WORKING DRAFT OF

TECHNICAL PAPER NO. 12

# WATER CONSERVATION METHODS FOR IRRIGATION, AGRICULTURAL PROCESSING INDUSTRIES, AND DOMESTIC CONSUMPTION

Prepared by the

Supply, Allocation, and Use Work Group
Minnesota Water Planning Board

December, 1973

# PREFACE

This Technical Paper represents the analysis that has been completed on selected water conservation options by the Supply, Allocation, and Use Work Group of the Minnesota Water Planning Board. After review by the state agencies and regional advisory groups, the recommendations and options outlined in this report may require modification.

This report has been prepared by Bonnie Skelton and Steve Levy of the Department of Agriculture and Linda Bruemmer of the Department of Health. The assistance and advice provided by numerous individuals during the preparation of this report is greatly appreciated. This Technical Paper is a product of the Supply, Allocation, and Use Work Group and does not necessarily represent the views of the Departments of Agriculture and Health or other individual state agencies involved in the Framework Water and Related Land Resources Planning effort.

Thomas Kalitowski, Chairman
Minnesota Water Planning Board

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# I. SUMMARY AND RECOMMENDATIONS.

Water planning for the future traditionally has been concerned with the problem of acquiring and developing additional supplies. Water supply problems may occur because of community growth, facility obsolescence, and capacity constraints, in addition to limitations caused by competing uses, water quality problems, and the cost of distribution and treatment.

Water conservation in water resource planning is a relatively new idea at times other than those of drought. In 1978, the President's message on national water policy proposed financial assistance for states to incorporate water conservation into planning activities by providing public education, information dissemination, and technical assistance. The full details and definitions of this program will be available for public comment in May, 1979.

Aside from the measures to be taken in a drought, a state posture toward water conservation as a management tool has not yet been identified. The Water Planning Board recognized the need to examine the potential for including efficient water use in water resource planning in the areas of irrigation, food processing, and domestic/municipal water use. These three areas of water consumption were selected for study by the Departments of Agriculture and Health because of the potential which exists for changes in water use habits and existing rapport with the clientele through agency interests or programs. The methodology consists primarily of examining state-of-the-art water conservation options for their applicability in Minnesota as a part of the long range water resource management scheme.

The assumptions which are central to a proposal for some level of water conservation program in Minnesota reflect the following goals:

1. Maintain water supplies for the future.

2. Protect the quality of existing supplies.

3. Reduce costs associated with energy demand.

4. Postpone development of, as yet, untapped water supplies.

In the three areas which were examined in detail, the following options for progr [illegible] exist:

1. Irrigation options for conservation include the use of state of the art equipment, sprinkler or drip irrigation methods, flow meters, soil moisture monitors, and scheduling technical assistance.

2. Food processing plant options consist of the following elements: recycling and reuse, organizational support, in-plant water surveys, elimination of waste, plant cleanup operations, dry conveyance of solid waste, minimization of fresh water use, and less water intensive transport of products.

3. Conservation strategies to reduce domestic use are: information/education, water saving devices, metering, pricing, and leak monitoring and control.

The recommendations for the Water Planning Board are the following:

1. Efficient water use in irrigation practices and domestic consumption should be encouraged through educational programs and technical assistance to local areas.

2. The State of Minnesota should develop a technical assistance program in anticipation of national water policy to qualify for funding.

3. Programs should be implemented at the local level.

## II. WHY A CONSERVATION PROGRAM FOR MINNESOTA?

Water has generally been considered a free resource of unlimited availability. This attitude was not questioned in the past, but is one which cannot be afforded at present (Consumer Reports, 1978). Water supply problems are not always due to a lack of sufficient annual supply, but rather to non-uniform seasonal availability and irregular regional distribution (Ruesink, 1978). Minnesota is considered a "water-rich" state, but within its boundaries, areas of limited supply exist and demand conflicts arise. In addition to drought, water supply problems may occur because of community growth in population, area, economics, facility obsolescence, capacity constraints, and inflexible and long-range fiscal planning (Great Lakes Basin Commission, 1978). Water supply is limited by competing uses, water quality problems, and the cost of distribution and treatment (Sharpe, 1978).

The questions, "What is water Conservation?" and "Why does it warrant so much attention?" must be asked in light of the national interest it has gained. The term applies to a myriad of water management activities. Conservation generally means the protection of a resource from being used completely. Efficiency refers to the production of a desired effect without waste. With this difference in mind, a water conservation program for Minnesota should be efficient use/anti-waste rather than a purely conservation/anti-use campaign. Efficient water use is a tool which must be employed in managing Minnesota's water resources.

Traditionally, water planning for the future has been concerned chiefly with the problem of acquiring and developing additional supplies. Water conservation in water supply planning is a relatively new idea, usually turned to only in times of shortage. In 1972, when wastewater flow reduction was included in the Clean Water Act, PL 92-500, water conservation became a formal part of water management policy (Lattie & Vossbrink, 1977). In 1978, the Presidents's message on national water policy proposed financial assistance for states to incorporate water conservation into planning activities. This goal can be accomplished through concerted efforts directed at consumption assessment, resource impact identification, water use planning, implementation, and long-term management. The purpose of these efforts is to insure a reliable water supply and, if possible, to increase the amount available for use without jeopardizing the long-term supply.

Appropriate methods of conservation differ dramatically from state to state and within state borders. Due to varied regional characteristics, there can be no sweeping, ultimate solutions for the nation or individual states. Regions naturally defined by environmental characteristics must determine conservation needs and programs for implementation. Such regions may be defined by river basins, watersheds, or political boundaries. Local, state, and federal government agencies should provide cooperation and aid according to need and opportunity.

One of the prime requirements of conservation attempts is a change in attitude. Adjusted use rates demand new patterns of thinking, as well as different technologies. In many respects it is easier to construct a new machine than it is to change work habits or views on resources. In spite of the difficulty met in changing these habits, an effective conservation program must link new technologies with new thoughts.

Minnesota is experiencing a number of the same water-related problems which are occurring nationwide. Where water shortage is a problem, demand has out-stripped supply. Shortage does not imply that water resources are non-renewable. Water is one of the most readily renewed resources upon which society depends. The hydrologic cycle is continuous; ground and surface reservoirs are perpetually replenished (recharged) by precipitation. If the volume of water withdrawn from any lake, stream, or aquifer exceeds that provided by recharge, the water level will drop and shortage may be experienced.

Three factors contribute to localized water shortages. Increasing population pressure increases the demand of water from municipal and domestic supplies. High density population also increases the demand for services using water and goods requiring water for manufacturing and processing. Advancing technology and a rising standard of living are increasing water availability and encouraging increased use for agricultural, industrial, municipal, and domestic concerns. Finally, natural precipitation is not only unpredictable and erratic; it is quite unevenly distributed across the nation. Average annual rainfall over much of the eastern quarter of the nation exceeds 50 inches per year.

In the western Great Plains, 10 to 20 inches per year are average and in some areas of the southwest, less than 10 inches per year can be expected.

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3. To reduce costs associated with energy demands.

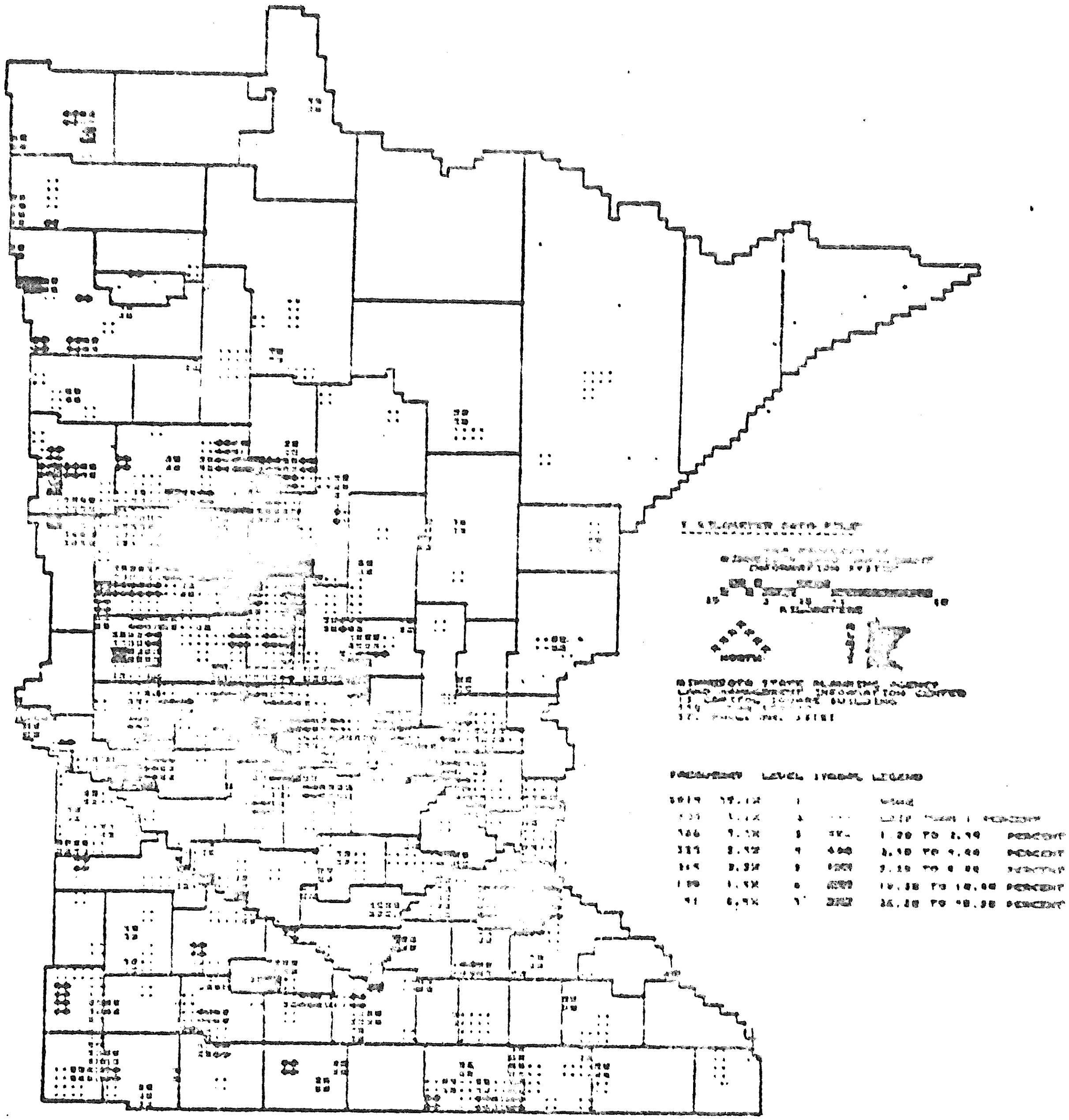
4. To postpone development of untapped water supplies.

