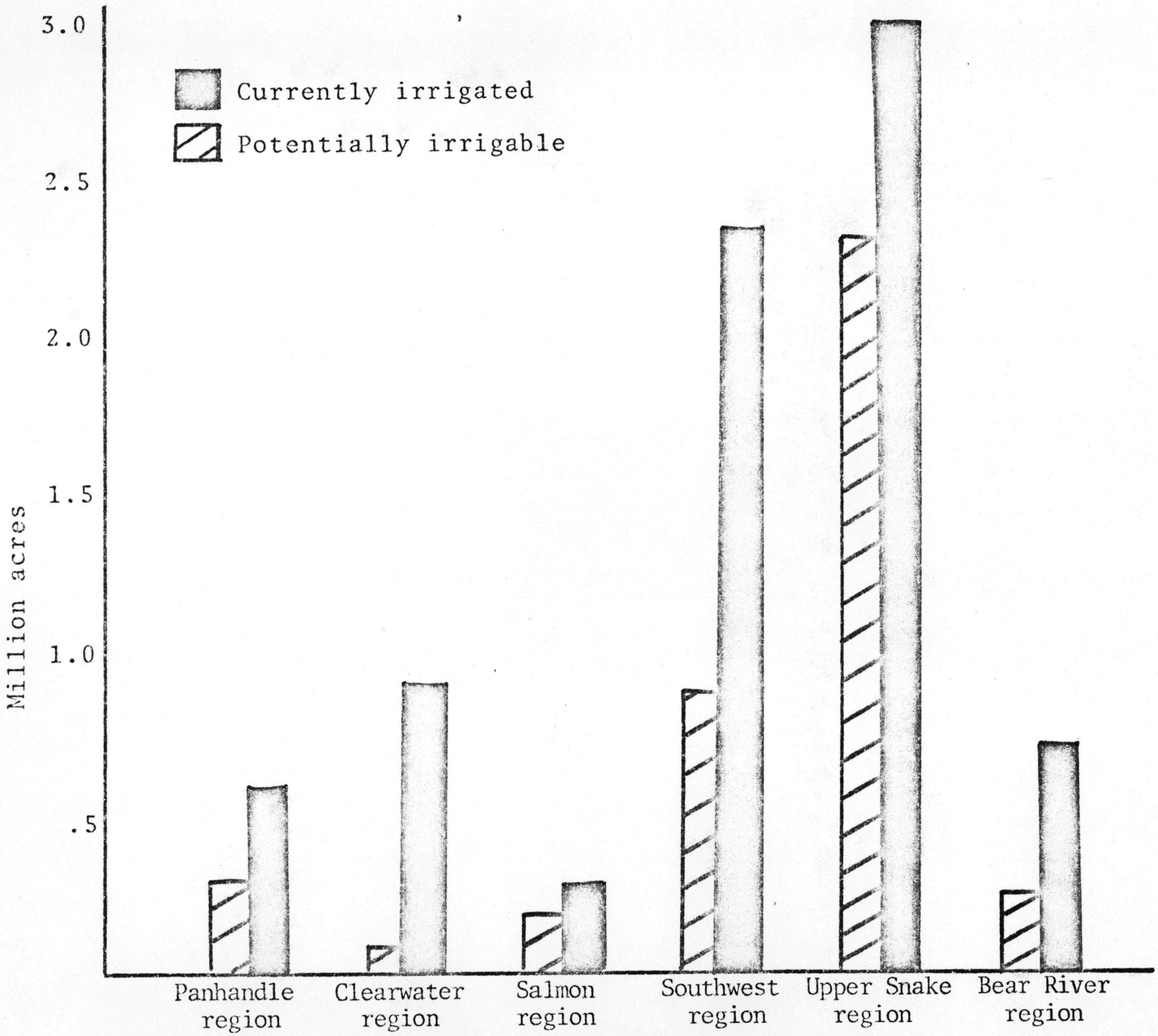


Figure 3. Irrigated and potentially irrigable land in Idaho, 1968. SOURCE: Idaho Water Resource Board. <u>Interim State Water Plan</u>. Boise: State of Idaho, 1972.

analysis has not been used in dealing with water, current pricing and administrative policies are inconsistent with economic realities and perhaps in direct conflict with efficient allocation of water resources" (14:426). While not addressed to Idaho's situation specifically, this may also be the case in Idaho.

The importance of water to agriculture, Idaho's first billion dollar industry, is apparent by noting that of the 6 million acres of cropland in Idaho, 3.8 million acres, 63 percent, are irrigated (10:10). This irrigated acreage accounted for 50 percent of Idaho's $658,982,000 crop market value in 1973 (9:7). While agriculture placed the heaviest burden in water use requirements, 16.9 million acre feet (16:22), industry required 504,050 acre feet and municipalities needed 124,320 acre feet (16:22).

Previous research concerning water in Idaho has dealt primarily with its physical availability. The Idaho Water Resources Inventory (18) and the Interim State Water Plan (10) have summarized the physical availability of water (Table 1) and predicted future water requirements (Table 3). Although several researchers [Kimball (12), Lindeborg (13), and Schatz (17)] have examined in detail costs for making water available for use in specific areas of Idaho, no attempts have been made to summarize the aggregate economic water supply situation as it exists for the entire state.

TABLE 3

CURRENT AND PROJECTED CONSUMPTIVE IDAHO WATER REQUIREMENTS

Needs	1970	1980	2000	2020	2070
Projected non-industrial	32,482	241,113	335,324	447,329	861,611
Projected industrial	17,922	251,860	391,410	499,540	1,014,240
Projected irrigation	5,264,526	5,392,000	6,415,000	7,563,000	10,408,000
Totals	5,314,931	5,758,973	7,141,734	8,509,869	12,283,851

SOURCE: G. R. Wells, Glenn D. Jeffery, and Robin T. Peterson. *Idaho Economic Base Study of Water Requirements*, Vol. 2. Boise: State of Idaho, 1969.

Although Idaho has a sufficient water quantity to meet current needs, projections by the Idaho Water Resources Board indicate water requirements will double by 2070 (10). The question remains as to the economic availability of this water. Increasing in-state water requirements will bring pressure for additional water development projects. By placing the cost-quantity relationship of making water available for use into an economic framework, it is hoped economic realities can be better related to the potential availability and the efficient allocation of water.

Objectives of the Study

The following are the objectives this study will attempt to accomplish:

1. Summarize the stock and flow water resources in Idaho.
2. Determine cost functions for supplying water by use: municipal, irrigation, and industrial.
3. Develop appropriate supply curves.
4. Evaluate the elasticities of supply for each curve developed.

The above objectives demonstrate the sequence the study will follow. Each step will build on previous objectives. Upon completion of Objective 3, a complete water supply analysis, placed in an economic framework, will be available. Objective 4 will provide a means of comparison between costs of making water available to users in Idaho and the physical quantity of water available in the state, for the major types of water users.

Cost and Production Functions

Inputs are required to change a physical quantity of water to an economic water supply. Normally, the inputs are categorized as fixed and variable. Fixed inputs are those inputs which are required regardless of the output produced. Variable inputs, on the other hand, vary in relation to the output produced. In the short run, inputs are either fixed or variable; in the long run, all inputs are classified as variable. A production function can be defined as "a schedule (or table or mathematical equation) showing the maximum amount of output that can be produced from any specified set of inputs (fixed or variable), given the existing technology. In short, the production function is a catalogue of output possibilities" (5:136).

The various physical quantities of inputs needed to make certain amounts of water available for use in Idaho is now defined as a production function. However, because "available accounting data are normally cast in money terms" (29:39), instead of physical terms as required by a production function, a cost function is more readily derived. A cost function can be defined as a production function with prices attached to the inputs.

If $q = f(x_1,x_2)$ is a production function where q is total output, x_1 is the amount of input one required, and

x_2 is the amount of input two required, then the cost equation can be stated in terms of input levels and input prices such as $C = (r_1x_1 + r_2x_2) + b$ where r_1 is the price of input one, r_2 is the price of input two, and b is fixed costs. Thus the cost function, denoting "cost expressed as a function of output" (7:71) will be, in the short run, $C = 0(q) + b$ where b, the fixed costs, are incurred regardless of output levels and $0(q)$ denotes variable costs which are a function of output quantities. From a cost function, one can correlate the relationship between the quantity of water made available for use and the cost required to make it available for use.

Supply

As previously stated (p. 1), Idaho has a sufficient quantity of water to meet its annual use requirements. Also, Idaho potentially has a sufficient water quantity to meet its annual use requirements for 2070. To transform this potential quantity into an actual supply requires that certain costs be incurred so the quantity of water may be used. Relating this water quantity to the cost involved for making it available for use results in a supply curve or schedule. In order to make more explicit the difference between a physical quantity of water and an economic supply of water, a brief review of economic fundamentals is required.

A physical quantity of a good and an economic supply are two different things. One thousand acre feet of water in an underground aquifer, because it is not available for use, is a physical quantity of water. However, once a well is drilled and the water is moved to the surface where it can be used, the one thousand acre feet has changed from a physical quantity to an economic supply of water. If one hundred acre feet of water costs $10 to bring to the surface, a point on a supply curve has been observed. A series of cost-quantity relationships for making various amounts of the one thousand acre feet of water available for use brings forth a supply schedule which can be plotted as a supply curve. A supply curve can be defined as a curve showing the relationship between specific amounts of water and the costs incurred for making the specific amounts available for use. This relationship can be estimated by observing actual costs for providing water in Idaho.

Evaluation of the elasticity of supply is one of the objectives of this study. Elasticity of supply is defined as a measure of the responsiveness of sellers to changes in price or costs of production. When the elasticity is greater than one, it is considered to be elastic and as a result small changes in cost result in greater than proportional changes in output production. If the elasticity of supply equals one, changes in the cost of production result in proportional changes in output; if the elasticity is less than one, less than proportional changes in output result from cost changes. The concept of elasticity is important for this study, and for public policy, because it measures the ability of water suppliers to adjust production to changing economic conditions continually confronting it (25:342).

Procedures

Base Year

The year 1970 was chosen for the base year for this study because it is the most recent year for which much information is published. Study data will be collected from the three principal water suppliers in Idaho: municipalities, industries, and irrigation districts. From these three suppliers, data will be collected concerning costs of making water available for use from two sources: groundwater and surface water. This type of data is known as cross-section data for a single point in time.

Sample Population

Municipalities. The sample of the municipalities surveyed will consist of the largest fifteen cities in Idaho plus a random selection of fifteen smaller cities. These thirty municipalities account for 338,126 people or approximately 72 percent of Idaho's 470,000 people served by public water systems. The municipalities selected are listed in Appendix A. The information collected will form the data base for estimating costs of making municipal water available for use.

Industries. For industrial water suppliers, only that portion of the water supply produced by the individual industry will be included. Any water purchased from municipal water suppliers will be included in the municipalities' total. At the time the study was undertaken, information was not available as to which industrial plants supplied their own water and which purchased water from municipal sources. Consequently, because self-supplied water is cheaper than water supplied from municipalities (10:78), it is assumed that the larger the plant, the better the possibility self-supplied water is used. The largest plants, based on number of employees and divided into four industrial categories, will be contacted. The information collected will form the data base for estimating the cost of making water available for industrial use.

Agriculture. In 1968, there were 58 irrigation districts registered with the State Reclamation Engineer. All of these districts, listed in Appendix C, will be contacted. In addition, information published concerning the thirteen Bureau of Reclamation projects in Idaho will be included in the study. The information gathered will form the data base for estimating the costs of making water available for agricultural use.

Determining Costs and Amounts of Output

Because the problem of the study is to determine costs of making water available for use in Idaho, two general categories of data will be collected from the sample population: total cost and total output.

Costs

For the time span of interest for this study, total cost consists of fixed costs and variable costs. Fixed costs are defined as total dollar expense incurred even when no output is produced. Fixed costs are not a function of output and are constant throughout the time horizon of the study, one year. Variable costs are a function of output and vary in proportion to the quantity of output produced. Variable costs can be altered during the time span of interest in the study.

Costs classified as fixed costs include current book value of permanent capital equipment such as transmission lines or canals, treatment and pumping works, distribution systems, and other general property. Classified as variable costs were power used for pumping, treatment costs, canal clearing and ditchrider expenses, in general all operation and maintenance costs. One cost not included in the study was "search cost." This cost, which applied to groundwater, would consist of costs involved in looking for water. Because aquifers are not present throughout the state, a certain number of dry wells are expected to be drilled. It is assumed that search costs were insignificant for the categories studied. However, this cost might be quite significant for the individual and if search costs were greater than the expected value of the water, this would preclude individuals from looking for aquifers. Search costs, though, are out of the pervue of this study.

Output

Total output for this study is the total water withdrawn or made available for use measured in acre feet.

Questionnaires

Specific cost and output information to be gathered for each of the three users is included in Appendix C in the questionnaires.

CHAPTER 2

WATER RESOURCES IN IDAHO

Idaho's water resources are divided into two separate categories: surface water and groundwater. Although separated into two categories, there is a complex relationship between the two. Originating from a single source, precipitation, influences which affect surface water quantities also affect groundwater quantities. The interdependency of surface water and groundwater is such that Hirshleifer commented "surface water is either the overflow from aquifers or water that has failed to reach them" (8:10).

In this chapter, the sources and quantities of both surface water and groundwater resources will be reviewed.

Surface Water

Surface water in Idaho will be divided into two principal categories: flow and stock. Flow water resources consist of streams and rivers. Stock resources consist of reservoirs and lakes, specifically bodies of water which, through natural or man-made means, act as storage facilities of flow water. Snowmelt provides the primary source of water for streams in Idaho. Water yield from watersheds varies from under one inch in the plains areas to over forty inches in the mountainous areas. It is estimated the high mountains of Idaho supply 82 to 95 percent of the yearly flow of water to the major rivers in Idaho (30:80). Average annual precipitation is almost 100 million acre feet (30:24) which yields approximately 38 million acre feet of water (30:100).

Flow Resources

In Idaho, "the principal (source) of consumptive water is the Snake River" (10:16). Originating in Wyoming, the river has an annual flow at the Idaho-Wyoming border of 3.4 million acre feet (10:183). It supplies water for over 1.6 million of Idaho's 3.8 million irrigated acres of cropland (27). The Snake River exhibits considerable seasonal fluctuation due to several causes. Depending on precipitation for replenishment, the river has regular patterns of low flows during the fall and winter with much higher flows during the spring and early summer (10:16). A second factor contributing to seasonal fluctuations is irrigation demands. During the summer, storage facilities along the Snake release large amounts of water to fill irrigation requirements. During the fall, flows are restricted to refill storage reservoirs. The average flow of the river at Neeley is 4.5 million acre feet (10:19) while downstream approximately 70 miles at Milner, average annual flows decrease to 1.2 million acre feet due to irrigation withdrawals.

Other major rivers in Idaho, such as the Kootenai, Pend Oreille, Spokane, Moyie, and Bear, contribute considerable quantities to the total water outflow of the state. However, these rivers are in Idaho for a rather short distance and consequently present small potential for development (see Fig. 4). The Snake River, though, flows the entire width and over half the length of the state, forming a collecting basin for a very large portion of surface runoff in the state. When the Snake River leaves Idaho at Lewiston, it has an annual flow of 35.7 million acre feet (30:77). This volume of water accounts for almost half of the total outflow from the state (see Table 1).

Because rivers in Idaho have water exiting the state does not mean the water is unused. Streamflow commitments and minimum flow requirements may preclude usage of water because of the right of downstream users, either through decreed water rights or minimum flow commitments.