## III. IRRIGATION.

Irrigation is a broad term referring to the displacement of water from its natural course for the purpose of enhancing plant growth. Nationwide, irrigation is the largest consumptive use of water, commonly practiced to benefit agricultural production, wild rice and sod farming, and golf course and cemetary greenery. Estimating the total water use by agricultural irrigation is difficult because only a small number of irrigators actually measure volume flow with meters. More often, water use is estimated based on fuel consumption or pump and distribution equipment capacity, estimated system efficiency and the period of operation. Individual farm estimates are used to generate statewide estimates which, in turn, are compiled for a national estimate, increasing in generality and perhaps magnifying gross errors. However, even general estimates are useful for illustrating trends and identifying existing or potential problems.

The national trend in irrigation displays a dramatic increase in both the acreage irrigated and the total amount of water withdrawn and consumed for irrigation. Over 57 million acres were estimated to be irrigated in 1977 in the United States. In 1960, a little more than 100 million acre feet of water were withdrawn for irrigation in the U.S.

## IRRIGATED LANDS



Irrigated Lands by Township according to Department of Natural Resources Water Appropriation Permits through December, 1977.

Map prepared by the Minnesota Department of Agriculture.

Coordinated by Bonnie Skelton for the Water Planning Board with funds provided by the Legislative Commission on Minnesota Resources.

This figure has increased to a total annual withdrawal of 160 million acre feet reported by the U.S. Geological Survey for 1975.

The trend toward irrigation is well illustrated by Minnesota statistics. Agricultural irrigation in Minnesota has rapidly gained acceptance as a viable farm management technique since about 1960. Best estimates indicate that from 1960 to 1970, irrigated acreage doubled from 22,000 acres to 44,000 acres. From 1970 to 1975, this acreage increased to 174,000 (University of Minnesota, 1975). One estimate for 1977 reports 433,000 acres irrigated in Minnesota. A statewide summary of irrigated lands is shown on the following page.

The water withdrawal and consumption which these irrigated acreages represent are a substantial portion of overall Minnesota water use.

TABLE I offers a comparison of water use by sectors within Minnesota. Minnesota Energy Agency estimates indicated that nearly eighty billion gallons of water were withdrawn for irrigation in 1976. For the most part, development of irrigation corresponds to the locations of geomorphic regions characterized by sandy soil, gently rolling topography, and relatively shallow sand and gravel aquifers. Irrigation is less likely to be developed in areas with generally heavier soils, extreme topography, or severely limited water supplies.

In dealing with the topic of water conservation and irrigation in Minnesota, the potential to reduce total withdrawals and consumption can be seen in light of the vast amounts of water used in irrigation practices. Irrigation is one of the largest consumers of fresh water in the state. To prevent waste, withdrawal volumes should be kept to the minimum required for consumptive use demand of the crop irrigated. By minimizing withdrawal, the water saved remains available for other uses. Efficient water use is a major factor in waste prevention and water conservation and also offers potential economic savings from reduced pumping costs.

## A. Why Irrigate?

Risk avoidance may be the greatest encouragement to irrigation. Farming is a high risk endeavor with many factors determining the ultimate success of a crop. Irrigation can be insurance against an unpredictable course of precipitation throughout the growing season. Final crop yields are affected by moisture availability during key stages of growth cycles. Irrigation can be used to prevent short-term stress during these periods of vulnerability.

TABLE I

MINNESOTA WATER USE - 1976
BY SECTORS ($10^6$ gallons)

| | Withdrawal | % | Consumptive Use | % |
|---|---|---|---|---|
| Residential | 95680.670 | 7.3 | 9578.067 | 4.4 |
| *Commercial/Institutional | 41404.835 | 3.2 | 5876.949 | 2.7 |
| Manufacturing | 118439.041 | 9.0 | 10525.909 | 4.9 |
| Mining/Dewatering/Quarrying | 277992.663 | 21.1 | 100449.682 | 46.7 |
| Electric Power | 687295.000 | 52.2 | 18425.200 | 8.6 |
| Agriculture | 79821.080 | 6.1 | 67888.258 | 31.5 |
| Livestock | 20156.930 | | 20156.930 | |
| Irrigation | 59664.150 | | 47731.320 | |
| Other | 15171.301 | 1.2 | 2578.358 | 1.2 |

*Commercial/Institutional includes hotel, golf courses, and ski areas.

(Minnesota Energy Agency, 1979.)

The higher the value of the crop grown, the more risk involved and, therefore, the more valuable the irrigation system. If a corn crop is threatened by drought one year in ten, the loss will be for one year only. If an orchard is threatened by drought one year in ten, the loss can persist considerably longer because fruit trees require many years to mature to fruit-bearing age. Likewise, a specialty crop with high value per acre yield will result in a much greater loss than corn, for example, if the same number of acres are destroyed. Where irrigation might not be cost-effective to reduce risk for a corn field, it could be highly cost-effective for a specialty crop.

A normal year in Minnesota has precipitation occurring every seven to ten days. Rainfall, combined with other predictable climatic factors, makes the state highly productive agriculturally. A break from the normal like the 1976 drought has caused many of the productive areas of the state to be officially declared disaster areas. Irrigation saved many crops from total loss by providing moisture when normal precipitation failed to do so.

Annual consumptive water use for grain corn exceeds 20 inches. Precipitation in Minnesota averages 19 inches annually in the northwest, gradually increasing to 30 inches in the extreme southeastern portion of the state. Approximately two-thirds of the year's precipitation falls during the five month growing season. On the average, corn is a highly successful crop, but every year some yields suffer from lack of moisture during critical growth periods. Irrigation has developed to insure sufficient available moisture for maximum crop production.

In addition to risk reduction and stress avoidance, irrigation may be used to modify soil moisture conditions so that crops can be cultivated in otherwise undeveloped areas. An estimated one million acres of Minnesota land has topsoil too sandy for normal cultivation. Sandy soils are generally well-drained with soil moisture percolating rapidly downward, becoming unavailable for consumptive use. As moisture leaves the root zone, dissolved nutrients are carried with it, robbing the soil of fertility. Such sandy soils produce high yields for many crops with proper fertilization and controlled moisture application.

Under normal climatic conditions, heavier soils have a high water holding capacity so moisture is retained in the root zone for longer periods of time and irrigation is generally not required to produce high yields. With careful scheduling irrigation of heavy soil can be efficient though cost-benefit of this water use may be questionable. Heavy soil irrigation without proper scheduling can result in water standing on the surface. Too much water can ultimately be as detrimental to crop yields as too little water. Drought in 1976 spurred some experimentation with sprinklers on heavier soils but the vast majority of irrigation in Minnesota occurs on those soils which are light and well-drained.

Irrigation cannot be recommended as a sound management practice for most of the 23 million tillable acres in Minnesota. Recommendations and site specific planning, design, and engineering advice are available through the Agricultural Extension Service of the University of Minnesota, the U.S. Soil Conservation Service, and many equipment dealerships. Irrigation can be advised under the following conditions:

1. The soil is too sandy for productive, dry land cultivation.

2. The reduced risk of crop loss is cost-beneficial.

3. Topography is not restrictive.

4. Adequate water is available.

5. Other farm management practices are amenable to the additional time required for irrigation.

Once irrigation has been determined as necessary, many environmental and mechanical parameters are found to affect the water use efficiency which, in this case, is called agricultural application efficiency. The variables which determine the amount of water needed for irrigation are equipment, scheduling, soil type, topography, water quantity and quality, crop type, land use practices, and climate.