The primary area of interest for minimum flow lies in the Middle Snake River. The Corps of Engineers has calculated that approximately 6.9 million acre feet of water is required to meet flow requirements for boating and recreational purposes (10:63). The possible constraints this might have on upstream irrigational development can be noted by comparing the 6 million acres of potentially irrigable land in southern Idaho (10:84) with the 10.9 million acre feet of water outflow from the region at Weiser (10:63). This outflow would allow for 1.82 acre feet of water per acre, or just barely consumptive use requirements for any

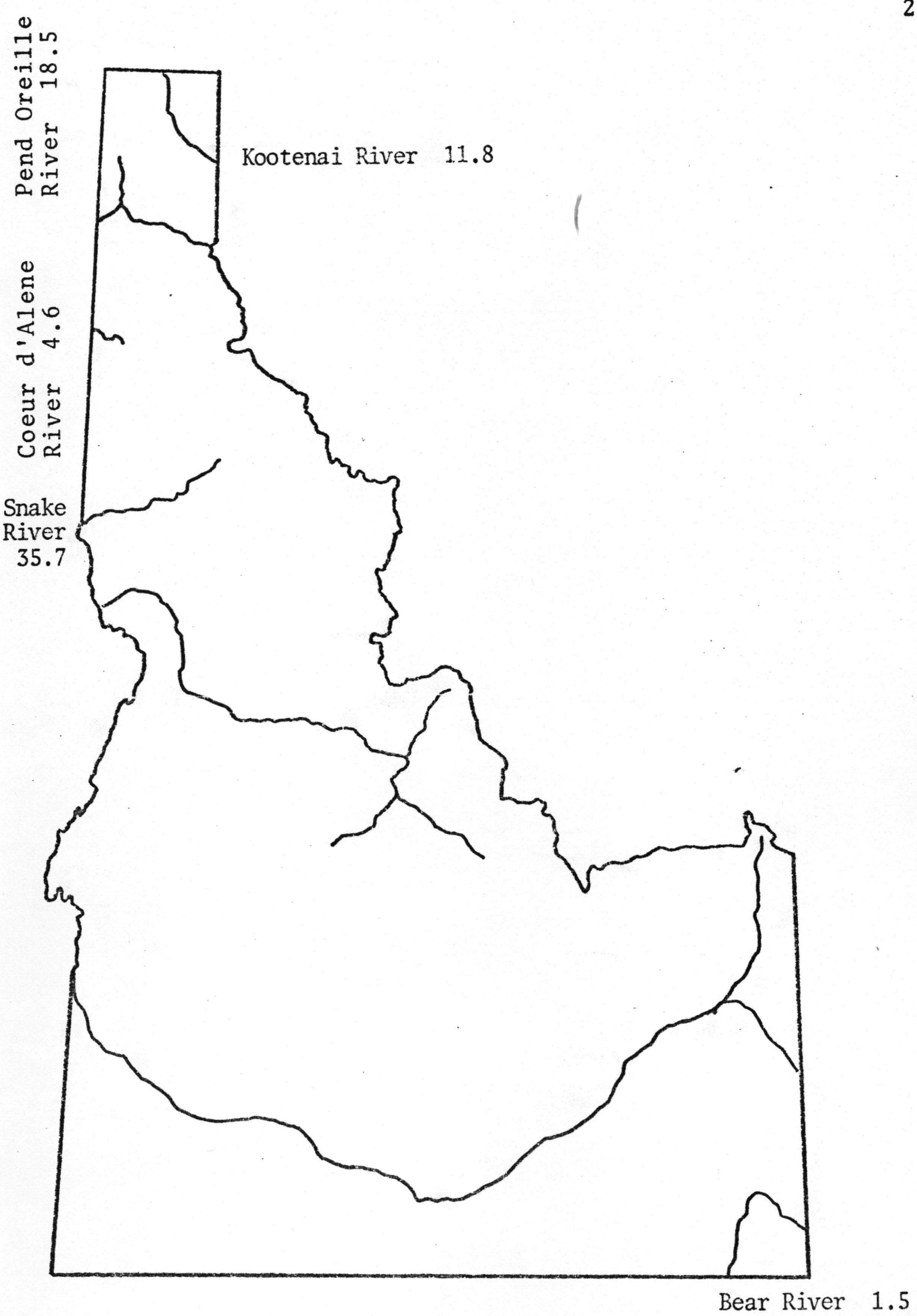


Figure 4. Millions of acre feet of water exiting Idaho in major rivers, 1970. SOURCE: Water Resources Research Institute. Idaho Water Resources Inventory. Moscow: University of Idaho, 1968.

crop but small vegetables (24:7). Assuming minimum flow requirements at Weiser of 6.9 million acre feet per year as recommended by the Corps of Engineers, only 0.67 acre feet of water per acre would be available for irrigating the potentially irrigable land. This amount of water, which does not meet the consumptive use requirements for any crops currently grown, indicates a situation where water quantity problems may appear.

The majority of the major rivers in southern Idaho, such as the Snake, Big Lost River, Portneuf, and Owyhee, have heavy irrigational demands placed on them and, as a result, water is available to new appropriators only during periods of high flows in the winter and spring. However, in central and northern Idaho, there are far fewer decreed water rights and the majority of flows in these areas are open to appropriation (30:209).

Stock Resources

A second form of surface water is the lakes and reservoirs in the state. The majority of Idaho's 2000 lakes are in the central mountainous region and are used primarily for recreational purposes (10:22). The larger natural lakes, such as Payette, Pend Oreille, and Coeur d'Alene, are regulated and serve as a source for meeting municipal, industrial, and irrigational water requirements. The physical quantity of water in these natural lakes varies considerably during the year. Consequently, a quantification of the amount of water is only tentative. One report has estimated the average amount of water in these natural lakes as being approximately 6 million acre feet (30).

Reservoirs are bodies of water formed entirely by man-made efforts. They differ in several ways from natural lakes. Reservoirs contain little "dead storage" (water which cannot be released). By comparison, natural lakes are almost entirely "dead storage." Also, reservoirs, because they are constructed along streams or rivers, generally have a greater inflow than do natural lakes and consequently can be replenished more rapidly than natural lakes (30:102-103).

The majority of the large reservoirs in the state are along the Snake River and are used primarily for irrigational and hydropower purposes. The largest reservoir is American Falls and contains 88 square miles of surface water. The quantity of water in reservoirs varies considerably more than that of lakes because of irrigational demands depleting the reservoirs during the summer runoff being trapped during the fall in order to return water levels to their original levels. Reservoir water may also have several competing uses such as flood control, power, irrigation, and recreation. Water can be released from the pools serving each of these uses to meet the needs of the various users in these multipurpose reservoirs (30:103). The estimated average quantity of water in reservoirs in Idaho is in excess of 12 million acre feet (30).

Groundwater

Underground storage is another principal source of water in Idaho. Of the 223 million acre feet of water in Idaho listed in Table 1, over 60 percent of the total is groundwater. Despite its importance to Idaho's total water resource picture, only 2.8 million acre feet (1.3 percent of Idaho's total water resources) were withdrawn for use in 1970 (16). The principal user of groundwater was irrigation. "In addition, nearly all water requirements for municipal, industrial, domestic and livestock uses are met from groundwater sources" (30:153). Two of the nation's most productive aquifers, the Snake River Plain and Rathdrum Prairie, are in Idaho. Combined, these two aquifers discharge approximately 7.9 million acre feet of water yearly (30:139). (See Figure 5.)

The heaviest user of groundwater, irrigation, required approximately 2.3 million acre feet in 1970 (16:22). Demand for irrigational water, however, is seasonal. It is doubted that this quantity of water could be withdrawn for an extended length of time within current economic limits (30:153). Small quantities of groundwater are obtained throughout the year for municipal and industrial uses.

The accurate measurement of technologically available groundwater quantities and recharge is difficult. Groundwater aquifer replenishment is seasonal and sometimes cyclical resulting in variation of groundwater availability

Figure 5. Expected yield of wells in Idaho, 1970.
SOURCE: Water Resources Research Institute. *Idaho Water Resources Inventory*. Moscow: University of Idaho, 1968.

from year to year. In addition, the interdependency of surface and groundwater makes double or even triple counting of these two resources possible. For example, water diverted from the Snake River for irrigation may percolate into the Snake River aquifer, return back to the river or into a reservoir, only to be again diverted for irrigation. As the water moves from the upper end of the Snake River Plain to the lower end, it may cycle in and out of the aquifer at least three times (10:26).

Summary

Idaho has a significant quantity of water resources. In addition, these resources are renewed annually from runoff from snowmelt and other precipitation. However, in the northern areas of Idaho with the greatest quantities of water, physical and economic limitations preclude widespread use. In southern Idaho, water quantities are almost entirely claimed, leaving little available for future or alternative uses. Consequently, water supply problems and associated costs probably vary considerably by area.

CHAPTER 3

WATER SUPPLIERS IN IDAHO

Groups that supply water in Idaho can be divided into three broad categories: municipal, industrial, and irrigation suppliers. Taken together, these three categories withdrew 17.5 million acre feet of water for use in 1970 (16). Irrigation suppliers provided the preponderance of this amount, over 96 percent. Industrial uses accounted for 3 percent and the remainder was supplied by municipalities.

Irrigation

During the early years of irrigational development in Idaho, almost 100 years ago, lands adjacent to streams were first irrigated. As technology improved over the years, water was pumped to higher land and transferred considerable distances from its source. Also, as demands for irrigation water increased, groundwater became a more important source. Today, irrigation has helped agriculture become Idaho's first billion dollar industry (9:4). The value of crops grown on irrigated land was approximately 320.4 million dollars in 1973 (9:7).

Agricultural land, with production ranging from forage crops such as hay and feed grains to intensive cash crops such as potatoes and sugar beets, can be divided into three categories. In the first category, where most irrigation currently takes place, the regional water quantity is diminished by agriculture because vegetation and evaporation use more water than precipitation naturally brings. The second category, where the bulk of dry land farming takes place, does not add to or diminish the water quantity because vegetation requirements and evaporation are balanced by precipitation. Mountainous areas and high plateaus constitute the third type of area where agriculture transpires in Idaho. In this last category, there is an excess of water beyond that which vegetation consumes and is lost from evaporation. However, there are limited agricultural endeavors in these areas because of soil conditions and limited growing season.

The preceding demonstrates a basic paradox of the distribution of soils and water in Idaho. In areas where soil conditions and length of growing season combine to allow for large amounts of cultivation, there are limited quantities of water available; however, where ample quantities of water are available, even allowing for a reasonable growing season as in the Coeur d'Alene region, limited areas are available for cultivation. Consequently, although Idaho's water resources are considerably larger than water supplied, it is estimated that in 1971, 614,000 acres of land in Idaho needed supplemental water totaling 732,000 acre feet (10:88).

The majority of water produced for irrigation in Idaho is handled by federal reclamation projects under the direction of the United States Bureau of Reclamation. In 1970, there were thirteen projects or irrigation districts in Idaho which were included in this grouping. These are listed in Table 4. These projects supplied water for irrigating 2.1 million acres of land throughout Idaho. In addition, the projects supplied water for a variety of other uses such as recreation and municipal water supplies.

Numerous other canal companies and water user organizations, ranging from those serving the needs of a few people to larger organizations serving many people and thousands of acres, also supply water for use in Idaho.

Future Requirements

The Idaho Water Resource Board has estimated future agricultural water needs for Idaho (11). In the prediction, it was estimated, as an upper limit, by 2070, 7.8 million acres of land in Idaho would be irrigated. Consumptive use requirements were projected to be 10.4 million acre feet of water.

Consumptive use refers to water which is not immediately available for reuse but which goes directly into plant tissue or is evaporated. More efficient irrigational practices might reduce evaporation losses. However, because no irrigational practices are 100 percent efficient,

TABLE 4

FEDERAL RECLAMATION PROJECTS IN IDAHO, 1970

Project	Acres irrigated
Avondale	528
Boise	342,528
Dalton Gardens	701
King Hill	7,889
Lewiston Orchards	550
Little Wood River	7,706
Mann Creek	4,636
Michaud Flats	10,667
Minidoka	1,102,724
Owyhee	110,267
Palisades	528,397
Preston Bench	4,006
Rathdrum Prairie	4,165
Total	2,124,764

SOURCE: U.S. Bureau of Reclamation. Summary Report of the Commissioner, Bureau of Reclamation, to the Secretary of the Interior, 1970. Washington, D.C.: U.S. Government Printing Office, 1970.

considerably more water must be made available for use than consumptive needs dictate.

In 1970, 5.3 million acre feet of water were consumptively used. However, because of operational spills, transportation losses, and other factors, 16.9 million acre feet of water were required to be made available for use to meet the consumptive irrigational requirements. If this 3:1 ratio of supply to consumptive use requirements were projected to 2070, 33 million acre feet of water would be required for irrigational purposes.

Self-Supplied Industries

Self-supplied industrial use of water in 1970 was 504,500 acre feet (16:24). Of this total, 380,838 acre feet (76 percent) came from groundwater sources and the remainder from surface sources. Unlike municipal-domestic withdrawals, industrial water withdrawals are normally recycled several times before being discharged as waste. In 1971, the estimated reuse factor was 3.0 (10:78), which means water was recycled three times before being discharged.

Because of unequal distribution of Idaho's natural resources, certain areas dominate in specific industrial water use over others. In northern Idaho, primary metals and metal mining are the predominate users; in central Idaho, 98 percent of the water requirements are associated with forest and wood products. In southern Idaho, food and chemical production are the heaviest users. Although comprising only 0.2 percent of Idaho's water intensive industries, fresh and frozen fish production water withdrawals accounted for almost 50 percent of Idaho's total water withdrawals for industries (10:77).

Projections made by the Idaho Water Resource Board indicate self-supplied industrial water requirements will more than double within one hundred years (31). The largest increase was predicted for the Gooding, Twin Falls, and Jerome areas where requirements were predicted to increase over 10 times. This will probably be due to the extensive food processing industries projected for the area.

Municipal

Municipalities supplied approximately 124,100 acre feet of water for use in 1970 (16:18). Despite its small importance in relation to total water supplied, municipal usage has priority over all other uses in Idaho (12:15).

Water supplied for public use served 470,000 people in 1970 (16:18). Groundwater was the largest single source, providing 107,000 acre feet of water for 407,000 people. Surface water sources served 63,000 people with 16,801 acre feet of water (16:18). For this study, water supplied by municipalities to industries was counted in the municipalities total. Northern Idaho depended mostly on surface sources for water. Southern Idaho municipalities depended much more heavily on groundwater as a water source.

By 2070, municipal water requirements are expected to almost quadruple to 861,611 acre feet (31:109). In Gooding, Jerome, Twin Falls, and Minidoka counties, municipal water requirements are predicted to increase 4.4 times, from 40,000 acre feet to 176,000 acre feet (31:114).

Summary

Idaho is primarily an agrarian state and will probably remain so into the foreseeable future. Consequently, irrigational water requirements will continue to be far greater than industrial and municipal water requirements combined. Irrigation, the heaviest user of water, and the majority of Idaho's population and industry are all in southern Idaho. Predictions indicate that by 2070, water suppliers will need to make 29.6 million acre feet of water available for use in Idaho. While this amount would be only 13 percent of Idaho's current total water resources, the largest increase in water requirements will be in southern Idaho which has the most limited quantities of water.

CHAPTER 4

WATER SUPPLY COSTS

This chapter will very briefly review the economic concepts of cost and production functions and their relationship to supply. Cost requirements peculiar to making water available for use by irrigational, industrial, and municipal water suppliers will be examined in more detail.

Cost and Production Functions

Cost Functions

As has been previously stated (p. 1), the value of water is in having the proper amount in the proper place at the proper time. Because water is not always where it can be immediately used, some effort, or cost, must be borne to make the water available for use when needed. A cost function for water can then be described as the cost of inputs required to make a specific quantity of water available for use. These costs, whether they are tangible (i.e., monetary) or intangible (i.e., time) can be further divided into fixed costs and variable costs.

Economic literature defines the long run as a period of time such that all inputs and costs are variable; this study is concerned with the short run where total costs consist of both fixed and variable costs. Fixed costs consist of costs which must be borne regardless of output produced. For example, once a well or dam is constructed, the cost of the facility must be paid for and the cost does not vary with the amount of water produced. Power for pumping of water or water treatment costs depend on the amount of water made available for use. If no water is pumped, no pumping costs are incurred. A cost function can be linear (straight) or curvilinear depending on the nature of the relationship of cost to output.

Production Functions

While cost functions deal with cost-output relationships, production functions are concerned with the "physical relationship between the output of a specific commodity and the inputs of the factors used in the production of that commodity" (18:1).

For example, consider the production function $q = f(X_1,X_2)$ where q is the amount of total water made available for use, and X_1 and X_2 are the inputs required for making that amount of water available. If X_1 is a variable factor input and X_2 a fixed or constant factor (X_2*), the production function now is $q = f(X_1, X_2*)$. From this total production function can be derived average product and marginal product functions. Average product is the "output-input ratio for each level of output and the corresponding volume of variable input" (5:139). This can be written

$$\frac{q}{X} = \frac{f(X_1,X_2*)}{X_1}.$$

The change in total output, q, achieved from the increase of one unit of variable input, X_1, is the marginal product:

$$\frac{dq}{dX_1} = f'(X_1,X_2*).$$

Taken in its entirety, the neo-classical production function has three stages: Stage I where

$$\frac{dq}{dX_1} > \frac{q}{X_1},$$

indicating the increasing effect on total output of the variable input X_1; Stage II where

$$\frac{q}{X_1} > \frac{dq}{dX_1} > 0,$$

in other words where additional inputs result in less than proportional increases in total output; and finally Stage III where

$$\frac{dq}{dX_1} < 0.$$

The final stage depicts a region where greater quantities of X_1 are used resulting in decreasing total output.

These three stages of production are shown in Figures 6a and 6b.

Relationship of the Two Functions

A total cost function can be derived from a production function by the addition of prices to the physical inputs (22:17). If the production function is $q = X_1 + X_2$, the total cost function is $C = P_1X_1 + P_2X_2^*$, where C is the total cost, P_1 is the price of variable input X_1, and P_2 is the price of fixed input X_2^*. Average variable cost is total variable cost divided by output:

$$\frac{P_1X_1}{q} = P_1(\frac{1/q}{X_1}).$$

Remembering that average product is q/X_1, then average variable cost equals the reciprocal of average product times the factor's price. Marginal cost is the exact rate of change of total cost, C, as output, q, changes. Marginal cost equals:

$$\frac{dC}{dq} = P_1 \; (\frac{1/q}{X_1}).$$

Marginal cost is the price of input X_1 times the reciprocal of the marginal product. Referring to Figure 6d, Stage I exhibits decreasing marginal costs. In Stage I, marginal costs are below average variable cost resulting in total

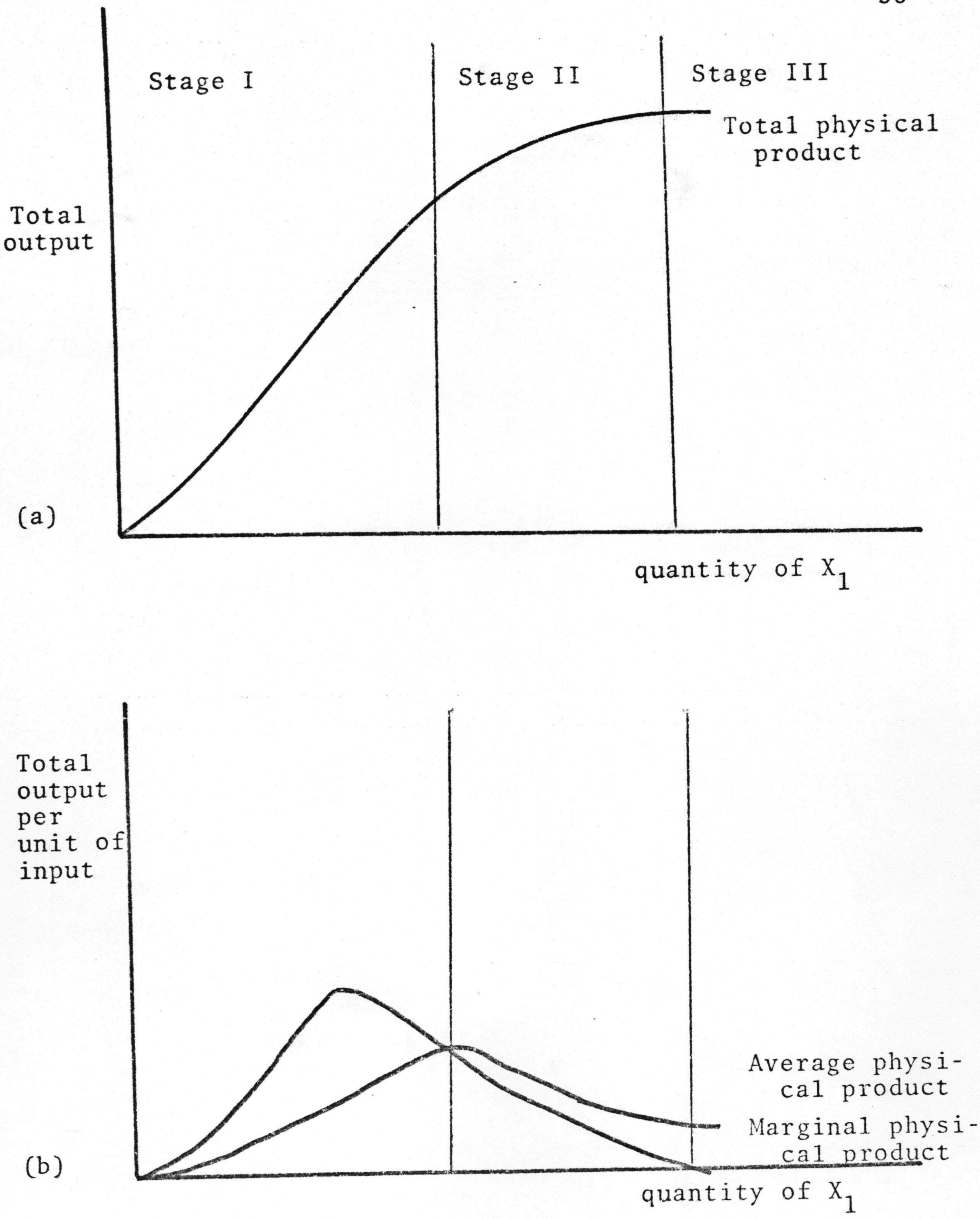


Figure 6. The classical production function and the three stages of production

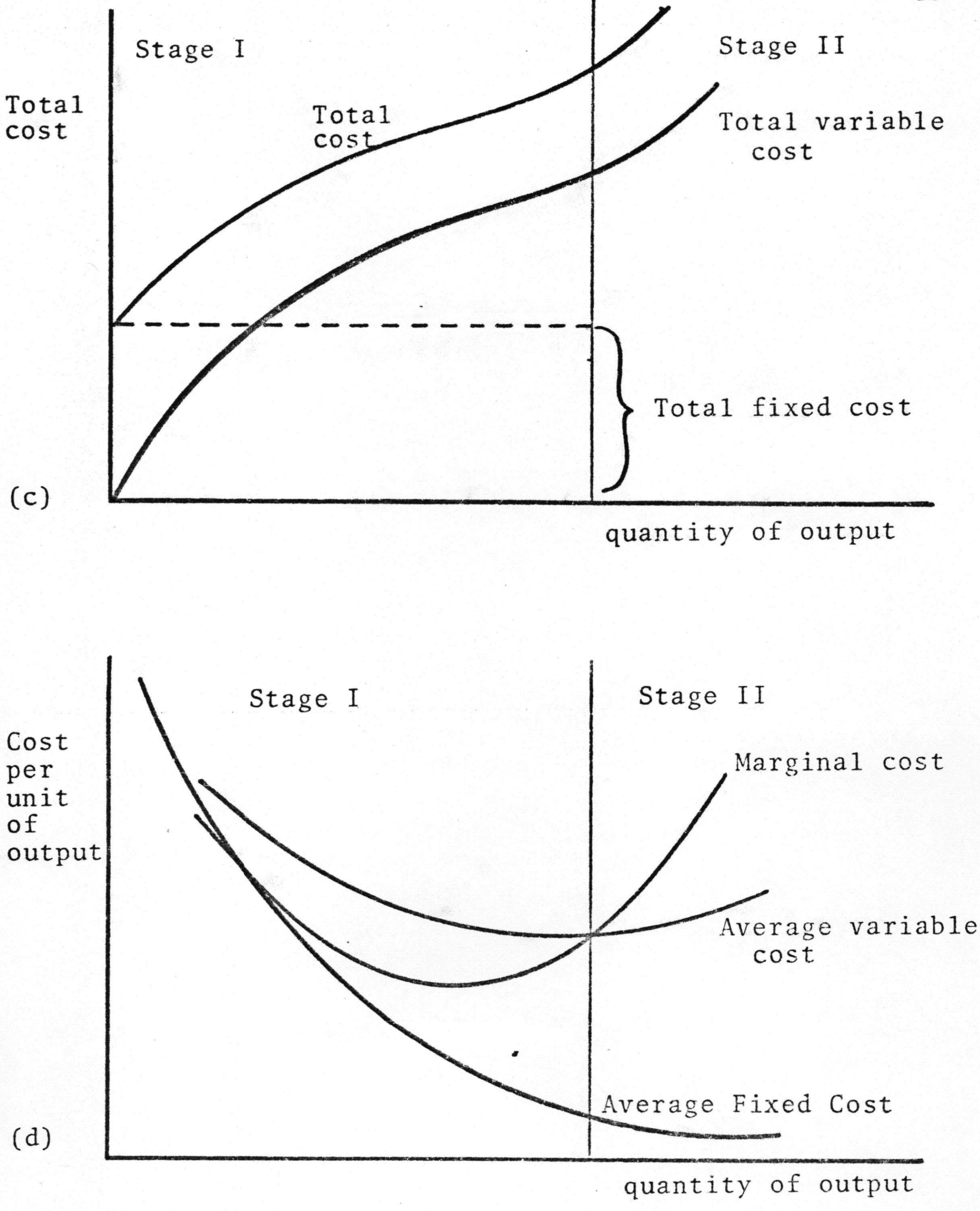


Figure 6. (Continued) Cost curves for the classical production function

product increasing at an increasing rate. Stage II begins where the marginal cost curve crosses the average variable cost curve. Total output is increasing at a decreasing rate and total cost is increasing at an increasing rate. Symbolically, this means $f''(q) < 0$ and $f''(C) > 0$. Finally, in Stage III, additional inputs of the variable factor results in decreasing production and increasing costs.

Total cost is composed of total fixed cost and total variable cost. Total fixed cost is unchanging; consequently, the slopes of the total cost curve and total variable cost curve are the same, but separated by an amount equal to total fixed cost. The total cost curve derives its shape from the production function. When graphing the total physical product curve, Figure 6a, the total output is a function of the quantity of variable input X_1. In graphing the total cost curve, total cost is a function of total output. Because a dependent variable is placed on the y or vertical axis, the vertical axis in Figure 6a becomes the horizontal axis in Figure 6c.

When depicted graphically, in Stage I, total physical product is concave from above and total cost is concave from below. At the start of Stage II, this relationship reverses itself and total cost becomes concave from above and total physical product concave from below. Although graphically this appears to be an inverse relationship, because of the change in axes, the functions are similarly sloped. This is apparent when recalling that the cost function has been defined as a production function with prices attached. The prices are assumed to remain constant.

For the discussion of supply, market conditions are assumed to be perfectly competitive. Although there are a number of assumptions on which perfect competition lies, Professor Joan Robinson's definition of perfect competition, that the demand curve for the output of an individual seller is perfectly elastic (1:197), implies all of the necessary assumptions for this study.

Supply

Supply refers to the amount of a good, in this study water, which can be made available at various costs or prices. More specifically, a supply curve is the functional relationship between those quantities which are economically feasible and those which are not. In Figure 6d the supply curve for a firm is that portion of the marginal cost curve lying above the average variable cost curve. The summation of marginal cost curves for individual firms gives the aggregate marginal cost curve for the relevant industry. If marginal cost equals average variable cost, then that portion of the marginal cost curve which equals the average variable cost curve becomes the supply curve.

Referring to Figures 6a and 6c, there are two stages in which the rational water producer would not operate: Stages I and III. Cost curves are graphed only for

Stages I and II. Costs for Stage III are not graphed because marginal cost, which equals the price of the variable input times the reciprocal of the marginal physical product, becomes undefined when marginal physical product is zero, at the start of Stage III.

Stage I would not be a rational area of production because the marginal cost curve lies below average variable cost meaning the addition to total cost of an additional variable input results in a more than proportional increase in quantity produced. Although total cost is rising, total product is increasing at a greater rate than total cost.

Stage II of the production and cost function is the region where the rational water supplier would operate: the slope of the total product curve is greater than zero, and marginal costs are equal to or greater than average variable costs.

When dealing with water suppliers, it is assumed that there are no external effects on marginal cost curves. Usually water supplied by one firm imposes no appreciable external pecuniary diseconomies on other firms supplying water. Assuming no pecuniary diseconomies then, the supply curve is that portion of the marginal cost curve equal to or lying above the average variable cost curve for both the single supplier and the entire water industry.

In order to appropriate water in Idaho, water rights are filed with the Department of Reclamation (30:253).

By filing for water rights, precedence of users is established so that priority of subsequent claims to water appropriation may be determined. It is the author's belief that prevention of external diseconomies is one justification for the filing of water rights.

Cost of Water Supply in Idaho

Irrigation

Water for irrigation is supplied from both ground and surface water sources. Approximately 14 percent of Idaho's total irrigational water originates from groundwater sources, and the remainder, 86 percent, from surface sources. Of the surface suppliers, the federal government, through the Bureau of Reclamation, is the principal supplier, accounting for 72 percent or 10.8 million acre feet of the total surface water supplied (27:240). The remainder of the irrigational water is supplied by private irrigation districts or individuals.

The early days of irrigation in Idaho were successful primarily through the efforts of homesteaders irrigating small tracts of land. To meet increasing demand for irrigation water, existing irrigation facilities were expanded and new projects initiated. For irrigation water suppliers to increase the quantity of water which could be used, financial aid from state and federal agencies was required. Consequently, while individual water suppliers are probably closer to surface water resources, meaning that less cost is involved in making water available for use, it is assumed that government assistance through large reclamation projects tended to mitigate this cost difference through economies of scale.

From the above, one may conclude that the lands adjacent to streams which were initially irrigated by private irrigation companies or individuals result in low capital cost required for capturing and transporting water from its source to where it could be used. The doctrine of appropriation, subscribed to by western states, stipulates that water rights are acquired by using the water (8:233). Consequently, in order for individuals with land further from surface sources than the early homesteaders to acquire water rights, storage facilities and canals were needed to capture and transport water from its source to where it could be used. In the absence of a private market for water, governmental assistance was required to meet these high investment requirements.

As opposed to the tremendous capital requirements involved for making surface water available for use, $72 million initial investment for the Boise Project alone (27:21), capital requirements for groundwater are quite small. Kimball found, in the areas of Idaho he studied, that the largest amount of money expended for making groundwater available for use, for a single farm, was $19,300

(13:24). However, the life expectancy for Bureau of Reclamation projects is 100 years (28:46), while the life expectancy for a well drilled for groundwater is 20 years (3:382). Thus the comparison of federally funded projects in Idaho versus smaller private projects is a case of heavy initial cost versus relatively heavy continuing costs.

It is important to keep in mind, though, that Bureau of Reclamation projects provide water to a larger area than do groundwater projects for individual farms. The Boise Project supplied water for 342,528 acres (27:240), or $210 per acre. Without converting figures to present value, the expenditures Kimball noted, over a hundred year span, total to $96,500, or a per acre cost of $329. Thus economies of scale appear again for large irrigation projects.

The initial investment for the Minidoka Project was approximately $37 million. Of this total, $25 million, or 68 percent, was associated with canals and other distribution outlays. Although groundwater suppliers do not incur this large capital expenditure for distribution facilities because wells are dug where water is available, groundwater is not available throughout the state.

Municipal

The total cost of public water systems in Idaho can be divided into two main elements: (1) costs incurred in transmitting water from its origin to a central distribution facility (facilities) and (2) costs incurred in distributing the water to users. The following features are also typical of most public water systems in Idaho: (1) source of water, normally groundwater; (2) pumps and storage areas associated with the collection of the water; (3) the distribution system; and (4) items incidental to transmission, collection, and distribution such as valves and meters used to measure and control the flow of water from its source to its place of use (8:176).

Most cities in Idaho have little cost incurred for transmission of water from its source to a central pumping facility since groundwater is a primary source. Consequently, most expenses are in the distribution system for the cities. Some cities in southern Idaho, or where the terrain is level enough, have all water distributed by gravity flow. In such cases, elevated structures are sufficient to maintain pressure and equal flows throughout the system. In other cities, where there is a marked elevation difference, pumping stations are required to maintain pressure and equal rates of flow.