B. Irrigation Application Efficiency.*

Irrigation application efficiency is defined as the ratio of the average depth of irrigation water stored in the root zone to the average depth of water applied. Water stored in the root zone is available for consumptive use. Irrigation water not stored in the root zone evaporates, leaves as run-off, or percolates down beyond the root zone.

Surface irrigation is considered, on the average, to have the lowest application efficiency. There are several types of surface irrigation and these are grouped together for simplicity in the following discussion. The same holds true for sprinklers.

Surface application efficiency is estimated to average about 50 percent with a range from 30 to 70 percent. Run-off or tailwater recovery and reuse may increase this figure to 85 percent. Sloping land decreases efficiency due to non-uniform water application. Seepage and evaporation also contribute to inefficiency. Substantial efficiency variations exist from system to system. Surface irrigation returns approximately 40 percent of the water withdrawn for immediate use. Surface irrigation in Minnesota has long since been replaced by sprinkler operations, with the exception of wild rice paddies. Sprinklers are generally more efficient than surface methods because water is applied in more frequent, lighter applications.

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*A more complete discussion of irrigation efficiencies can be found in the November/December issue of the Journal of Soil and Water Conservation published by the Soil Conservation Society of America. Many equally valuable materials have been published on this topic.

Average sprinkler application efficiency is estimated to be 70 percent with a range from 60 to 90 percent. Inefficiency is caused when the application rate exceeds soil intake capability resulting in surface runoff; the application rate exceeds soil water depletion in the root zone resulting in deep percolation; distortion of the distribution pattern caused by wind, resulting in a loss of irrigation water outside the designated field; and evaporation.

Under certain circumstances, trickle or drip irrigation can be assumed to be nearly 100 percent efficient. Because water is placed around or near the growing plant, evaporation from the soil surface can be reduced substantially, particularly in fields with widely-spaced crops like fruit trees. Application rates for trickle systems are easily controlled, thus preventing deep percolation and run-off. Closely-spaced crops irrigated by this method may not provide an efficiency advantage because such a large soil surface is wetted. Here again, evaporation becomes a major factor.

## C. Conservation Potential - Method of Irrigation.

Conservation of water should begin with the planning of an irrigation system. Equipment must be designed to operate efficiently and to meet specific field needs. Many irrigators purchase system components separately to reduce initial costs. A makeshift system cannot achieve the high efficiencies of a specially planned and engineered operation. Planning and equipment costs are repaid over time by water and energy savings.

The method of irrigation employed can grealty affect water consumption. As was mentioned previously, surface irrigation in Minnesota is used almost exclusively for wild rice, comprising a very small percentage of total water use. In 1976, approximately six million gallons of water were used for this purpose while an estimated 49 billion gallons were used for all other agricultural irrigation (Richardson, 1978).

Sprinkler systems are used for nearly 100 percent of the agricultural irrigation occurring in Minnesota. Approximately 70 percent of all existing systems and 60 percent of all new systems are center-pivots. Other types of sprinkler systems include the traveler, side-wheel roll, hand-move gun, boom, hand-move sprinkler, tow-line, and solid set.

An important trend in irrigation technology is the rapidly increasing popularity of less labor intensive systems that are more energy intensive. Generally speaking, as new technology has reduced the required labor input, greater water application control has evolved creating a great conservation potential for the state.

Many sprinkler systems require daily supervision and labor intensive transfers at the end of each irrigation cycle. (For a brief description of system types, see the U.S. Soil Conservation Service, "Irrigation Guide" - Chapter 4). Center-pivots are designed in a circular path such that at the end of one cycle the system is in position to automatically begin again, assuming the full circle is irrigated.

Center-pivots are essentially fully automatic sprinklers systems strung between mobile towers mounted on large flotation tires. Water is pumped through the system from the pivot point and the towers are self-adjusting to allow a full circuit of the field with little or no supervision. Because the system travels in a circle, corner acres are omitted unless a cornering device is employed. Without cornering devices, center-pivots on 160 acre fields can irrigate only about 133 acres.

Center-pivots are designed such that water application rates can be controlled according to environmental dictates. Herein lies the greatest conservation potential. Consideration of crop stress, soil moisture, ambient air temperature and wind speed can be used to determine how much water should be applied and the tower speed per unit of time. While topography is very limiting for many types of sprinklers, center-pivots can operate as recommended on up to 12 percent grades. Operations on grades of 20 percent and higher have been reported, but run-off and erosion reduce system efficiency (Sprinkler Irrigation Association Proceedings, 1975).

Fertilizer and pesticides may also be applied via center-pivot during normal irrigation procedures. This practice can reduce overall moisture applied to the field and generates energy savings by reducing the number of field operations.

Evaporation and wind disturbance are difficult to prevent but have been reduced under some circumstances by recent technological advances. Concern for conservation has spurred manufacturers to examine these problems and invent options offering better application control. Such options include: low pressure systems, shorter towers, and sprinklers situated downward to moisten plants at the soil line below most foliage. Under carefully controlled circumstances, these options have proved successful.

The third irrigation method to be considered is drip or trickle irrigation, currently used on about 135,000 acres in the United States. In Minnesota the actual acreage irrigated by this method is uncertain but probably less than 100 acres. This type of system used on widely-spaced crops has the greatest potential for reducing waste and conserving water and energy. Required water pressure is very low, so only low capacity wells are necessary. With proper scheduling the minimum amount of water needed is applied, evaporation is minimized, and deep percolation is prevented.

However, it should be noted that many of these attributes do not follow for drip systems irrigating closely-spaced crops because the soil surface wetted is substantially larger, in fact, comparable to that with sprinkler systems.

Drip systems consist of plastic tubing of small diameter laid on or under the surface of the field and alongside the plants to be irrigated. Water is delivered to the plants slowly but frequently from holes or special emitters located at appropriate intervals along the tube. A typical system is made up of a network of plastic pipe of graduated sizes laid out in the field. The largest pipe brings water to the field edge and a series of main lines of smaller diameter carry it into the field. Sub-mains of smaller diameter may carry the water to lateral lines from which it is delivered to individual plants through holes or emitters. For small fields or simple layouts, lateral lines may be connected directly to the main line. The system also requires a control station which could include filtering units, injectors for addition of fertilizer or chemicals, pressure regulators, flow meters, and valves and pumps required to control water flow. Properly scheduled, drip irrigation provides to the root zone just enough water to replenish the amount consumed by evapotranspiration.

Drip systems have been used to irrigate a variety of crops that can be grown in Minnesota including: alfalfa, apples, asparagus, christmas trees, corn, cucumbers, egg plant, gladioli, grapes, lettuce, melons, orchards, ornamentals, pasture, peas, peppers, radishes, shrubs, sod, sorghum, strawberries, tomatoes, and wheat (Gustafson, 1974).

D. Scheduling.

For each of the irrigation methods, scheduling is of utmost importance when trying to use available water efficiently. Irrigation science and technology have improved equipment in response to the need for water conservation. Irrigation scheduling has not always kept up with conservation needs because until recently, many management procedures were difficult to implement and, in many cases, immediate water availability provided no incentive for the effort. Scheduling requires that management decisions determine when and how equipment should be used.

Irrigation scheduling is a procedure that accounts for or monitors either plant water status or soil moisture to enable forecasting the optimum time and amount of irrigation water to be applied. Often times, equipment capacity limitations dictate that scheduling decisions be made several days in advance to enable meeting crop moisture needs as they arise. If a center-pivot requires 36 hours to make a full circle, waiting until crops show physical signs of stress means water may arrive already overdue. If irrigation begins before a moisture deficit occurs, crop stress is avoided. However, by waiting for root zone moisture depletion, application efficiency may be maximized. An important trade-off must be made between water use efficiency and potential crop stress. "Programmed soil moisture depletion" is a scheduling method that promotes crop stress but only during times in the growing season when injury to plants will be minimized (Sprinkler Irrigation Association Proceedings, 1974). Less water is used and yield loss is avoided.

Many approaches have been devised to supply data for scheduling decisions. All are based on the theory that optimum irrigation timing and application can be achieved only by knowing in advance the soil's water holding capacity, the water depletion point where crop damage begins and the soil moisture content throughout the growing season. Soil moisture can be estimated or measured in a variety of ways. The simplest method of determining soil moisture depletion in the field is by the feel and appearance of soil samples taken from below the surface. Estimation accuracy is based entirely on the experience of the handler. Tensiometers, electrical resistance blocks, and neutron depth moisture gauges arranged in the field measure soil moisture and crop moisture stress. Readings should be taken at different soil depths often enough to predict soil moisture deficits. As mentioned earlier, visual observation of crop condition can be employed but this method may indicate a moisture deficit too late for irrigation to prevent yield losses. Estimates for this method are based strictly on guess work, building great inefficiency into the system.