Although water loss through seepage and evapotranspiration is not as excessive as in irrigation, municipalities are subject to similar problems. Water losses in municipal distribution systems, estimated to be approximately 12 percent of total water delivered (8:179), are often difficult to detect.

Water requirements for municipalities, like irrigation, are highly seasonal. Swimming pools, lawns, and air conditioners all need water during the summer months; and municipal water suppliers incur high marginal costs to meet these peak demands (8:180). In addition to factors creating cyclical demand for water, municipalities attempt to maintain on hand at all times a certain minimum amount of water for fire protection. Consequently, water production, treatment, and distribution systems are built to make larger quantities of water available for use than are normally used. Besides meeting domestic requirements, municipalities make available over 2 billion gallons of water for industrial use.

Self-Supplied Industrial Water

One of the primary differences between municipal and irrigation water suppliers compared to industrial water suppliers is that water provided for industrial use is normally recycled several times before being discharged. However, the largest industrial water user in Idaho, fresh and frozen fish production, does not recycle water. Although recycling of water for fish production is physically possible, present cost constraints preclude this possibility (10:80). For the entire state, the estimated re-use factor for water is 3.0, somewhat less than the re-use factor of 3.43 for other mountain area states (10:78).

A feature common to all three categories of water suppliers is the seasonal variation in water withdrawals. For example, in Idaho's dehydrated food products industry, water withdrawals were eight times greater in April than in July (31:88).

Groundwater is the primary source of water quantities for both industrial and municipal water suppliers (76 and 87 percent of total water supplied, respectively (16)). Consequently, costs incurred by industrial water suppliers were expected to be similar to those encountered by municipalities. Any additional costs could be expected in meeting more stringent water quality standards required for some industries. The last expectation is not unrealistic in that for "many industrial users, the quality of water . . . is of utmost importance" (6:22). For some industries, federally established standards for drinking water are not strict enough for commercial purposes. For example, in the canning industry, water quality standards must meet federal drinking water standards, yet have less iron and manganese than the federal standards require (8:24).

Summary

A supply of water is the amount of water made available for use at different costs. A production function shows the relationship of the physical inputs required to make specific quantities of water available for use. By attaching prices to the physical inputs, a cost function, showing the cost incurred to make specific quantities of water available for use, is derived. By taking the first partial derivative of total cost with respect to quantity produced, marginal cost is derived. The marginal cost curve which is equal to or lying above the average variable cost curve is the supply curve for a firm. An industry's supply curve is the summation of all relevant firms' supply functions.

Certain cost problems encountered in the process of making water available for use are common to all three categories of water suppliers. Each type of supplier, however, has certain cost problems distinct to it: the huge initial capital requirement for some irrigational supplies, the many facets of water distribution faced by municipalities such as fire protection and supplying water to industries, and self-supplied industries sometimes needing specific water quality standards and recycling of water.

CHAPTER 5

COLLECTION AND INTERPRETATION OF STUDY DATA

This chapter will detail the methodology involved in the collection and organization of the study data, the statistical methods applied to the data, and an analysis of the data.

Data Collection

Irrigation

It was originally planned to contact all 58 irrigation districts registered with the State Reclamation Engineer. During the initial testing of the questionnaire it was learned that many of these districts were quite small and had limited facilities and records available. As a result, information was collected from 37 of the irrigation districts listed in Appendix A.

Three sources of information were used: interviews, financial statements published in newspapers, and information published by the Bureau of Reclamation. Although only 55 percent of the originally designed population was contacted, these suppliers accounted for 76 percent of the total water supplied in Idaho for irrigation.

Operation and maintenance cost records maintained by the irrigation districts contacted were all excellent. The primary guide used for determining variable costs which were unique to irrigation districts was Brockway and Reese (1).

The cost of plant, property, and equipment (fixed costs) for the districts was based on original expenditures for the items, not on replacement costs. Needless to say, replacement costs at current prices would be considerably higher. In addition to the cost of plant, property, and equipment, repayment contracts in dams or reservoirs and storage in the facilities were included as fixed costs. Information from eight irrigation districts contacted as to fixed cost were not as complete as information on variable cost. As a result, fixed cost for eight districts under the Boise Project Board of Control were determined by multiplying the total cost of the project by the percentage of water distributed to the districts to obtain an approximation of total fixed costs for the districts. Certain items such as vehicles and office space were not included for these districts because of insufficient information. As a result, the total fixed costs of these districts is probably biased somewhat downward.

Municipalities

Of the thirty municipalities originally intended to form the data base for cost of supplying water for municipalities, 27 provided sufficient information. Records for some of the smaller communities were inadequate for several reasons:

1. Records for 1970 were not available or were incomplete.
2. There were no funds allocated specifically for water system maintenance; a single maintenance fund might include funds for street repair, cemetery care, park maintenance, etc.
3. City personnel did not feel the project was sufficiently important to participate in it.

However, six cities under 1000 population did provide sufficient information which could be used for the study. The data collected from 27 municipalities accounted for 70 percent of the water supplied by municipalities in Idaho. City engineers in 13 municipalities were personally interviewed; information from the remaining 24 was furnished by a combination of responses to questionnaires and budget information published in newspapers.

As was the case with irrigation districts, records for operation and maintenance were excellent. However, information concerning fixed costs was almost non-existent. Consequently, to arrive at fixed cost information, the cities were asked to list physical amounts of items: amounts of pipe in place for water distribution, number of wells, number of treatment plants, etc. The physical quantities of these items were then multiplied by 1970 replacement costs taken from Engineering News-Record (26) to arrive at estimated total investment costs. These costs, as opposed to irrigation districts, were replacement costs, not original installation costs. Like irrigation districts, though, the figures are probably biased somewhat downward because office space, vehicles, etc., were not included in fixed costs.

Industries

A certain amount of difficulty was encountered in data collection from industries supplying their own water. The primary problems were lack of information as to which industries had their own water supply and unwillingness to participate in the study. Of the 22 industries contacted, 8 companies chose not to participate and 4 companies purchased their water from cities. The remaining 10 provided sufficient information to account for 35 percent of the total water produced by self-supplied industries in Idaho. Not included in the study was the fresh and frozen fish industry. Although accounting for a very large portion of the 504,450 acre feet of water supplied by industries, 48 percent, costs for the water are extremely small. Because the fresh and frozen fish industry uses natural flows as the source of water, capital outlay amounted to only one dollar per 3000 acre feet of water used; and for this amount, no operating and maintenance costs were incurred (31:87). The limited number of observations precluded attempting statistical regression analysis on the data.

Data Organization

The organization of the collected data was quite straightforward. Gallons were converted into acre feet at the rate of 325,851 gallons equalling one acre foot. Water quantities, measured in acre feet, were considered as output. Total cost information was separated into fixed and variable costs and was analyzed for each of the categories studied. The three categories of water suppliers studied, municipalities, irrigation suppliers, and industries, appeared to be a satisfactory categorization based on similar quantities of output. This separation was maintained throughout data analysis except when the data from the categories was aggregated to examine the total supply and cost functions for the state.

Statistical Analysis

When all the data involved in the study was collected and organized, it was processed at the computer center at the University of Idaho using the simple linear regression program of the Statistical Analysis System (21).

R. D. D. Steel and J. H. Torrie, in Principles and Procedures of Statistics, list the properties of linear regression as:

> 1. The point $(\overline{x},\overline{y})$ is on the sample regression line.
> 2. The sum of the deviations from regression is zero.
> 3. The sum of the squares of the deviations is a minimum. (23:166)

Results of Regression Analysis

There were nine regression models which were applied to the municipal, irrigation, and aggregate models as was appropriate. The nine models were:

$$Y_1 = A + BX \qquad Y_2 = A + BX$$

$$Y_1 = A + BX + CX^2 \qquad Y_2 = A + BX + VX^2$$

$$Y_1 = AX^B \qquad Y_2 = AX^B$$

$$Y_3 = A + BX$$

$$Y_3 = A + BX + CX^2$$

$$Y_3 = AX^B$$

where Y_1 is total cost, Y_2 is total fixed cost, and Y_3 is total variable cost. X is output measured in acre feet.

Municipalities

Regression analysis was applied to data obtained from 27 municipalities. The results of the analysis are below.

Total Cost. The model $Y_1 = A + BX$ was applied to the 27 observations of this category. An R^2 of 0.68 was obtained; the t value for the B coefficient was highly significant. However, the t value for the A was insignificant, -0.05. The regression lines and observed data are graphed in Figure 7.

The quadratic model, $Y_1 = A + BX + CX^2$ yielded a negligible improvement in the R^2, 0.68. Neither the intercept nor the C coefficient were significant but the B coefficient was. Setting the first derivative of the regression model $Y_1 = -112{,}587.43 + 525.5X - 0.005X^2$ equal to zero and solving for X, the inflection point of 52,550 acre feet, far beyond the range of data, is derived. The second derivative is minus: $d^2y/dx^2 = -0.01$. Consequently because $f'(X) > 0$ and $f''(X) < 0$, the slope of the total cost curve is positive but decreasing--the value of the function is increasing but at a decreasing rate. Theoretically, with a total cost function, both the first and second derivatives of the function should be positive, indicating the slope is positive and increasing--the value of the total cost function increasing at an increasing rate. The observed data and regression lines are plotted in Figure 7.

A logarithmic transformation improved the R^2 to 0.76. However, as can be noted in Figure 7, the exponential function does not describe the data as well, particularly the extreme values. The improved R^2 may be due to the logarithmic function originating at the origin of the axes where much of the data lie. The linear model, $Y_1 = A + BX$, was accepted as the best estimate because of the high linearity of the data, particularly the extreme values. Figure 8 shows the total

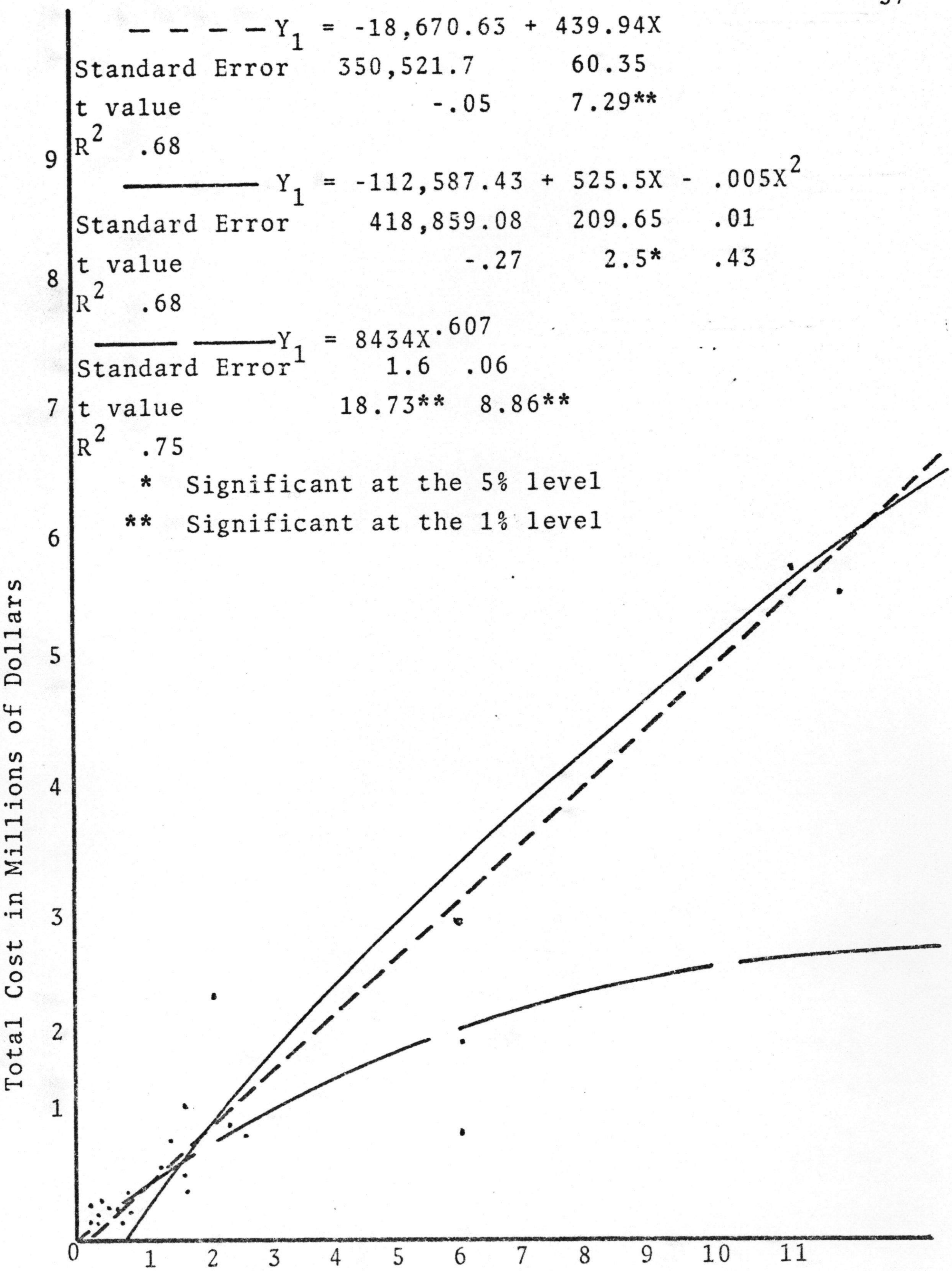


Figure 7: Total Cost Regression Analysis for Cities: Idaho, 1970

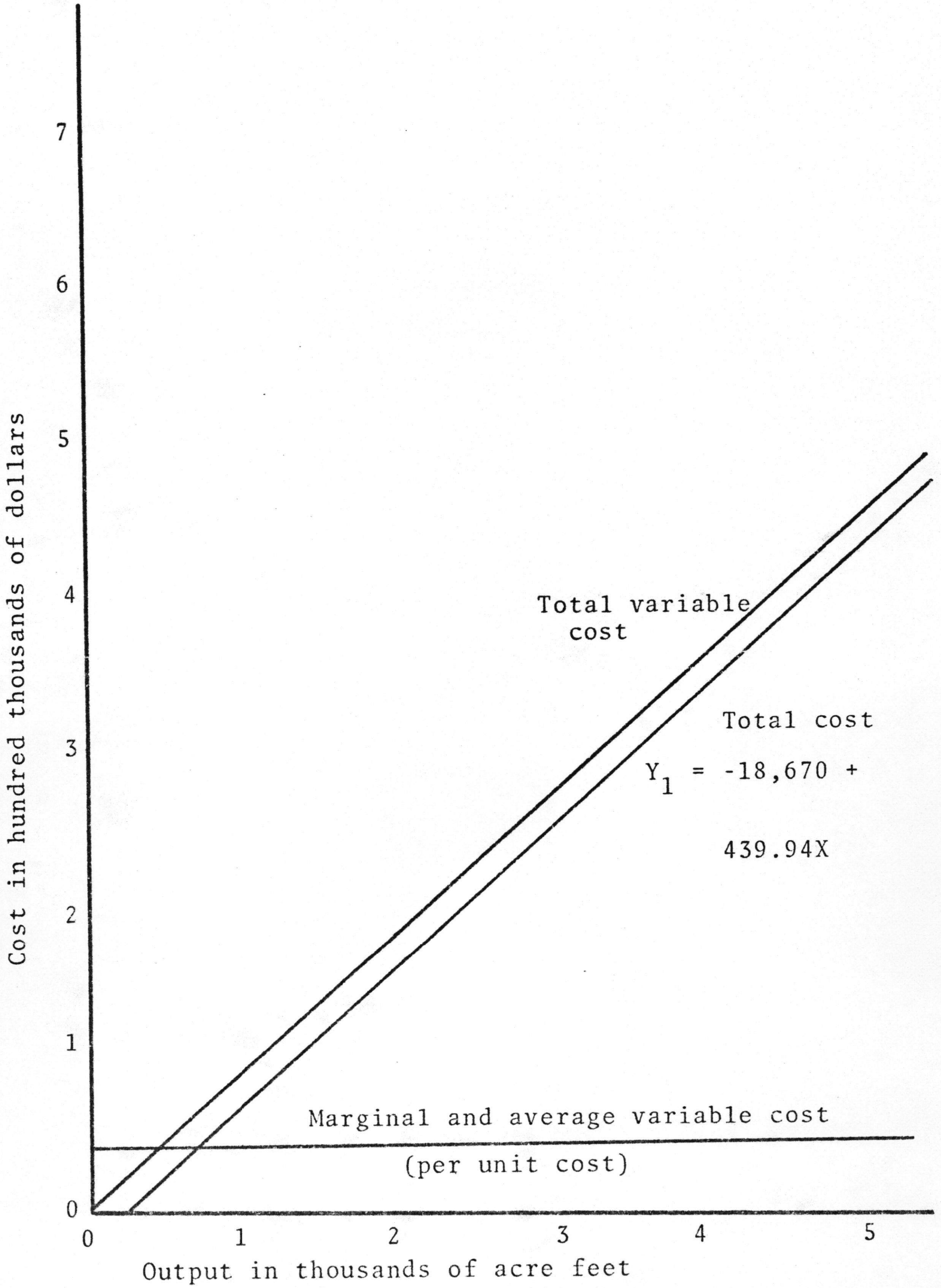
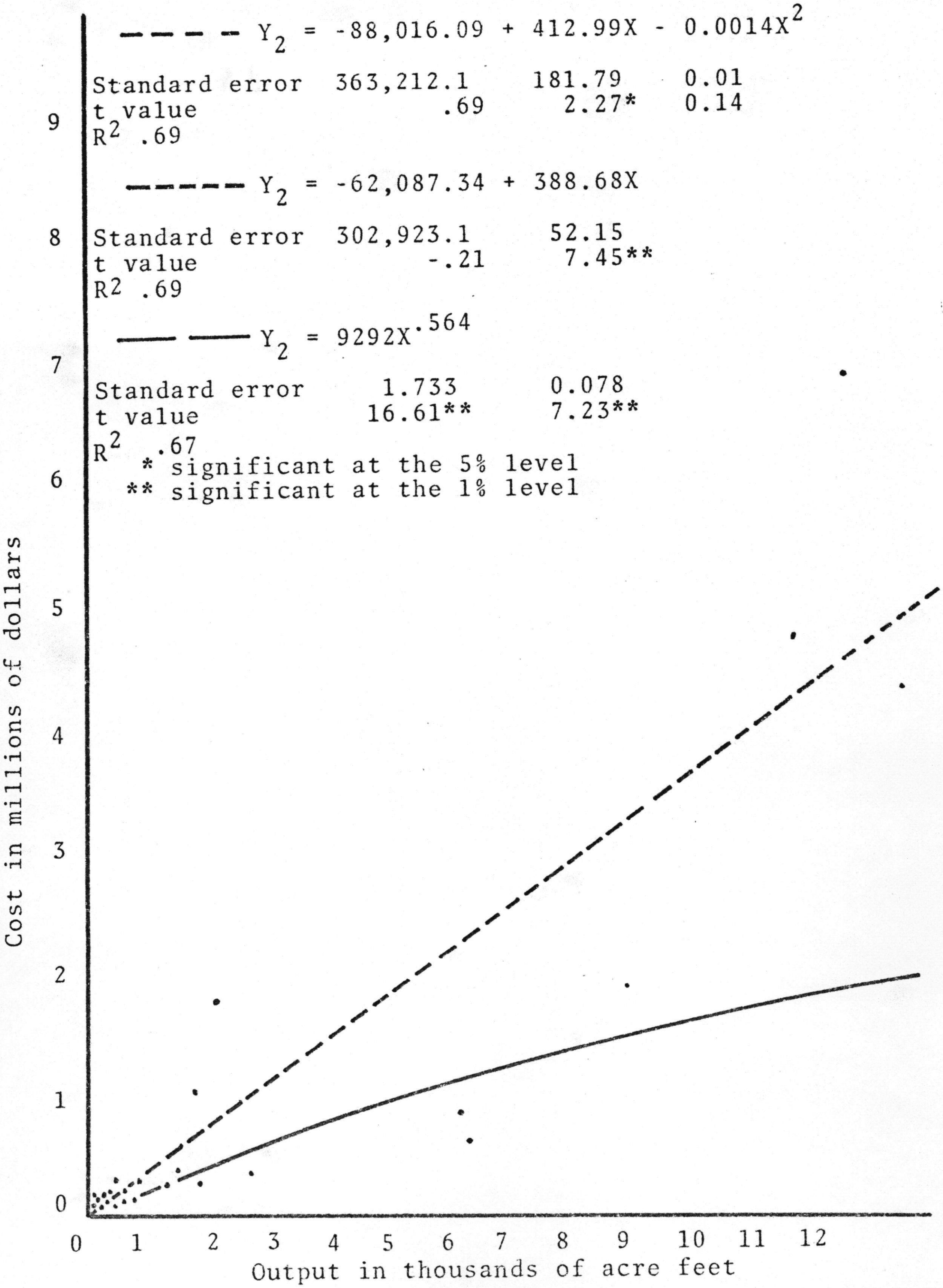


Figure 8. Total cost and per unit cost curves for cities in Idaho, 1970

fixed, total variable, average variable, and marginal cost curves based on the model $Y_1 = A + BX$. Because a linear model was accepted as the best estimate of total cost for cities, marginal cost is equal to average variable cost. The data and model indicate the average variable cost curve, the marginal cost curve, and supply curve are all constant.

Total Fixed Cost. Because fixed costs were not significantly related to output using the total cost model (note the negative A value for $Y_1 = A + BX$), further study was made. Three models were used for analyzing municipal fixed cost: $Y_2 = A + BX$, $Y_2 = A + BX + CX^2$, and $Y = AX^B$. Figure 9 contains the observed data and regression lines for the models. Note that the linear and quadratic functions are co-located on the graph. Although a larger graph would show a small difference between these functions, the high degree of linearity is apparent. Due to similar R^2s and the linearity of the functions, the linear function $Y_2 = -62{,}087 + 388X$ was accepted as the best estimate of fixed cost for cities. From this model, approximate capital requirements for making various quantities of water available for use can be estimated.

Total Variable Cost. The linear model, $Y_3 = A + BX$, had an R^2 of 0.50. The t value of B was significant, but the t value for A was not. The quadratic model improved



$Y_2 = -88{,}016.09 + 412.99X - 0.0014X^2$

Standard error 363,212.1 181.79 0.01
t value .69 2.27* 0.14
R^2 .69

$Y_2 = -62{,}087.34 + 388.68X$

Standard error 302,923.1 52.15
t value -.21 7.45**
R^2 .69

$Y_2 = 9292X^{.564}$

Standard error 1.733 0.078
t value 16.61** 7.23**
R^2 .67

* significant at the 5% level
** significant at the 1% level

Figure 9. Total fixed cost regression analysis for cities in Idaho, 1970.

the R^2 to 0.56; however, the logarithmic transformation increased the R^2 to 0.77 with the A and B coefficients highly significant. The model $Y = AX^B$ was accepted as the best estimate of total variable costs for cities because of the improved R^2 and the high significance of both A and B. The data and regression lines are in Figure 10.

Irrigation

Regression analysis was applied to the data obtained from 37 irrigation districts. The results of the analysis are below.

Total Cost. The first two regression models for irrigation total cost had rather high R^2s. The linear model, $Y_1 = 2,618,211 + 6.31$, had an R^2 of 0.75 with the A and B coefficients highly significant. The quadratic, $Y_1 = 1,625,528 + 11.96 = 0.000001X^2$, had an R^2 of 0.81 with the A, B, and C coefficients all highly significant. A logarithmic transformation resulted in the lowest R^2, 0.73, with both A and B coefficients highly significant. The quadratic model was accepted as the best estimate of total cost for irrigation districts because of the best R^2. The data and regression lines are in Figure 11.

Similar to the quadratic cost functions for the cities, the first derivative is positive for the quadratic cost function for irrigation, the second negative, indicating the slope of the total cost function is positive but

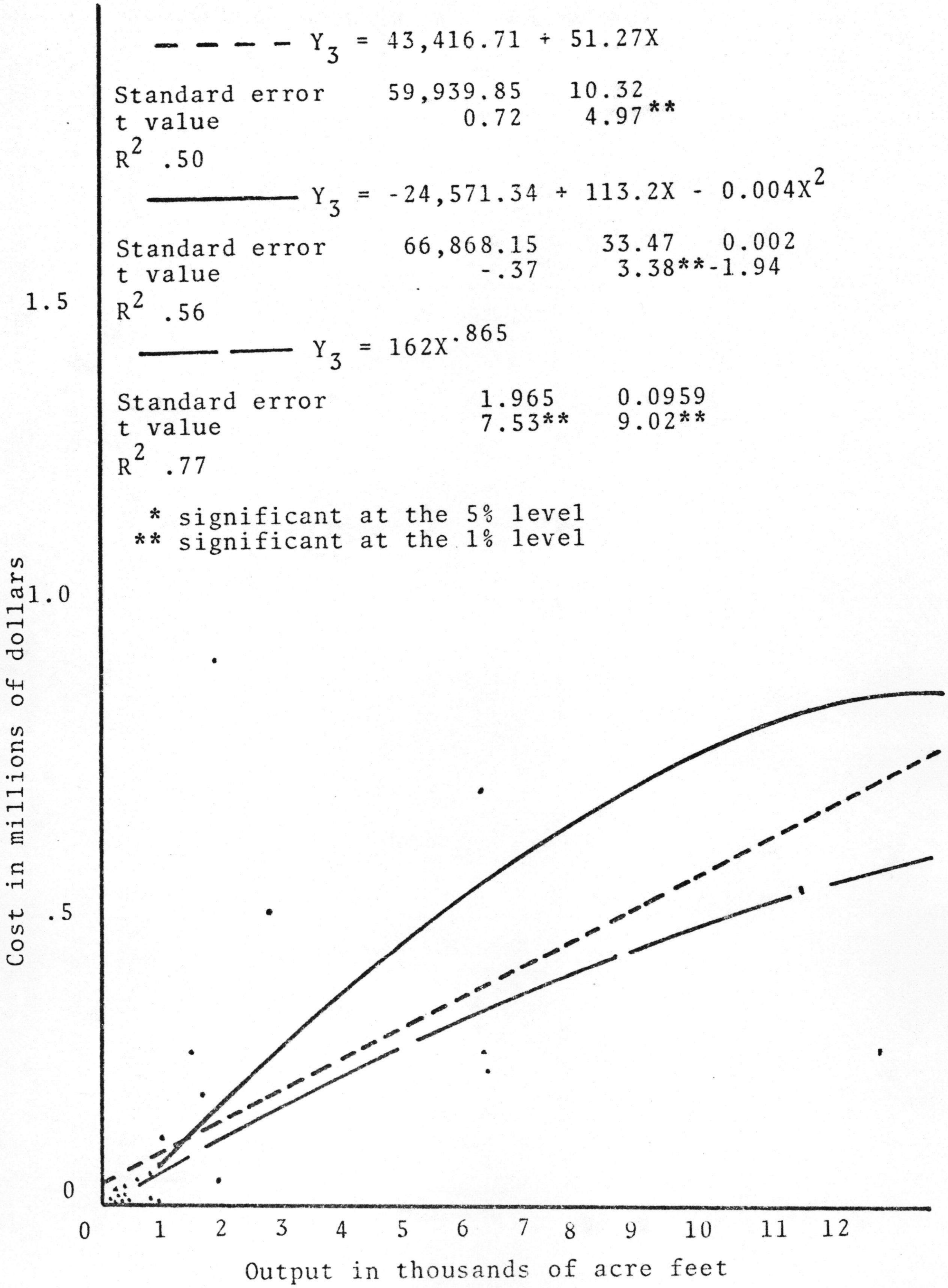


Figure 10. Total variable cost regression analysis for cities in Idaho, 1970

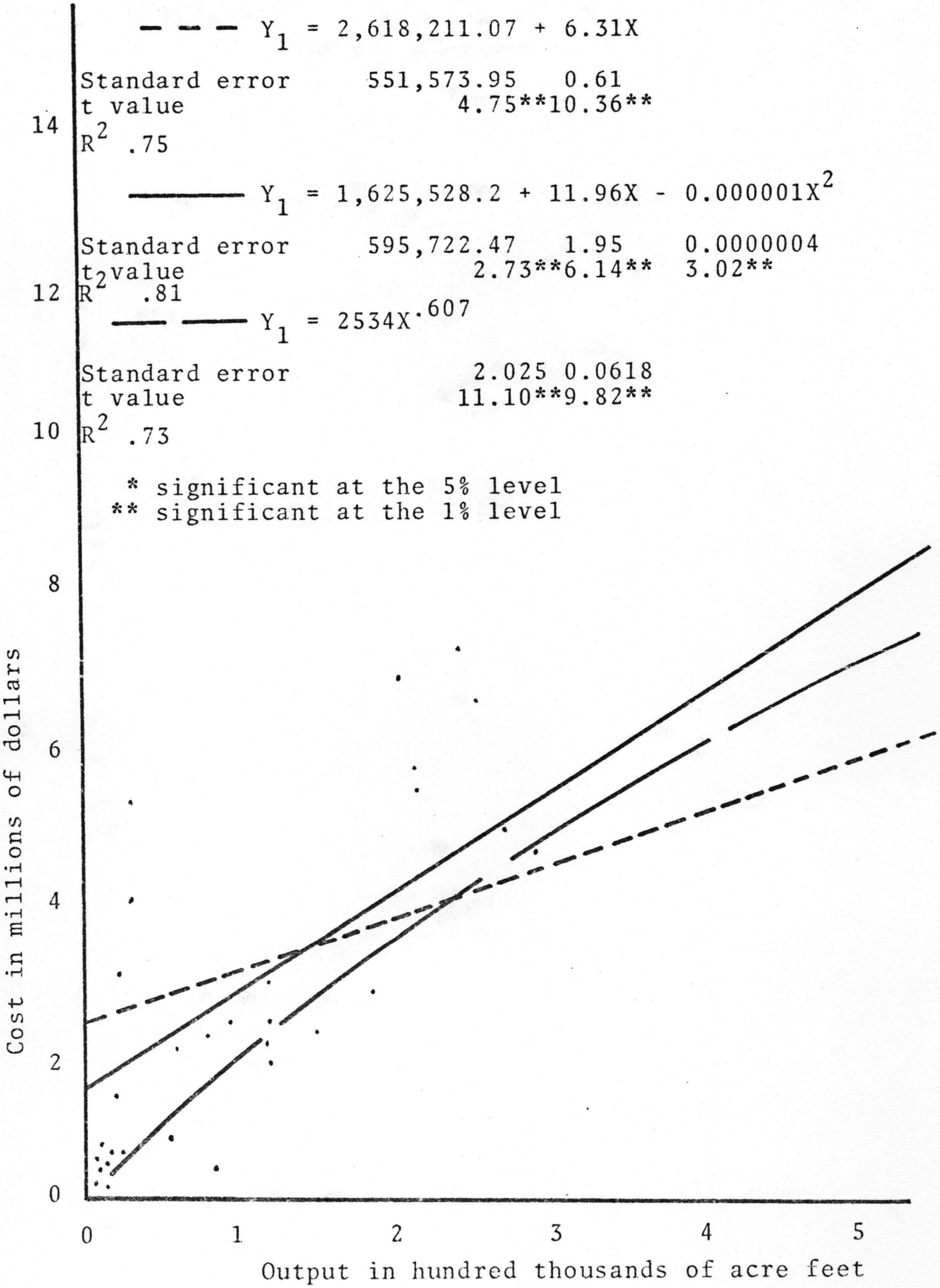


Figure 11. Total cost regression analysis for irrigation in Idaho, 1970

decreasing. With an inflection point of 4,983,333 acre feet, the function is highly linear throughout the observed data. Once again, the marginal cost curve lies below the average variable cost curve. Figure 12 contains the cost curves for the irrigation total cost quadratic.