Soil water deficits are also estimated by "bookkeeping" procedures standardized by both the Soil Conservation Service and the University of Minnesota Agricultural Extension Service. Soil moisture is determined early in the season. Estimated evapotranspiration is substracted and precipitation is added throughout the season to keep a running estimate of soil moisture. This system has proved to be highly successful but is somewhat time consuming.

Regular scheduling and a well-designed, efficient distribution system is required for optimal use of irrigation water. Scheduling is an absolute requirement for water conservation. If Minnesota irrigators utilize recommended management and conservation techniques, water savings for the state have been estimated at 20 percent (Bergsrud, 1978).

Scheduling provides long-term benefits to irrigators including:

1. Decreased financial expenditures by reducing water and energy consumption.

2. Soil protection by reducing run-off, erosion, and nutrient leaching.

3. Water quality protection by reducing deep percolation to ground water and sedimentation of surface waters.

4. Reduced aquifer drawdown which may help the individual irrigator and protect neighboring wells from interference.

Most methods of data collection for scheduling require considerable inputs of time that compete with other farm responsibilities. Many irrigators are hesitant to make this time commitment, accounting in part, for the proliferation of management services in the U. S. These services essentially take over responsibility for observing field conditions. They decide when the system should be activated and how much water should be applied.

In many states, management services are available that provide individual schedules to irrigators. In some cases, groups of irrigators schedule together because they share a limited supply of water and/or energy. Varying levels of sophistication are employed by such services, ranging from networks of tensiometers or evapotranspiration estimates based on all available environmental data.

Computerized scheduling was discussed in the literature as early as 1952. It was not adapted to popular use in the United States until about 1965 (Sprinkler Irrigation Association Proceedings, 1971). Nationwide, both private and governmental agencies are involved in computer scheduling for irrigation. The United States Department of Agriculture in conjunction with the Agricultural Research Service have a program which reported water savings up to 25 percent as a result of proper scheduling. Yield increases of up to 25 percent have also been reported by private scheduling firms. Computer scheduling can provide information on how much water to apply for maximum yields or how to schedule irrigations for greatest production per unit of water, an especially valuable approach when water is limited.

The main objective of these programs is to identify all environmental aspects impacting on a crop to enable computer modeling of field evapotranspiration. This includes daily or weekly information on:

1. Soil condition.

2. Quality and quantity of irrigation water.

3. Atmospheric data including: minimum and maximum temperature, dewpoint, wind speeds, solar radiation, cloud cover, and rainfall.

4. Crop data including: emergence date, growth stages, fertilizers, and diseases.

Computer print-outs of all data are made available to clients and kept on file by the scheduling service. By hiring a scheduling service an irrigator frees time that otherwise would be spent on data collection. The service fee may eventually be recouped from water and energy savings, decreased chemical use and increased yields. Nitrogen fertilizer savings in some cases have been reduced from 50 to 100 pounds per acre. Even the best intentioned conservationist may be hard-pressed to make accurate decisions when faced with the multitude of data involved with irrigation scheduling. Computer scheduling has not become popular in Minnesota because sandy soil conditions and weather change more rapidly than most services can accommodate.

Drought can introduce special scheduling problems. Even though a system may be well designed and managed under normal climatic conditions, high temperatures, wind, and low humidity can lower sprinkler application efficiency to 50 percent or less.

Peak moisture use periods for the crop may be extended from a few days to a few weeks, greatly increasing the volume of water needed. Often moisture in the soil profile is depleted early in the season and system capabilities are unable to ever catch up. Such problems can be mechanically avoided by keeping the soil profile at field capacity though this may require late fall irrigation to provide early spring reserves. In this case, efficiency may also be reduced by evaporation and deep percolation prior to the winter freeze and between spring thaw and planting. It is difficult, in many cases impossible, to increase the capacity of a system once it has been designed for a particular field and soil type under normal conditions. Drought may require restricting the growing season to the best schedule available. This may be accomplished by instituting programmed soil moisture depletion, by expecting less than optimum yields, by cutting back on the plant population (reducing evapotranspiration) and by planting shorter season hybrids.

E. <u>Equipment: Soil Moisture Monitors and Flow Meters.</u>

Efficient irrigation depends on application of the right amount of water when its needed by the crop. Soil moisture, or the lack of it, can be directly monitored by using electrical resistance blocks or tensiometers both commonly used in Minnesota. Other methods of judging soil moisture are available however, properly used, this equipment is reliable and easily integrated into automatic sprinkler systems.

Electrical resistance blocks are usually small cylinders cast of gypsum or nylon-impregnated gypsum. When placed in the soil, electrodes in the sensor register variations of electrical resistance which depends upon soil moisture content. Electrical resistance is inversely proportional to the amount of water in the soil so as the soil dries out resistance goes up. In essence, these monitors indicate plant stress although some also give readings on the percent of available moisture.

Tensiometers are sealed, water-filled tubes equipped with a vacuum gauge to be left above ground and a porous tip which is buried in the soil. When properly calibrated and buried, tensiometers measure "soil moisture tension" caused by evapotranspiration drawing moisture away from the sensor. As soil begins to dry, tension goes up and a vacuum is formed in the tube showing a moisture deficit. When moisture again becomes available, tension in the soil goes down and lowers the monitor reading.

Placement of soil moisture sensors are recommended in at least two different areas of the irrigated field. Each area is also recommended to have sensors at two depths within the root zone. A shallow placement will indicate early root activity and a deep placement will monitor mature root system demands.

Flow meters are devices that measure the volume and rate of water flow from wells or through pipes. Direct measurement of the gallons flowing through an irrigation distribution system provides data for accurately calculating gallons pumped per acre or per unit of crop yield. Distribution system and pumping plant efficiencies can also be calculated from this information. Without flow meters, water application estimates often prove to be unreliable. This can be attributed to varying efficiencies of system components and well problems. Many irrigators installing flow meters have found considerably less water being pumped than expected. By indicating this deficit flow meters have contributed to increased yields. Irrigators finding they are pumping more water than necessary can also improve yields and reduce pumping costs through improved scheduling.

Flow meters are strongly recommended for achieving the greatest possible irrigation efficiency. North Dakota has instituted a state law requiring irrigators to measure and record, via flow meters, the amount of water they pump. Minnesota does not require meters, however, installation is advised for maximum irrigation efficiency and consequent water conservation.

F. Environmental Parameters.

In addition to the variety of mechanical options for irrigation, environmental factors may be used to increase irrigation application efficiency. Climate is a major factor influencing irrigation. Wind, ambient air temperature, humidity, radiant energy, and precipitation combine to influence the rate of evapotranspiration and the volume of irrigation water needed.

Incoming radiant energy, low humidity, and high ambient air temperature increase the rate of crop evapotranspiration. Evapotranspiration combines transpiration from foliage, sprinkler evaporation, and evaporation from soil and leaf surfaces. Evapotranspiration in essence increases the humidity near crop foliage and if still air conditions exist, the rate of evapotranspiration can ultimately be reduced. Wind increases evapotranspiration by replacing humid air near the crop with less humid air from outside the field. High rates of evapotranspiration hasten the need for irrigation as soil moisture is depleted more rapidly.

Evapotranspiration peaks during the hottest part of the growing season. Between May 1 and August 12, solar altitude ranges between 60 to 68 1/2 degrees. June 22 is the summer solstice with the highest solar altitude of the year. Total solar incoming radiation peaks at this time in Minnesota. Through this period, daily temperatures peak and the percent frequency of cloud cover is lowest for the year.

Winds vary throughout the year and by time of day. The hours between 6:00 a.m. and 6:00 p.m. experience, on the average, higher wind speeds than those recorded for the period between 6:00 p.m. to 6:00 a.m. The average annual frequency of calm periods also correspond to night-time hours. Reports from the southern plains of the United States indicate sprinkler irrigation losses of less than 10 percent with average wind speeds below 10 miles per hour. Losses increase exponentially to a maximum of 30 percent as wind speed increases.

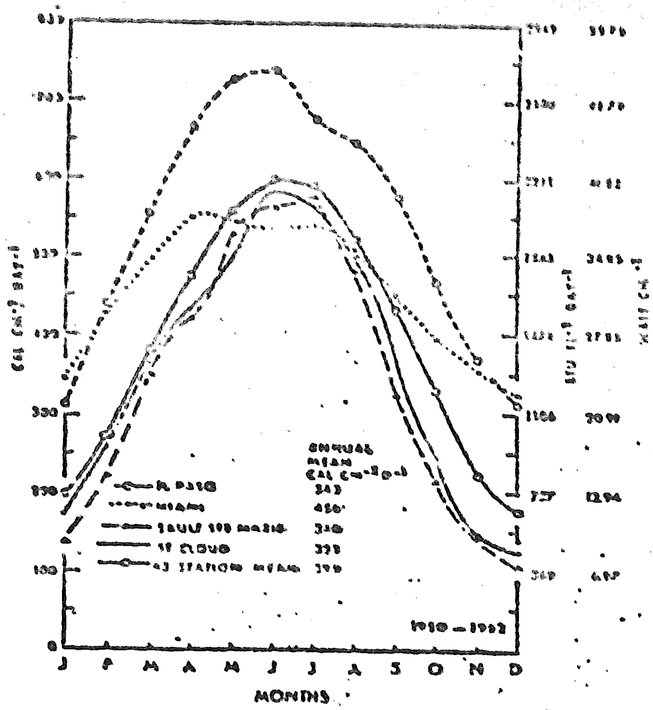
The data in Figure 1 suggests that sprinkler irrigation efficiency can be maximized by night applications if distribution system capacities are able to keep up with crop demand. Night application should be a major conservation consideration going into the design of new systems.