Total Fixed Cost. Of the three regression models used for total fixed cost for irrigation districts, the quadratic model, $Y_2 = 1,545,448.67 + 11.48X - 0.000001X^2$, yielded the highest R^2, 0.81. The A coefficient was significant; the B and C coefficients were highly significant. The second highest R^2, 0.76, was in the linear model, $Y_2 = 2,487,165.96 + 6.13X$. Both A and B coefficients were highly significant. An R^2 of 0.73 resulted from the logarithmic transformation. The quadratic model was selected as giving the best estimates of total fixed cost for irrigation water suppliers. The regression lines and observed data for total fixed cost for irrigation suppliers are in Figure 13.

Total Variable Cost. The linear regression estimate of total variable cost for irrigation was $Y_3 = 131,045.11 + 0.19X$ with both A and B coefficients highly significant. The quadratic model, $Y_3 = 80,079.54X + 0.48X - 0.00000006X^2$, with all three coefficients highly significant, improved the R^2 to 0.68. The best estimate of total variable cost for irrigation was in the logarithmic transformation. In the

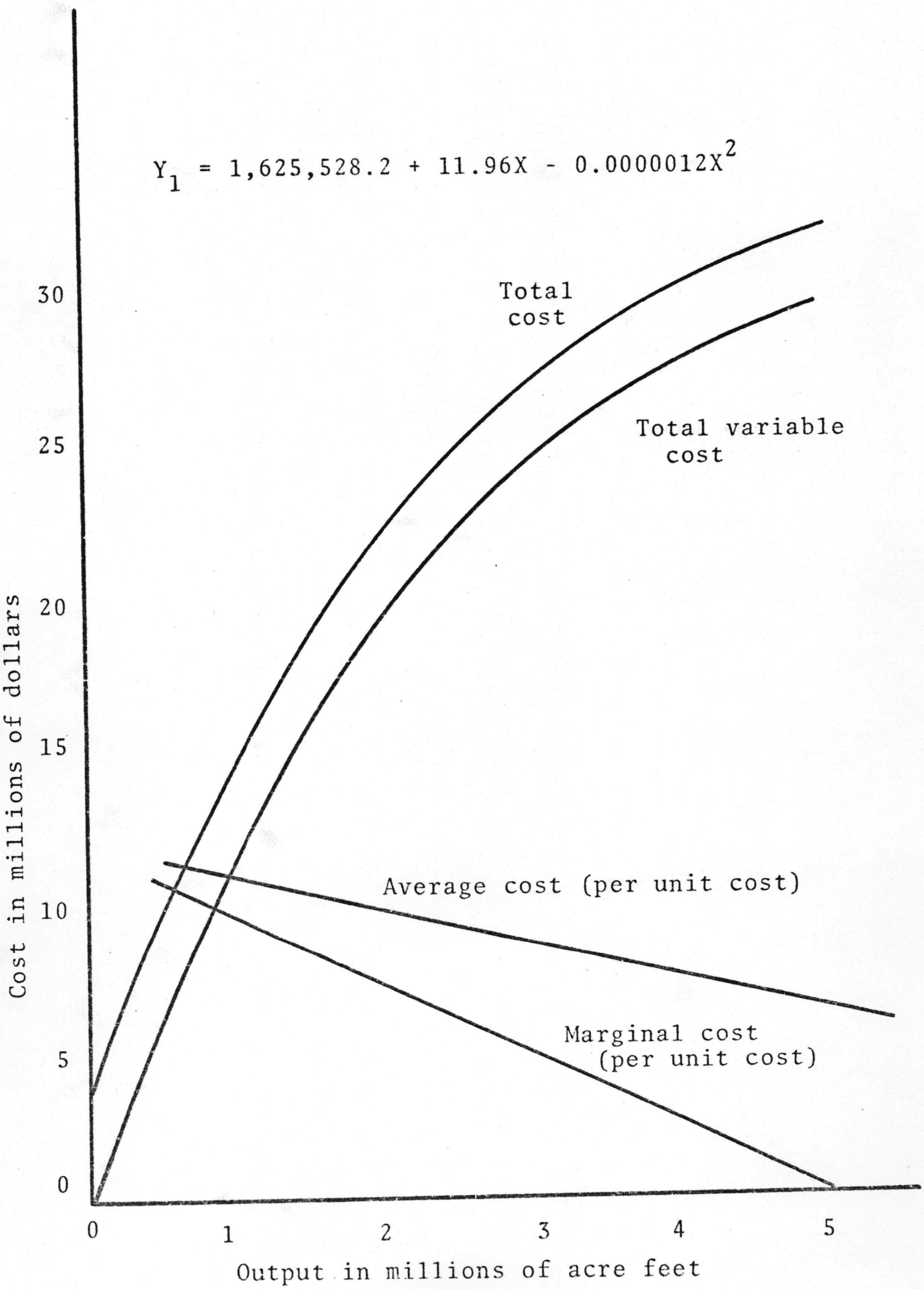


Figure 12. Total cost and per unit cost curves for irrigation water in Idaho, 1970

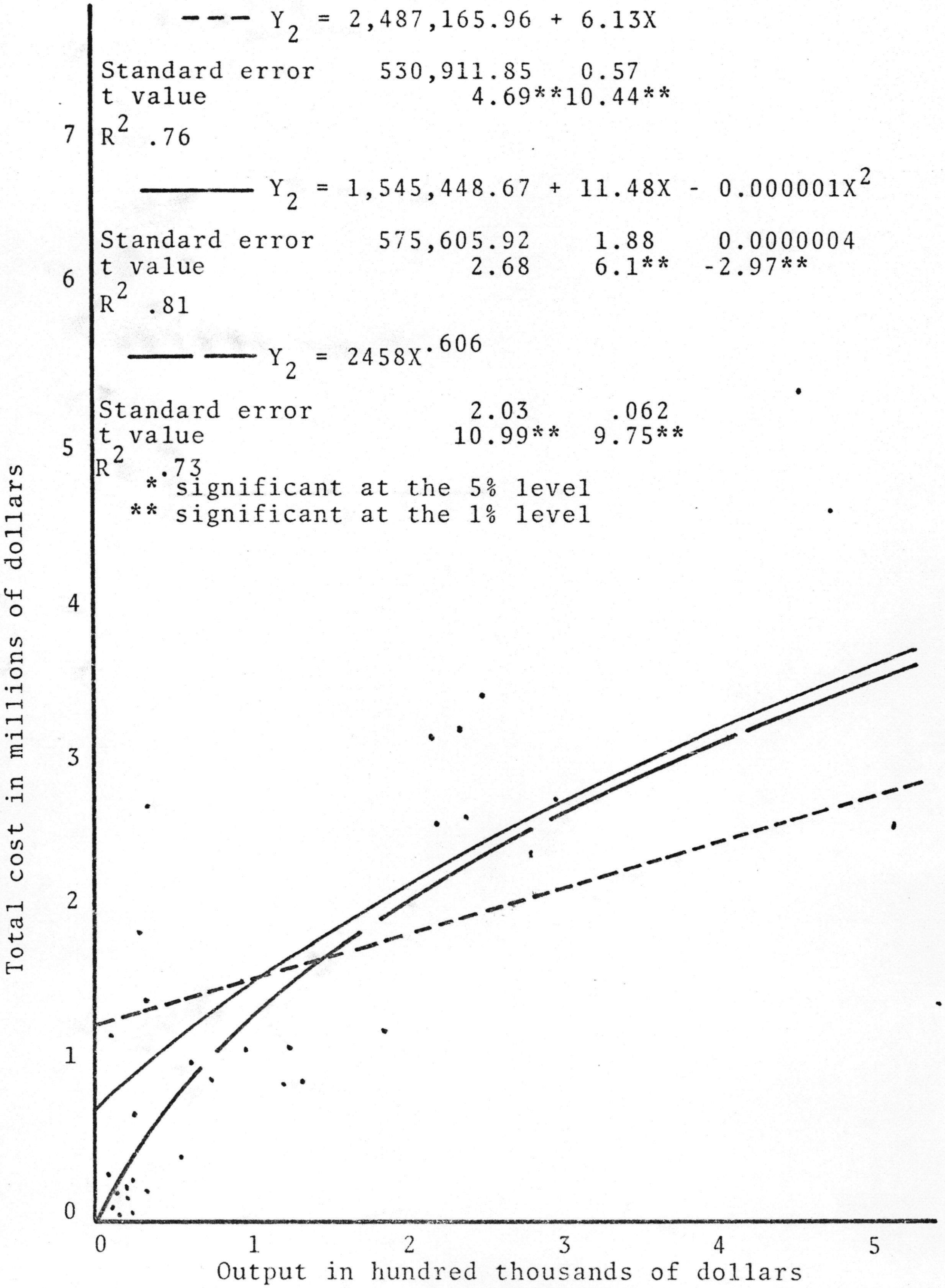


Figure 13. Total fixed cost regression analysis, irrigation water in Idaho, 1970

model, $Y_3 = AX^B$, the R^2 was improved to 0.74 and A and B were highly significant. This model was chosen as giving the best estimate of total variable cost for irrigation. The observed data and regression lines are shown in Figure 14.

Combined Results

The data for irrigation and municipal water suppliers was aggregated in order to gain a total concept of Idaho's water industry.

Total Cost. The linear regression model of total cost for Idaho's water industry resulted in the estimate, $Y_1 = 2{,}025{,}135.09 + 6.57X$, an R^2 of 0.69, and the A and B coefficients highly significant. A logarithmic transformation improved the R^2 to 0.73 with both coefficients highly significant. The quadratic model, $Y_1 = 1{,}445{,}062.34 + 12.41X - 0.000001X^2$, was accepted as the best estimate of total cost because of the highest R^2, 0.74. All of the coefficients for the quadratic model were highly significant. The inflection point was 6.2 million acre feet, far in excess of the range of observed data. Figure 15 depicts the regression lines and observed data. Figure 16 shows the total cost and average variable and marginal cost curves. Because of average variable cost exceeding marginal cost, the cost function is in Stage I.

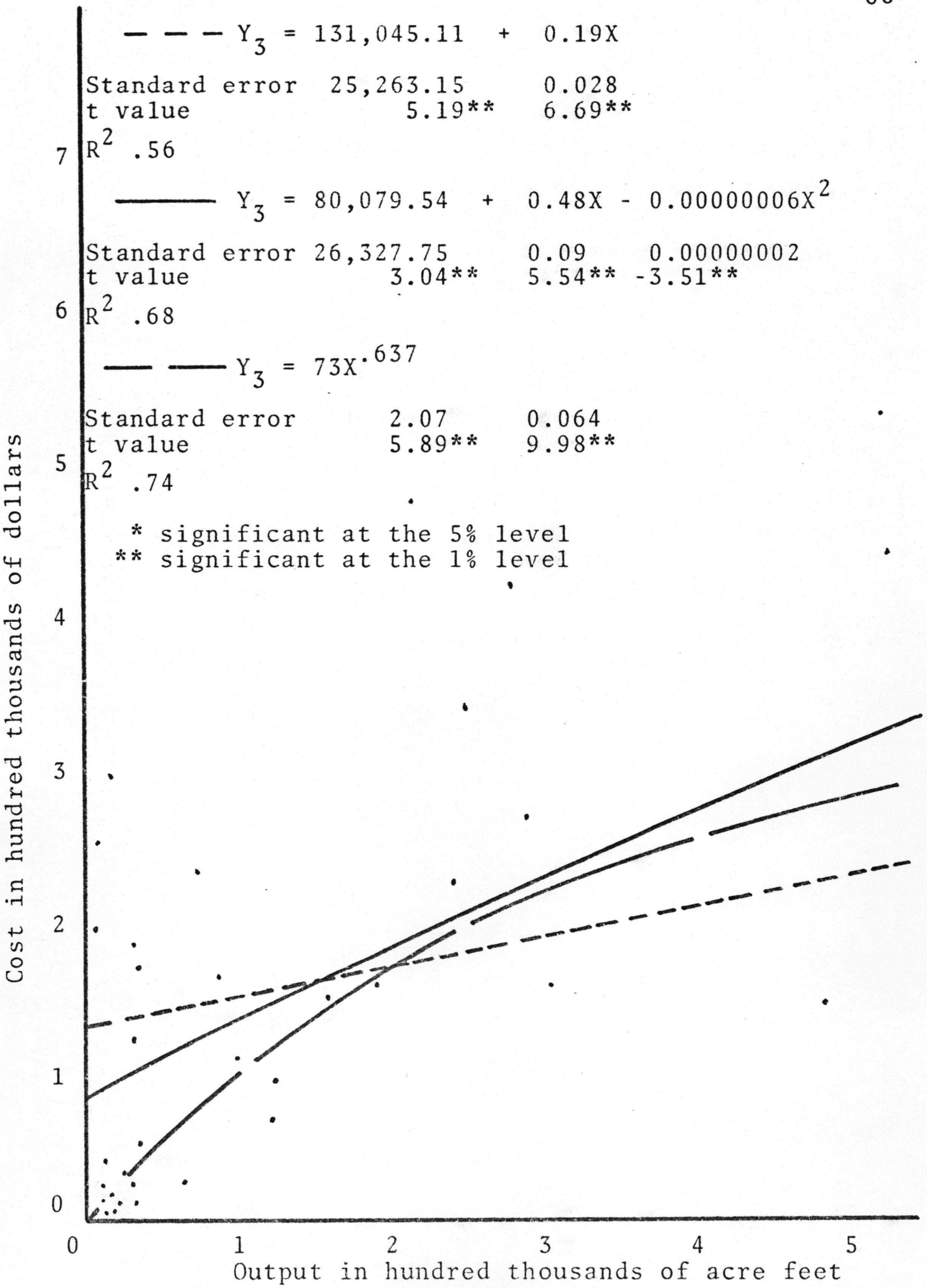


Figure 14. Total variable cost regression analysis for irrigation in Idaho, 1970

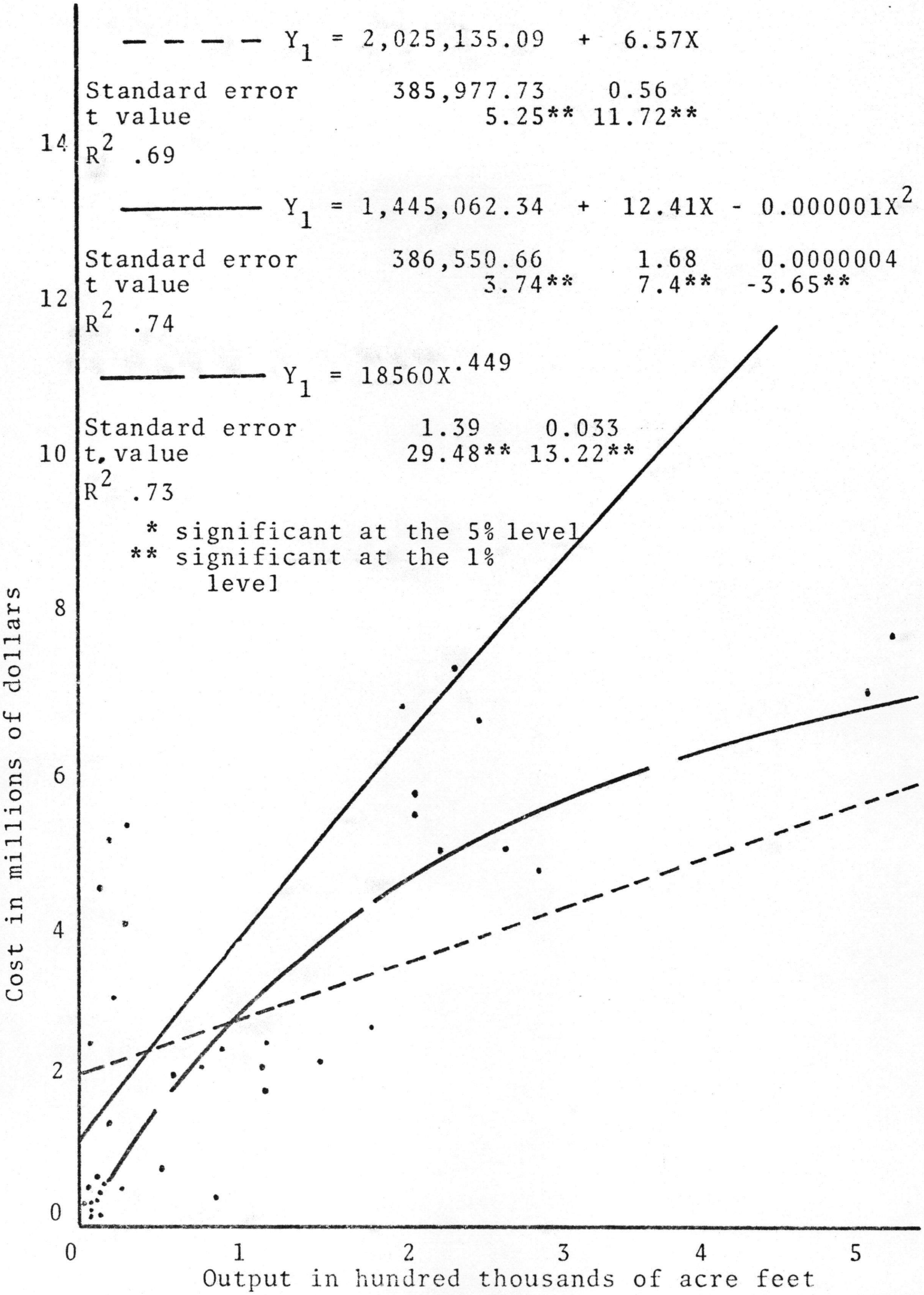


Figure 15. Total cost regression analysis, water in Idaho, 1970

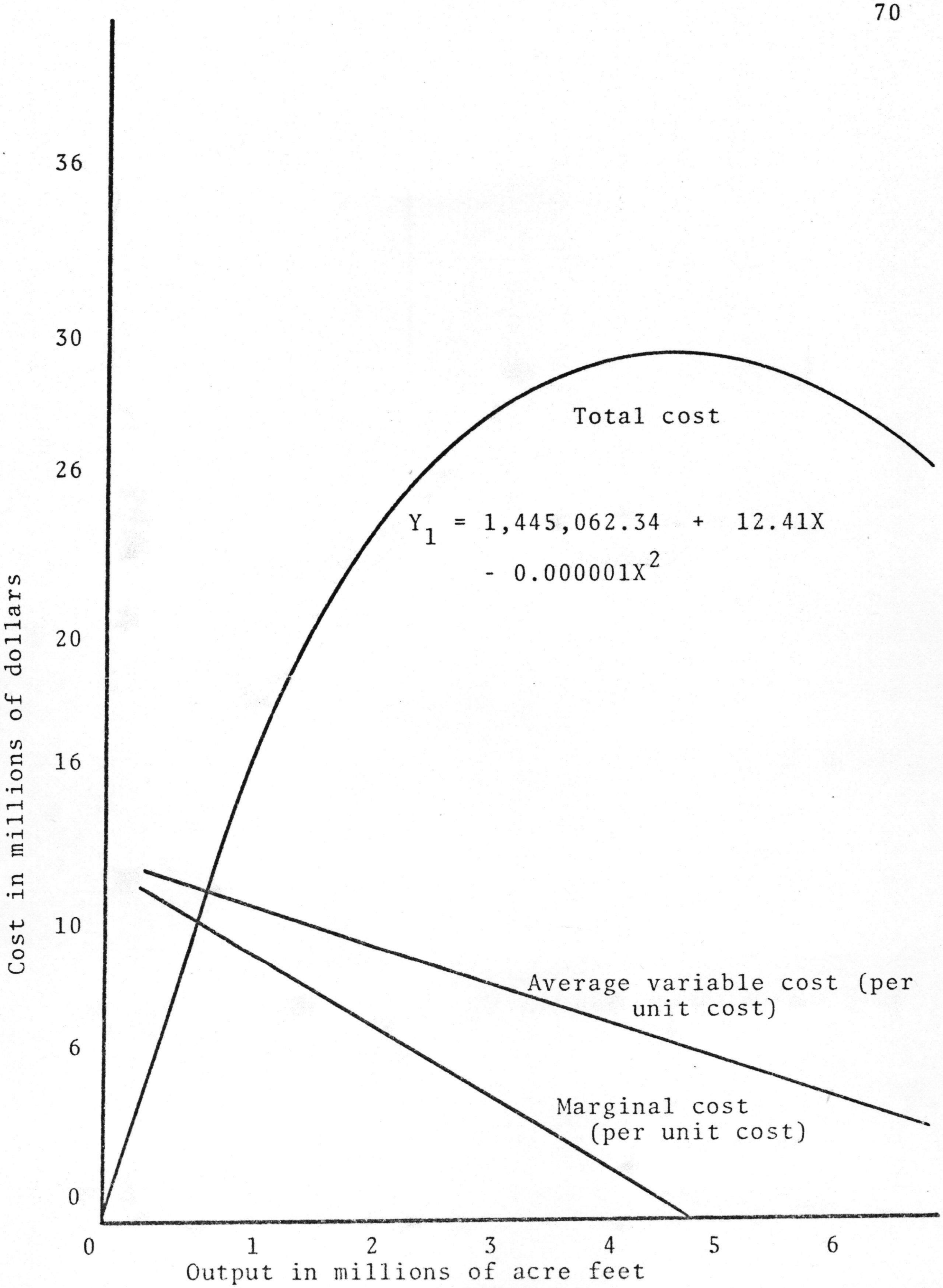


Figure 16. Total cost and per unit cost curves, water in Idaho, 1970

Total Fixed Cost. The curvilinear model, $Y_2 = A + BX + CX^2$, yielded the highest R^2, 0.76, with all three coefficients highly significant and was considered the best estimate of total fixed cost for Idaho's water industry. The lowest R^2, 0.70, resulted from the linear model, $Y_2 = 1{,}861{,}050.48 + 6.4X$. A logarithmic transformation produced an R^2 of 0.75 for the estimate $Y_2 = 14{,}691X^{.4623}$. The coefficients for the linear and logarithmic models were all highly significant. Regression lines and observed data are shown in Figure 17.

Total Variable Cost. Both the linear and quadratic models had low R^2s for total variable cost estimates. The linear model had an R^2 of 0.17 and the quadratic model an R^2 of 0.18. The logarithmic transformation improved the R^2 to 0.43 with both A and B coefficients highly significant. Although 0.43 is a rather low R^2, it was considered to be the best estimate of variable cost for the Idaho water industry. Figure 18 contains the regression lines and observed data for total variable cost.

Summary

Following collection of data from 27 municipalities and 37 irrigation districts in Idaho, the data was processed using least squares regression analysis. Information from industries was not included because of lack of data. The results of the analysis indicated the municipal and

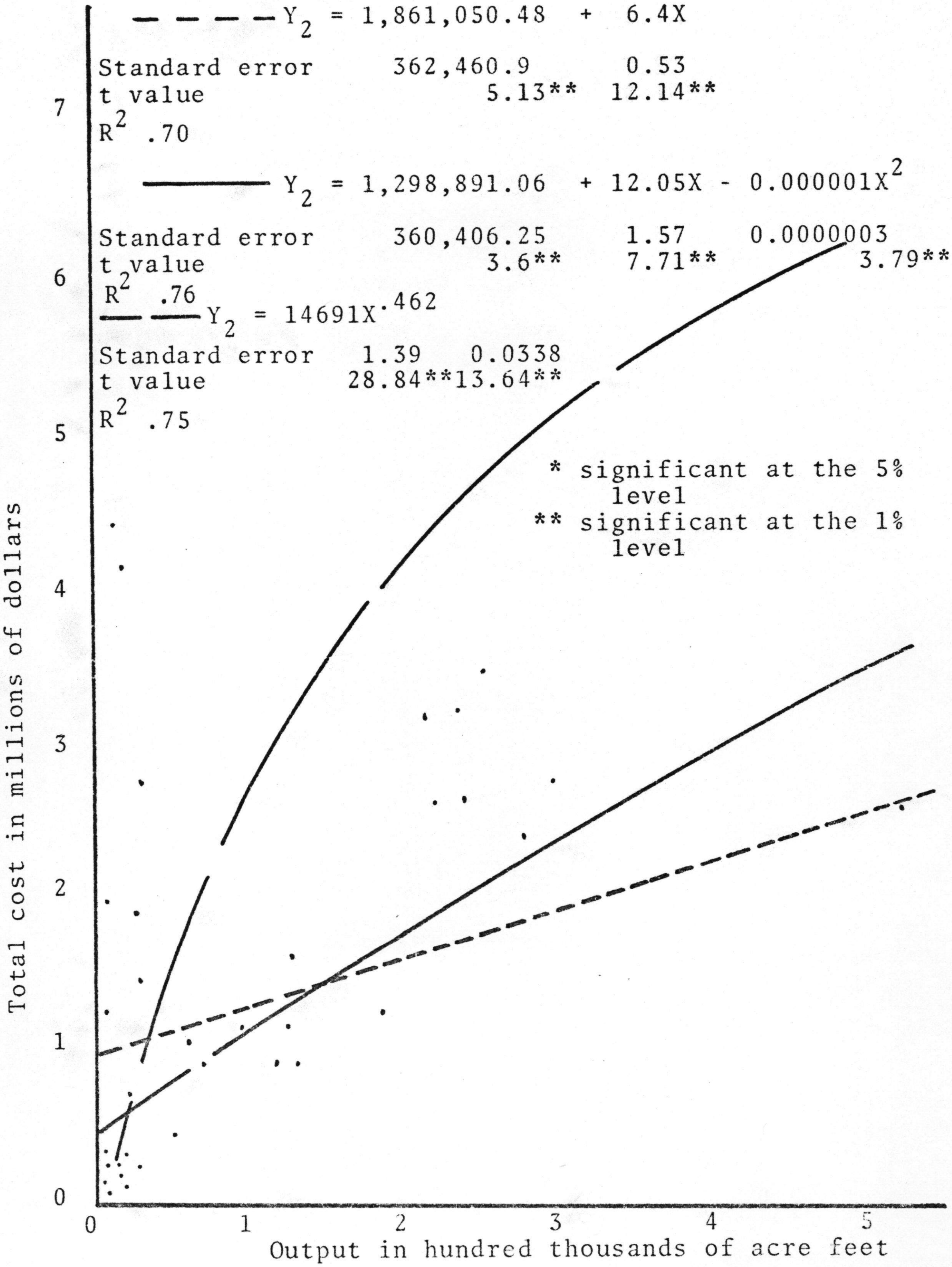
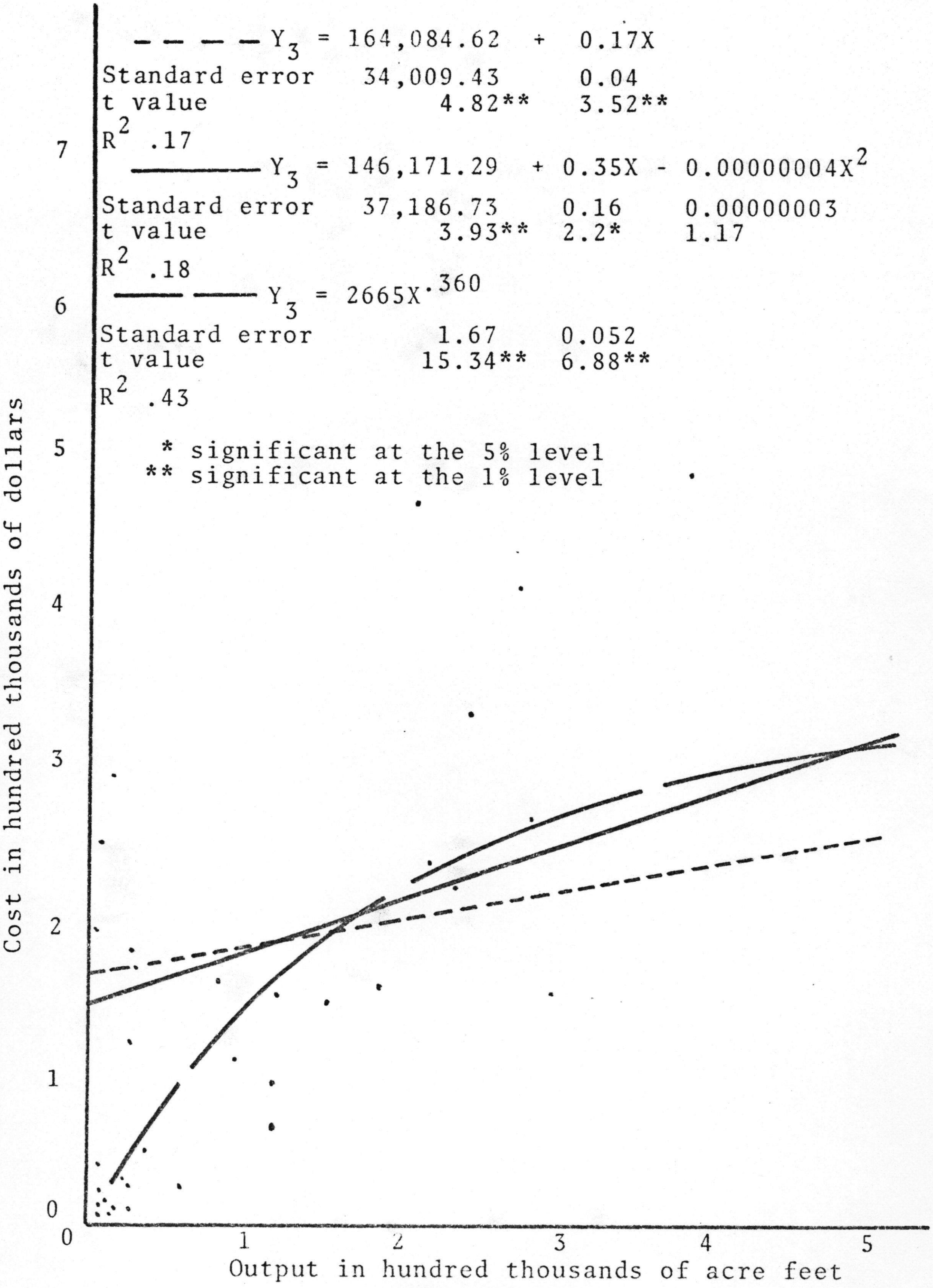


Figure 17. Total fixed cost regression analysis, water in Idaho, 1970



– – – – Y_3 =	164,084.62	+ 0.17X	
Standard error	34,009.43	0.04	
t value	4.82**	3.52**	
R^2 .17			
——— Y_3 =	146,171.29	+ 0.35X	- 0.00000004X^2
Standard error	37,186.73	0.16	0.00000003
t value	3.93**	2.2*	1.17
R^2 .18			
—— —— Y_3 =	$2665X^{.360}$		
Standard error	1.67	0.052	
t value	15.34**	6.88**	
R^2 .43			

* significant at the 5% level
** significant at the 1% level

Figure 18. Total variable cost regression analysis, water in Idaho, 1970

irrigation water suppliers, when considered separately and when considered in the aggregate, are subject to economies of scale which result in decreasing costs and are indicative of industries which are operating in Stage I of the production and cost functions.

Through regression analysis, cost estimates for making various quantities of water available for use were derived. For example, with the estimate $Y_2 = 1,545,448.67 + 11.48X - 0.000001X^2$, the total fixed cost estimate for irrigation, in order to make 500,000 acre feet of water available for use, one merely substitutes 500,000 for X in the estimate. This results in the total fixed cost estimate of $7,035,448 required to make 500,000 acre feet of water available for irrigation use.

CHAPTER 6

CONCLUSIONS

This chapter will present the results of the study in terms of the originally stated objectives and offer an economic interpretation of the results.

Objective One

The initial objective was to summarize the stock and flow resources of the state. Chapter 2 dealt with this objective rather extensively. The findings are: Idaho has approximately 185,640,000 acre feet of water resources. Each year this quantity is renewed by approximately 38 million acre feet of water from precipitation. In 1970, water suppliers made available for use over 17 million acre feet of water. This amount constituted only 8 percent of Idaho's total water resources. Of the remaining 92 percent of water resources, 72 million acre feet or approximately one-third of the total water resources, exited the state in rivers. The remaining two-thirds were either lost through evaporation or entry into aquifers.