Crop demand for [illegible]

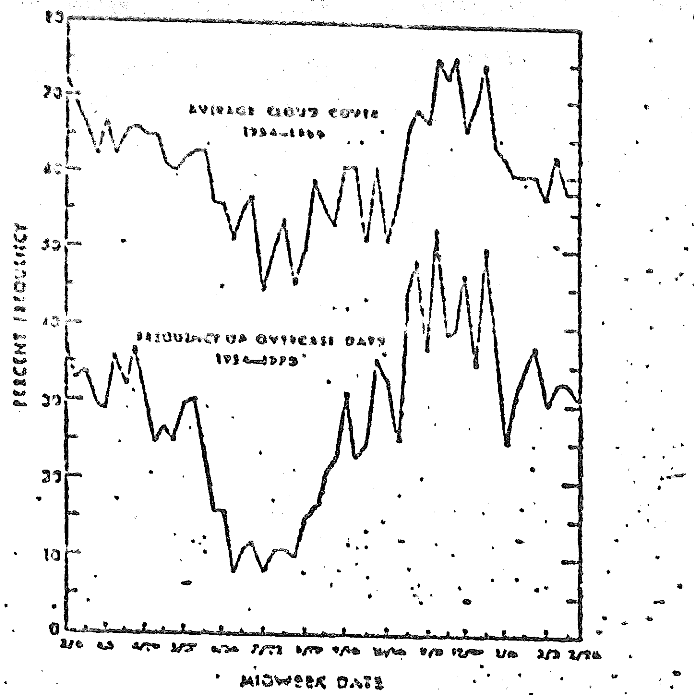
During germination and seedling stages, root systems are poorly developed and water in only the top few inches of soil is available to the crop. A soil profile kept at field capacity is unnecessary for maximum crop benefit at this time.

For a soybean plant, the pattern of water use increases from less than .10 inches per day during germination and seedling stages to .30 inches per day during the rapid growth and reproductive stages. Water use drops off rapidly at maturity (Schleicher, 1977).

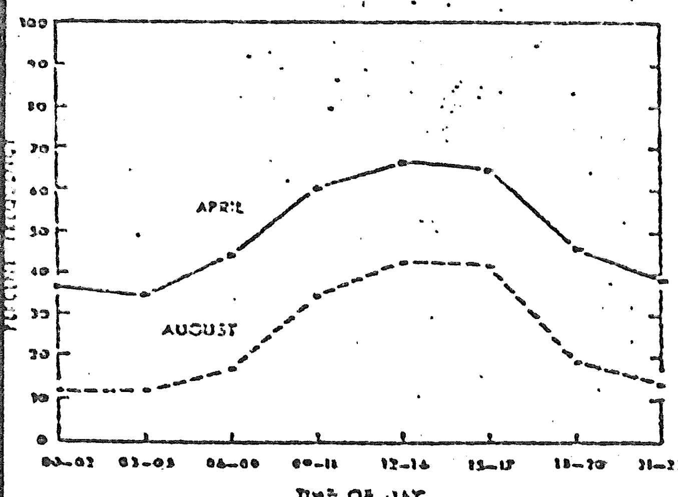
For corn, the first four to six weeks of growth after plant emergence show very limited water demand. When plants attain approximately 3 1/2 feet in height, the rate of evapotranspiration peaks for that time of year. Maximum ear development requires adequate water from just before tasseling to maturity. Corn yields can be seriously reduced by moisture shortage during this period. At maturity, irrigation has no further effect on development and can be terminated (Swan and Hicks, 1977).



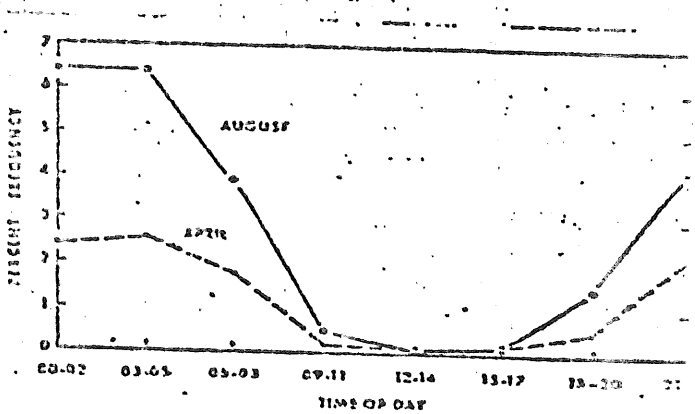

Average daily total solar radiation received per month on a horizontal surface at St. Cloud compared to El Paso, Texas; Miami, Florida, Sault Ste. Marie, Michigan; and the average of 43 United States stations.




Average cloud cover, 1954-1966, (1) and average weekly occurrences (in percent) of overcast days (1954-1970) at Minneapolis-St. Paul.




Average annual frequency of wind speeds of at least 11 miles per hour (7.7 m sec⁻¹) for each 3-hour period of the day in April and August at Minneapolis-St. Paul, 1945-1970. Frequencies of other months fall between the two months shown.




Average annual frequency of calm periods for each 3-hour period of the day in April and August at Minneapolis-St. Paul, 1945-1970. Frequencies of other months fall between the 2 months shown.

FIGURE 1. Climate of Minnesota (Technical Bulletin #312 by D.G. Baker, Agricultural Experimentation Station, University of Minnesota)

Wheat planted in the fall has a root system extending only into the upper foot of soil. In the fall, the wheat plant is estimated to require only about .07 inches of moisture per day, winter dormancy reduces this figure to about .03 inches per day. These figures are low, but a full soil profile in the fall may be recommended to ensure adequate moisture in the spring. Wheat eventually develops an extensive, deep root system making it an excellent soil moisture competitor during times of potential stress later in the season. It has been suggested that by concentrating water applications in the fall and during the developmental period known as the "flowering to milk" stage, wheat yields can be maximized with limited irrigation applications (Trimmer, 1977).

Experimentation with hybrids is approaching the moisture shortage problem from different perspectives. By developing drought-resistant hybrids, crops can be produced that require less moisture, ultimately demanding less irrigation water (Reagan, 1977).

Plants with larger, more numerous roots are more efficient at conducting moisture and taking advantage of a larger portion of the root zone. Water may still be available in the root zone between plants while the soil immediately around the plant root system has been depleted. More extensive root systems decrease the likelihood of moisture stress.

Corn hybrids have also been successfully inbred to encourage development of a drought dormancy period. These plants enter a period of dormancy when exposed to water stress and resume normal growth when stress is abated. A mechanism of this type could eliminate reliance on irrigation because waiting for adequate precipitation would have less impact on crop yield.

G. <u>Conservation Tillage</u>.

Historically, conservation tillage was planned for conserving soil and water resources and for improving production efficiency during and after the 1930's drought. More recently, conservation tillage has been explored for potential energy savings and water quality protection. Also, known as minimum tillage or no-till agriculture, conservation tillage is a method of crop production that applies "new farm production technologies to reduce soil manipulation practices to the minimum consistent with local soil, climate, and economic conditions" (Minimum Tillage, 1975).

Reports on the effects of conservation tillage are highly controversial and difficult to define because maximum beneficial results depend entirely on local conditions.

Experiments show that water savings can be achieved under certain conditions using specifically designated tillage methods. Water is saved by reducing soil evaporation and by increasing the water-holding capacity of the soil. Because of more complete ground cover, soil erosion caused by water and wind is also reportedly reduced.

These practices may result in practical trade-offs. For example, reports from Bushland, Texas, indicate that increased water storage allowed high-yield crop production without irrigation but required increased pesticide use.

H. Wind Breaks or Shelter Belts.

Irrigation of agricultural crops has a reputation for being incompatible with other land covers. Center-pivots, in particular, are generally incapable of traveling a square field on which standard wind breaks or shelter belts have been established. Wind breaks and shelter belts reduce wind speed across fields which, among other things:

1. Reduce top soil lost to wind erosion.

2. Reduce crop damage caused by blowing soil.

3. Reduce irrigation sprinkler pattern disruption.

Permanent vegetation can also reduce erosion by slowing run-off velocity and increasing infiltration rates.

Across the state, land cover vegetation has been removed to accommodate advancing irrigation technology. Efforts directed toward remedying this problem have successfully produced alternative vegetative patterns that co-exist with center-pivots and still reduce wind speed across fields (Isakson, 1977).

I. Appropriate Water Conservation.

This discussion on appropriate water conservation measures for irrigation has been largely limited to reduction of the quantity of water used. Water quality enters into consideration when ground water becomes contaminated by nutrients dissolving in the irrigation water and leaching from the soil. Nitrate contamination in particular can render a water source unfit for human consumption along with other water use restrictions which may arise from degraded quality.

Finally, sprinkler application of wastewater has been moderately successful although public acceptance of this procedure has not been widespread in Minnesota. Many of the canneries in Minnesota have been disposing of their wastewater by irrigation, some for more than thirty years. Some milk plants and municipalities also use irrigation and other forms of land disposal.

It seems reasonable to assume that irrigation increases like those in Minnesota have a substantial impact on the state economy. Economic impacts of irrigation are beyond the scope of this report. One observation is pertinent: Any impacts, whether economic or resource-related, will be strongly regional in nature because irrigation is limited to specific areas of the state. Because of the regional nature of irrigation development, it is emphasized that although state concern is imperative, the impetus for irrigation water conservation should be locally or regionally initiated. Cooperation at all government levels is strongly advocated to further educational and technical assistance programs to increase the awareness of conservation potentials.

## IV. WATER CONSERVATION IN THE AGRICULTURAL PROCESSING INDUSTRY.

The purpose of this section is to serve as a general introduction to water conservation for the agricultural processing industry in Minnesota. Other papers prepared by the Water Planning Board have already examined the quantitative needs and purposes of water in various sectors of agricultural industry (Water Requirements and Issues in the Minnesota Agricultural System), the economic value of their products, and the economic impact of drought on their operations. Future papers will deal with water priorities and state allocational policies. A discussion of water conservation is extremely important to complete the picture.

Agricultural processing firms in the state include canneries, dairy processors, slaughterhouses, sugar refineries, and poultry producers. Each of these firms processes raw agricultural goods produced in the state. Although there has been a tendency for processing firms to become more centralized, the majority of firms are still located in rural municipalities. These firms are often the major or only industry in a locality. Water supplies and waste treatment services for these industries are either private operations or municipal systems. Plants decide to use these utilities on the basis of individual hydrologic, technical, and financial considerations. The demand for water by these plants is extremely large, often exceeding one million gallons per day. Requirements for waste treatment facilities are equally demanding due to the quantities of waste water and organic matter leaving the plants daily. Plants operating in both rural and metropolitan settings are capable of putting severe stress on local hydrologic conditions and on water-related capital equipment. Processing firms and municipalities alike have been feeling the financial pressure of increased water and waste treatment costs.

Food processing firms have always been aware of the need for vast amounts of water for their internal operations. However, this concern was (and is in many cases) primarily technologically rather than economically oriented. Water is needed to wash, cook, cool and transport the product, and to keep all the equipment and facilities clean and sanitary. Since water was deemed an inexpensive and often free resource, plant facilities were designed without regard to water use. In the days before the environment was viewed as a resource, water resource use for waste assimilation was not a major issue. Decisions on plant locations were based on water availability for technologic needs, not on the resource cost of supplying these needs.

As resource supplies and demands shift, so do their prices, both real and imputed. While there is always a cost associated with resource use, it is only now beginning to show up in municipal and industrial fiscal statements. These costs go under the headings of water, energy, waste treatment, depreciation, and interest charges. Water has become a constraint on continued operations and projected growth.

Some industries and residential communities are experiencing both an increase in the cost of water and related resources and an inability to obtain sufficient quantities at any cost. In the extreme, agricultural processing firms cannot operate without sufficient supplies. They must either halt operations entirely or move the plant. Under less dire circumstances, plants may have to curtail output and absorb increased input costs. Given the competitive cost disadvantage that many food processing plants have in Minnesota due to factors such as climate and transportation, increases in average operating costs can have serious impacts on the market position of Minnesota produce and the general business climate.

Many food processing operations in the state are now adjusting their use rate of water downward in order to compensate for increased costs and diminished supplies. This change in the distribution of water use generally can be termed water conservation. Conservation can be accomplished by altering the input mix without deferring output and by deferring output with no change in input ratios. Conservation goals also can be reached through different technological means. Consequently, different patterns of use rates are achieved through adjustments to the technology and through different combinations of inputs and outputs (Ciriacy - Wantrop, 1963).

One of the prime requirements of conservation attempts is a change in attitude. Adjusted use rates demand new patterns of thinking as well as different technologies. In many respects it is easier to construct a new machine than it is to change work habits or views on resources. However, an effective conservation program must link new technologies with new thoughts.

A. The Limits to Water Conservation.

A major constraint on the institution of water conservation programs in food processing plants, especially for the reuse of water within the plant, is the stringent sanitation regulations that are enforced by federal and state authorities. Due to the potential threat of wide-spread contamination caused by improper handling of food or an inferior water supply, regulatory authority must be maintained to protect the public. Official positions on water conservation are quite clear, consumer safety and product integrity come first.

Conservation techniques which do not endanger consumer health or product quality, and do not have the potential for doing so, do not violate existing regulation. A Food and Drug Administration (FDA) official has said that there is no legal prohibition against the reuse or recycling of water provided certain conditions are met (Katsuyama, 1977). The FDA's Good Manufacturing Practices Regulations, Sec. 128.7 (2) limit water reuse by stating, "Water used for washing, rinsing, or conveying of food products shall not be reused for washing, rinsing, or conveying products in a manner that may result in contamination of food products."

The head of the sanitation section of the National Canners Association proposed the following health guidelines for water reuse in food processing operations.

1. That the water be free of microorganisms of public health significance.

2. That the water contain no chemicals in concentrations toxic or otherwise harmful to man.

3. That the water be free of any materials or compounds which could impart discolorations, off-flavor, or off-odor to the product or otherwise adversely affect its quality.

4. That the appearance and content of the water be aesthetically acceptable. (Katsuyama, 1977.)

All food processing firms in Minnesota are closely monitored by the Minnesota Department of Agriculture, the Food and Drug Administration of the United States Department of Health, Education and Welfare, and the United States Department of Agriculture (USDA). These agencies closely watch water supplies, water use, equipment maintenance, sanitation, and food preparation within the plant. Although there is some duplication of inspection staff and functions, there is very little confusion about what laws to obey. The Minnesota Department of Agriculture has adopted most of the USDA and FDA regulations for enforcement in this state. Discrepancies in interpretation are worked out in conferences between officials. There is certainly no agreement that all of the regulations are good or 100 percent effective. As new evidence and technical studies of food processing operations are obtained and new equipment is developed, regulations and requirements are updated. When regulations are not changed as fast as technology might allow, new conservation techniques are not adopted as soon as might be possible.

The USDA regulates poultry and meat slaughter and packing plants in Minnesota. The Minnesota Department of Agriculture is responsible for custom slaughter plants. The USDA enforces strict regulations on the water supplies, water use, and water reuse in federally inspected plants. Provisions of the law include the following:

1. The water supply shall be ample, clean, and potable; the pressure and facilities for distribution must adequate and protected against contamination and pollution.

2. A water potability report issued under the authority of the state health agency certifying to the potability of the water, must be provided.

3. Non-potable water must be restricted to parts of the plant where no poultry product is processed or otherwise handled and then only for limited purposes such as condensers not connected with potable water supply, vapor lines serving inedible-rendering tanks, and in sewer lines moving heavy solids and sewage. Non-potable water shall not be permitted for washing floors, areas, or equipment, nor in broilers, scalders, chill vats, or ice making machines.

4. In all cases, non-potable water lines shall be clearly identified and not be cross-connected with the potable water supply unless it is necessary for fire protection. Any such connections must have adequate breaks to assure against accidental contamination and must be approved by local authorities and the administrator.

5. Any untested water supply in official establishments must be treated as a non-potable supply (Carawan et al, 1974).

The Minnesota Department of Agriculture also has sanitary regulations for all food processing firms that it inspects. The basic intent of these rules is to insure that only potable water comes in contact with the product being prepared and that all equipment, facilities, and products are thoroughly and safely cleaned and maintained. Rules include requirements that water supplies must be ample, clean, and potable with adequate facilities for its distribution in the plant and its protection against contamination and pollution; establishments must be maintained in a sanitary manner; there must be efficient drainage and plumbing systems; and equipment using potable water must be installed to prevent back-siphonage into the potable water system (Minn. Rule Agr. 2174). Therefore, all water conservation efforts in this state must conform to current state and federal rules and regulations.

Certain government regulations detail that a specific amount of water must be used for particular processes in a plant. For example, the USDA requires poultry processors to add a minimum of one quart of fresh water per bird per minute in the scalding operation (Carawan et al., 1974). The Minnesota Department of Agriculture also states that the scalding equipment must be made of metal having smooth surfaces and of such a construction to permit proper and complete cleaning. The scalders must be constructed to prevent contamination of potable water lines and to permit continuous overflow (Minn. Rule Agr. 1710). Such types of regulations effectively limit water conservation in the interest of health and safety.