Despite this obvious abundance of water resources in Idaho, some areas of the state, specifically the Upper Snake River Basin between King Hill and American Falls, are apparently in need of supplemental water. This demonstrates a paradox in Idaho: where the potential for water use is greatest, there are limited quantities of water available for use and where the greatest quantities of water are, the smallest potential for use exists. This leads to the conclusion that while Idaho has a sufficient quantity of water to meet current and predicted needs, water resources are not always present at the proper place at the proper time in sufficient quantities throughout the state. To attempt to insure that water is available for use requires costs be incurred. This leads to the second objective of the study.

Objective Two

Chapter 5 detailed the results of various regression estimates of cost functions for supplying water in Idaho. One common theme existed throughout the results: the Idaho water industry is currently subject to economies of scale. This was indicated by the negative second partial derivatives in all the quadratic cost functions. All inflection points, except for variable cost for cities, were beyond the range of observed data. Consequently, the conclusions drawn are somewhat speculative. However, through the range of observed data, average variable costs and marginal costs were decreasing which is indicative of an industry subject to economies of scale--one still in Stage I of production. This allows one to view the cost curves empirically derived as being those segments of the total cost and average variable and marginal cost curves shown in Figure 6. For an industry to operate in Stage II, the economically efficient area of production, it must first pass through Stage I. As water output increases, it is possible to expect the Idaho water industry to pass out of Stage I and into the economically efficient region of Stage II.

Objective Three

Throughout the study, the supply curve has been defined as that portion of the marginal cost curve equal to or greater than the average variable cost curve. However, as the findings under Objective 2 indicate, the Idaho water industry is subject to economies of scale. This means the average variable cost curve consistently lies above the marginal cost curve and the previously defined perfectly competitive supply curve does not have an empirical counterpart in the study. It is apparent, though, that water is made available for use at various prices.

In order to arrive at the supply curve for each of the categories studied, a horizontal summation of the categories' individual supply curves is performed. Defining the aggregate supply curve under perfectly competitive theory as:

$$S = \sum_{i=1}^{n} S_i(p) = S(p)$$

where $S_i(p)$ is the supply function of the i^{th} producer (7:122), the following horizontal supply curves are derived.

1. The marginal cost, which defines the price at which municipalities will make water available, is 439.94 in the total cost function $Y_1 = -18{,}670.63 + 439.94X$. Consequently, the aggregate supply curve for the 27 municipalities studied is $27(439.94) = 11{,}878.38$. The supply curve is perfectly elastic.

2. Marginal cost, which defines the price at which irrigation districts will make water available for use under perfect competition, is $11.96 - 0.0000024X$. The aggregate supply curve for the 37 irrigation districts studied is $37(11.96 - 0.0000024X) = 442.52 + 0.000089X$. The supply curve is depicted in Figure 19.

3. Marginal cost, which defines the price at which the total observed water suppliers will make water available, in the total cost function $1{,}445{,}062.34 + 12.4. - 0.000001X^2$, is $12.41 - 0.000002X$. The aggregate supply curve for the 64 observations is $64(12.41 - 0.000002X) = 794.24 - 0.00012X$. This supply curve is shown in Figure 19.

Note the downward slope of the supply curves depicted in Figure 19. This indicates economies of scale which is consistent with previous findings of the study.

Objective Four

Point elasticity of supply, a measure of the responsiveness of sellers to price changes, is:

$$E_s = \frac{Y}{X}\frac{dX}{dY}$$

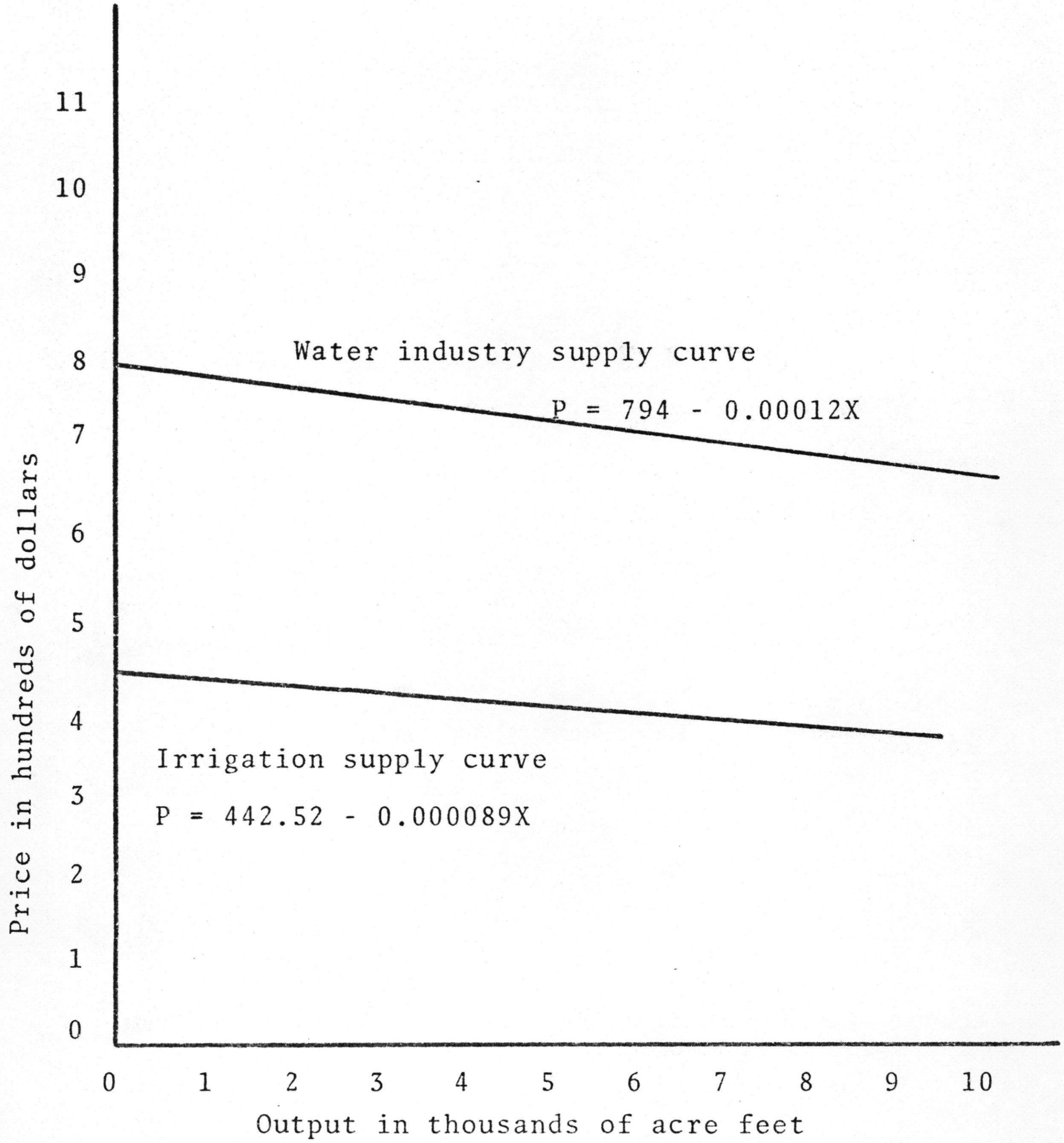


Figure 19. Aggregate supply curves for irrigation and total water industry in Idaho, 1970

where X is acre feet of output and Y is price. In our assumption of perfect competition, marginal cost equals price. Marginal cost is the first derivative of the total cost function so Y equals both price and the first derivative of the total cost functions. Applying the formula for the elasticity of supply to the appropriate cost function accepted as the best estimate of cost for making water available for use, the following point elasticities are derived.

1. E_s of municipal water supplies, where total cost is best estimated by $Y_1 = -18{,}670.63 + 439.94X$, is:

$$\frac{439.94}{X} = \frac{1}{0} = \infty.$$

The E_s of municipally supplied water is infinitely elastic for any quantity of X. This is always the situation when using a linear function with a positive B coefficient.

2. E_s of irrigation water, where total cost is best estimated by $Y_1 = 1{,}625{,}528.2 + 11.96X - 0.0000012X^2$ is:

$$\frac{11.96 - 0.0000024X}{X} \cdot \frac{1}{-0.0000024} = E_s$$

At 500,000 acre feet, for example, the E_s is 8.96. For 1 million acre feet, E_s is 3.98.

3. E_s of the total water supply in Idaho, where total cost is best estimated by $Y_1 = 1{,}445{,}062.34 + 12.41 - 0.00001X^2$, is:

$$\frac{12.41 - 0.000002X}{X} \; \frac{1}{-0.000002} = E_s$$

At 500,000 acre feet of water, E_s is 11.41. For 1 million acre feet, E_s is 5.2.

4. E_s of the aggregate irrigation supply curve is:

$$\frac{442.52 - 0.000089X}{X} \; \frac{1}{-0.00089} = E_s$$

At 500,000 acre feet, E_s is 8.94. For 1 million acre feet, E_s is 3.97.

5. E_s of the aggregate Idaho water industry supply curve is:

$$\frac{794.24 - 0.000128X}{X} \; \frac{1}{-0.000128} = E_s$$

At 500,000 acre feet, E_s is 11.4; at 1 million acre feet, E_s is 5.20.

Implications and Recommendations

The question to be answered is what do the results of the study indicate in terms of water availability in Idaho. This can be answered in considering two aspects of the study: (1) the economies of scale which are present and (2) lack of participation by industry in the study.

The economies of scale imply the water suppliers in Idaho are in Stage I. This tends to encourage expansion out of Stage I into more economically efficient Stage II. The implication of this is that water availability in Idaho is plentiful and attempts to make more water available for use are economically justifiable in order for water suppliers to pass into Stage II.

The lack of participation in the study by self-supplied industrial users implies water availability is not a problem for industries in Idaho. This conclusion is based on the assumption that the industries which supply their own water would be interested in participating in a cost study if water availability was placing any constraints on their growth.

Table 5 details average total cost and average variable cost for cities and irrigation districts in Idaho. These are per unit cost estimates based on the appropriate total cost function. Unless these costs are covered by revenue, some form of subsidization is needed. The researcher recommends further study should be directed toward pricing policies for the various water suppliers in Idaho to determine the relationship between the price paid by the user for water and the cost incurred by the supplier.

Further research is also recommended for determining the demand for water in Idaho. The importance of the research should be to determine if demand for water would be sufficient for the industry to enter Stage II. Also, demand

TABLE 5

PER UNIT COST FOR MAKING VARIOUS QUANTITIES OF WATER AVAILABLE FOR USE IN IDAHO, 1970

Quantity (acre feet)	Average total cost ($)	Average variable cost ($)
	Municipalities	
1,000	421.27	439.94
5,000	436.21	439.94
10,000	438.07	439.94
15,000	438.69	439.94
20,000	439.01	439.94
50,000	439.57	439.94
100,000	439.75	439.94
500,000	439.90	439.94
1,000,000	439.92	439.94
	Irrigation Districts	
1,000	1,637.49	11.96
5,000	337.05	11.95
10,000	174.50	11.95
15,000	120.15	11.94
20,000	93.21	11.94
50,000	43.87	11.90
100,000	28.10	11.84
500,000	14.61	11.36
1,000,000	12.39	10.76

NOTE: One unit equals one acre foot.

for water is seasonal. This results in peak periods of use, normally during the drier summer months. Further research should also be directed toward determining if investments for meeting seasonal water demands are economically justifiable.

In conclusion, the decreasing cost functions, downward sloping supply curve, and high elasticity of supply indicate Idaho is not about to fall short in its water supply. Indeed, the opposite impression is given: water in Idaho is plentiful enough to meet current and foreseeable needs.

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APPENDIX A

LIST OF MUNICIPALITIES IN IDAHO INCLUDED AS STUDY DATA

List of Municipalities in Idaho
Included as Study Data

American Falls

Blackfoot

Boise

Burley

Caldwell

Challis

Coeur d'Alene

Council

Emmett

Furitland

Glenns Ferry

Idaho Falls

Jerome

Lewiston

Mackay

Moscow

Mountain Home

Nampa

New Meadows

New Plymouth

Parma

Payette

Plummer

Pocatello

Rupert

Salmon

Twin Falls

APPENDIX B

LIST OF IRRIGATION DISTRICTS IN IDAHO INCLUDED AS STUDY DATA

List of Irrigation Districts in Idaho
Included as Study Data

A & B

American Falls

Avondale

Big Bend

Big Wood

Black Canyon

Boise-Kuna

Burley

Dalton Gardens

East Greenacres

Emmett

Falls

Fremont-Madison

Gem

Idaho

King Hill

Lewiston Orchards

Little Wood

Mann Creek

Michaud Creek

Milner Low Lift

Minidoka

Mountain Home

Nampa-Meridian

New Sweden

New York

Northside

Owyhee

Pioneer

Preston Bench

Progressive

Rathdrum

Settlers

Snake River Valley

Strongarm

Twin Falls

Wilder

APPENDIX C

COVER LETTER AND QUESTIONNAIRES USED FOR DATA COLLECTION

University of Idaho
College of Agriculture
Department of
Agricultural Economics
Richard W. Schermerhorn, Head
Moscow, Idaho/83843
Phone (208) 885-6262

Dear Sir,

Of vital interest to the State of Idaho is information concerning the amount of money involved in meeting Idaho's water needs. As Idaho's population increases, water requirements will increase and the University of Idaho, in cooperation with the Idaho Water Resources Board, needs your help in determining how much money will be needed to fill these future water needs.

Enclosed is a questionnaire designed to determine cost requirements and water output in Idaho. Your assistance in supplying the information requested will be most appreciated. Please fill out the questionnaire, place it in the stamped envelope and mail it to us at your earliest convenience.

Thank you for your time in helping Idahoans plan for Idaho's future.

Sincerely,

William C. Bailey
Research Assistant

IRRIGATION DISTRICTS

District: ____________________

Water output: Total 1970 water diversions: _________A/F

Total 1970 water deliveries: _________A/F

Annual Fixed Costs

1970 book value of:	Initial investment for:
Canals $______	$_____________
Pipe $______	$_____________
Storage facilities $_____	$_____________
Dams $_____	$_____________
Wells $_____	$_____________
Other items associated with water withdrawal and distribution $_____	$_____________
Office and Admin. space $_____	$_____________
Total $_____	

Annual Variable Costs for 1970

Operation:

Admin salaries (Gross, including FICA, taxes, etc.) $____________

Vehicle costs $ __________ Office supplies $_________

Taxes $ _____ Insurance $ _____

Rent, per month, if applicable $ _____

Water control costs:

Salaries of ditchriders (gross) $ _____ Housing $ _____

Vehicle costs $ _____

Maintenance costs: These are cost required to keept a project in operable condition.

Salaries for maintenance force (gross) $_________

Equipment and vehicle costs $_________

Total Variable Costs: $_________________

INDUSTRIES

Name of company: ____________ Do you supply any of your own water? _______

If so, what percent? ________

Source of supply: Surface____ Groundwater____ Both____ Percent from each____

Supply to distribution system: Gravity ____ Pumped ____

Total water produced in 1970: __________________ gallons

Total water delivered in 1970: _________________ gallons

Annual Fixed Costs

1970 book value of:		Initial investment for:
Supply works and transmission lines	$ ________	$ _________
Treatment and pumping works	$ ________	$ _________
Distribution system	$ ________	$ _________
General property: service and office building, equipment, etc.	$ _________	$ _________

Annual Variable Costs for 1970

Administrative:

Salaries (Gross, including FICA, taxes, etc.) $ _________

Operating expenses:

Salaries $ _________

Power for pumping $ _________

Maintenance expenses:

Salaries $ _________

Material $ _________

Amount of water purchased from municipal sources in 1970: __________ gallons

MUNICIPALITIES

Community served: ______________ Number of users: ___________

Total water delivered in 1970: ________________ gallons

1970

Water department:

Salaries $_____

Supplies $_____

Capital outlay $_____

Water office:

Salaries $_____

Supplies $_____

Capital outlay $_____

Source of water: Groundwater _____ Surface _____

Amount of water from each: Groundwater _____ gal. Surface _____ gal.

Number of water treatment plants: _____

Plant capacity, gallons per day : _____

Year plant built: _____ Expected plant life: _____

Amount of pipe currently laid for water, in miles or feet:

24" _____

22" _____

16" _____

14" _____

12" _____

10" _____

8" _____

6" _____

4" _____

Under 4" _____

Comments: ____

____

____