Another constraint on water conservation adoption is due to existing technologic impediments. As was mentioned earlier, food processing technology was developed with inexpensive water in mind. Therefore, most equipment and processes require certain minimum flows to function efficiently. Although these flows may be well below existing use levels, these requirements do put a lower boundary on applicable conservation techniques when existing technology is kept.

Firms do have the option of adapting existing facilities to new resource cost conditions by investing in newer facilities. However, these options represent an investment of capital funds which may not generate a suitable corporate level of return. These cost factors can weigh against and limit the adoption of new resource savings equipment.

## B. General Conservation Techniques.

Minnesota is characterized by a wide variety and number of agricultural processing plants. In general, no two plants are the same either in terms of product line, capital equipment, plant layout, financial or market position, water supply, or utility costs. Each plant adapts itself to specific needs and requirements, both technically and financially. It is, therefore, impossible to detail a framework for water conservation in a modern processing plant. All plants require specific measures and have unique constraints on technological feasibility and fiscal ability.

Conservation programs can be broken down into two very general types, common sense (inexpensive) and capital intensive. Many plants with conservation programs have found that significant water and dollar savings can be attained with minimal capital investments. Some operations have reduced water consumption by as much as 50 percent by simply instituting "good housekeeping" procedures, such as, fixing leaks and replacing inefficient nozzles. Other operations have not had as great a performance. However, all plants practicing common sense conservation eventually reach a point where additional savings are going to cost money, and in many cases the investment can be quite large. The redesign of equipment or the construction of cooling towers and waste treatment facilities entail sizable capital outlays. In most cases, these decisions must be made on the basis of a thorough analysis of the benefits and costs of each alternative and on the goals of the firm.

Water conservation approaches can be comprehensive or piecemeal. A comprehensive effort will be more thorough and efficient, but also may be beyond the financial capacity of certain firms. A step-by-step planning horizon may be the best approach for other industries. However, all firms should be cognizant of the fact that water use in the plant is tied into all other resource, capital, and product needs. In this sense, all conservation efforts must be comprehensive in order to be truly successful.

The following discussion lists and explains several major areas where conservation programs can be feasibly instituted in processing plants. There is no implication that each suggestion should, must, or can be implemented in all operations. They simply serve as guidelines and water conservation "tips" for concerned audiences. These basic recommendations were developed at a conference on water availability and conservation sponsored by the National Canners Association and the Canners League of California in 1977 (Katsuyama, 1977). Given the scope of agricultural processing in California and their recent experiences with drought, this organization is highly qualified to give good advice.

Recommendation #1 - Organizational Support:

A conservation program must have the support of the entire organizational structure, from top management to the factory worker. Management must be willing to dedicate available financial and manpower resources to implement the program. Workers must be retrained and reeducated to employ conservation measures in daily operations. Once programs are instituted, they must continually be followed up and supervised.

Recommendation #2 - Water Surveys:

One of the first requirements of water the conservation program is an in-plant water survey to locate water lines, water using equipment, points of fresh water use, flow patterns, and water discharge sources. Flows should be measured with water meters. A survey helps to identify and quantify major water using processes and can serve as a yardstick to measure results.

Recommendation #3 - Elimination of Waste:

A major step in the conservation effort is the elimination of unnecessary water and energy waste. These wastes include: unattended hoses, idle equipment with flowing water, excessive overflow, and leaks. Waste can in part be avoided through employee education, the repair and maintenance of equipment, and the purchase of some new equipment. There are currently several valves and nozzles on the market which automatically shut off the water supply when not in use and eliminate unnecessary overflows. Waste avoidance can yield significant water and dollar savings to firms at a minimal expense. Also, procedures should be developed which operate effectively with a minimum amount of water.

Recommendation #4 - Plant Cleanup Operations:

The sanitary requirements for all food processing industries account for a large percentage of a plant's daily water requirements. Although proper sanitation is rigidly enforced, both within the industry and from regulatory sources, it has been repeatedly shown that good standards can be maintained with much less water than is currently used. One option for water reduction is to use brooms, shovels, and scrapers to remove waste material from the floor, rather than flushing with high volume hoses. Although these tools have higher labor requirements and are less convenient, this mode of cleaning can present opportunities for water reduction savings.

In cleaning operations where hoses and sprays are required, greater cleaning and water use efficiency can be achieved by using equipment that produces high pressure cleaning power with low volumes of water. Hoses equipped with automatic shut-offs can be used to prevent hoses left running on the floor.

There are also potential savings available for systems which require chlorinated belt sprays to control slime on conveyor belts. Rather than have these sprays on continuously, the flow can be controlled with timers for intermittent water application. The frequency of application is dictated by the type of product and the type of belting. Similar cleaning and protection results can be achieved with a much smaller water input.

An additional method for reducing water use in cleanup operations is the continued development of equipment that is easily and inexpensively cleaned. Less water is needed to do a more effective job.

Recommendation #5 - Dry Conveyance of Solid Waste:

Large volumes of water can be conserved when solid waste materials are handled with dry rather than fluid methods. Augers, buckets, pans, bins, hoppers, and floor scrapers can often be employed with efficient results. The dry handling of waste also substantially reduces the organic strength of wastewater effluent from the plant, imparting additional savings to the plant from waste treatment costs. A third advantage to the use of dry by handling is that it can help promote the more efficient recovery a valuable industrial by-products.

Recommendation #6 - Minimize Fresh Water Use:

It is vital that fresh water is used to its maximum efficiency. A great deal of fresh water is used in the plant for the washing of raw products to remove dirt, debris, and contaminants. The key to effective cleaning is not the volume of water, but rather how the water is applied. Water can be saved in washing procedures by using high pressure valves and nozzles which require less water. Greater efficiency can be achieved through the proper placement of spray nozzles.

Proper maintenance is also important for minimizing water use. This includes the replacement of broken pipes and nozzles, and upkeep of general equipment.

There should also be an increased exploration into the use of non-potable water for operations where there is no likelihood of food contact or adulteration or violation of state and federal guidelines.

Rubber disc cleaning systems have been shown to be extremely effective for peeling and for raw product cleaning of many types of produce. These can be used to replace water driven systems. (Figure 2.)

Recommendation #7 - Water Transport of Products:

There should be continued development of dry or less intensive water using transportation of the product within the plant. In some instances, conveyor transport is more efficient than water flumes. Where flumes are necessary, they can be redesigned to carry the same amount of product using much less water.

Recommendation #8 - Recycle and Reuse:

In general, the reuse of water offers the greatest avenue for savings within a food processing firm. There are numerous options for reusing water which do not contaminate products or water supplies and are not in violation of state and federal sanitation requirements.

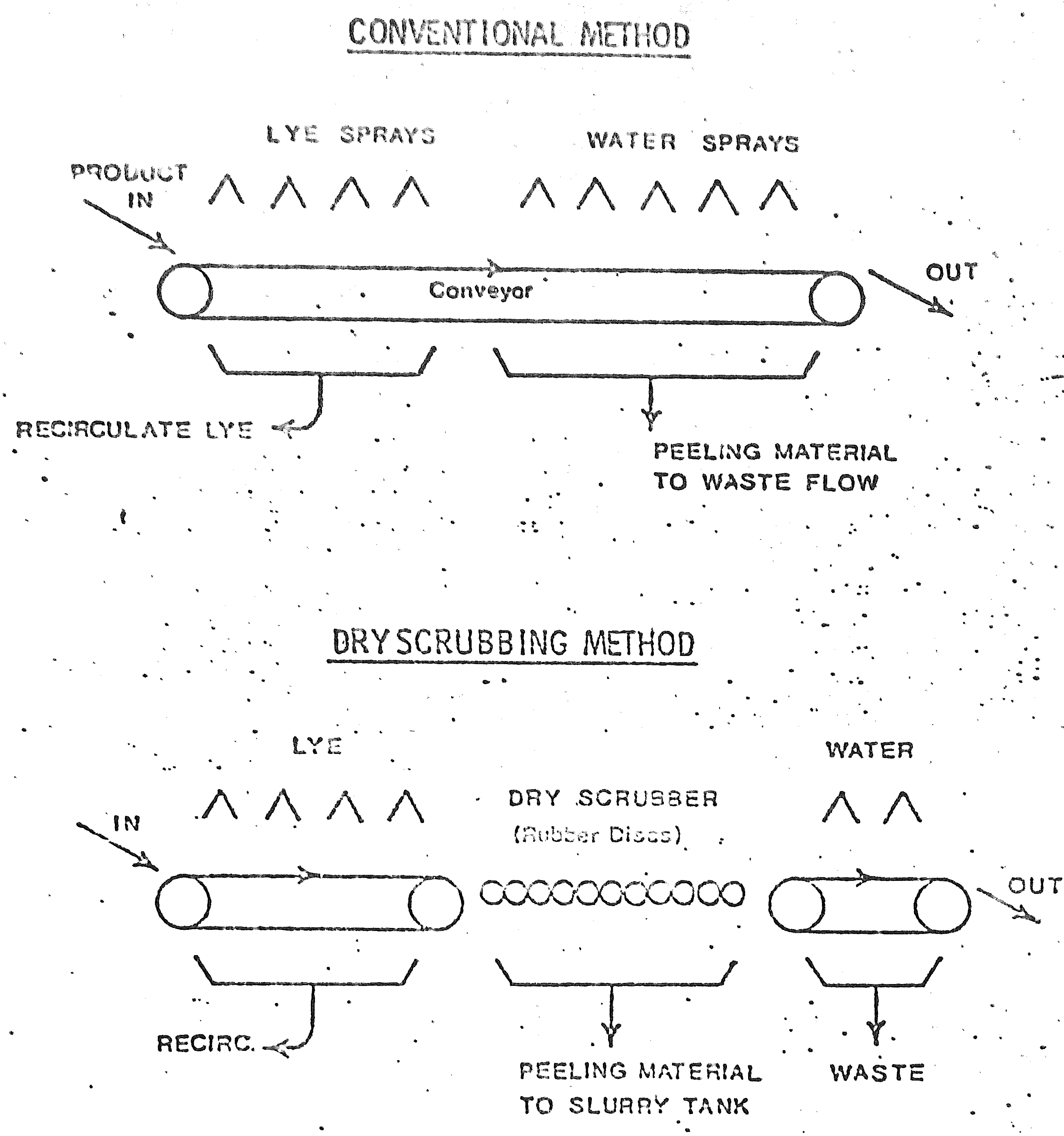



FIGURE 2: Diagram of conventional vs. dry scrubbing methods for peel removal.

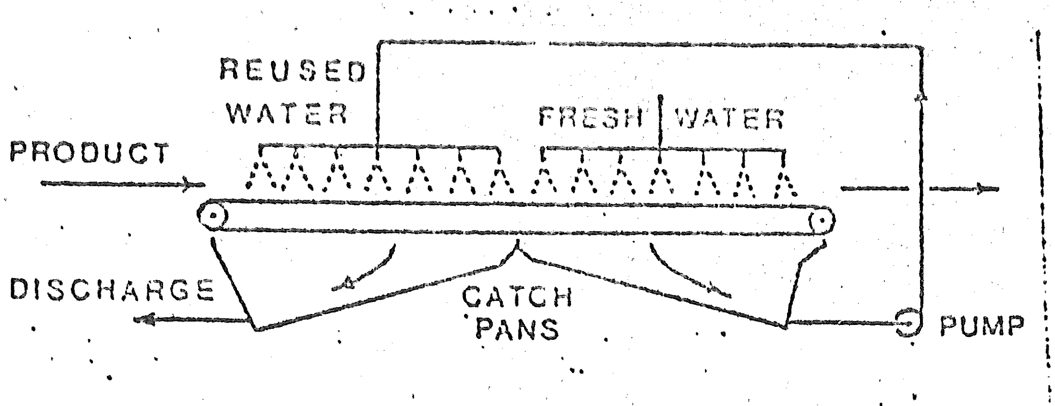
(Katsuyama, 1977)

One method of extending the use of water in dump tanks, flumes, and flood washers is to strictly regulate the replacement rates. Another method for intensifying water use is to use fresh replacement (makeup water) for rinsing products as it leaves the system and to use "reuse" water as the product enters the system. This is especially true in spray wash processes. Many studies have shown that the majority of contaminants on a product are removed during the first third to half of the washing cycle. Minor modifications to conventional washers can result in up to 50 percent reductions in fresh water use within the system. This is accomplished by limiting fresh water to the final spray rows, which still assures product cleanliness and reduces water consumption. The water from these final sprays can also be collected, screened, and used in the initial spray operation to remove contaminants and debris. If the water is still of suitable quality, it can be reused again in preceding wash or surge tanks. (Figure 3.)

This same type of process can also be used in spray cooler operations. Clean water collected from the final section of the coolers is very clean, and can easily be reused in other production systems without any treatment.

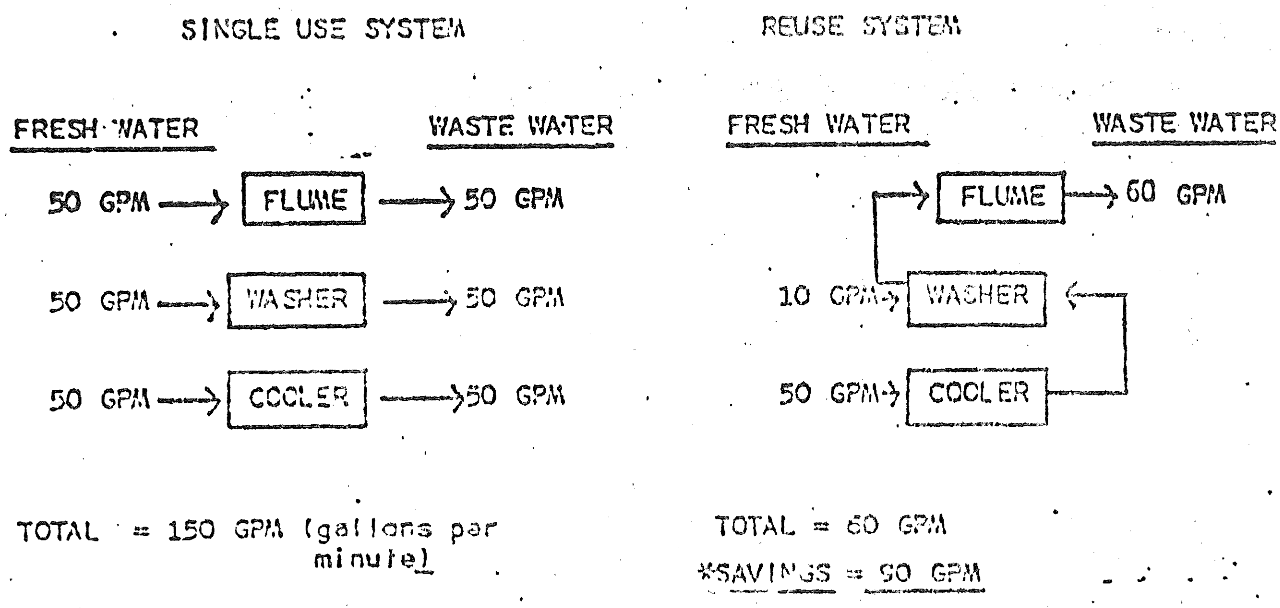
This method of replacing fresh water with clean waste water is known as the counter flow reuse pattern. It can be adapted with several modifications in many agricultural processing plants. When fresh water is used in each individual process the total water use rapidly mounts up. When good quality waste water is reused in earlier stages the savings can be substantial. Figure 4 gives a simple example of the nature of these savings.

FIGURE 3




(Katsuyama, 1977)

FIGURE 4




(Katsuyama, 1977)

An additional source of reusable water is from evaporators, especially in plants where products are concentrated. Large volumes of clean, warm water can be readily reused in many processes. Special advantages can be taken of the fact that the water has been heated. Studies have illustrated that warm water is much more effective in raw product washing.

C. Economic Incentives for Conservation.

Due to the numerous interrelationships of water use with most food processing plant operations, economic incentives for water conservation programs can be found in several different areas. The most immediate savings for in-plant water reductions is from the decreased cost of obtaining water supplies. Firms that rely on municipal water supplies can probably reduce their water bills. Also, communities supplying industry with water may witness substantial benefits from not having to invest in additional water supply capacity. Firms operating with private wells will also see substantial cost savings in the form of reduced supply costs.

A second component of water conservation savings is energy costs. Less water running through the plant means less energy is needed for water pumping, circulation, and heating. With the recent increases in fuel bills, agricultual firms have found major rewards in linking water conservation and energy conservation programs.

Another impetus for water conservation programs is rapidly escalating waste treatment costs, both internally and for municipal charges. Reductions in water use translate into reduced waste to be treated and reduced costs. Although the reduced flow of waste from a plant into a municipal waste treatment facility may have higher concentrations of effluents, increased concentration surcharges will usually be far outweighed by diminished charges on flow reductions.

Plants instituting an intensive water conservation program are usually conscientious about reducing waste loads leaving the plant. Due to the organic nature of most wastes leaving the plant, waste material is often suitable for use in agricultural and industrial inputs and products. Spray irrigation water, animal feeds, and glue are only a few of the products of agricultural waste. Therefore, reduced waste loads from water conservation techniques lead not only to reduced waste treatment costs but also to salable or usable commodities.

In general, a conservation effort relies heavily upon increased efficiency in plant operations. This includes: reductions in spillage, waste of product, handling charges, cleanup time and maintenance costs. Each of these improvements leads to decreased costs in production. Given the competitive nature of the food processing industry, cost reductions can lead to increased profit margins.

## D. Water Conservation Costs.

The advantages of water conservation must be weighed against the costs of these programs. Decisions must be made on an individual plant basis. Although it is difficult to assess the costs and problems of a program by generalization, there are typically some drawbacks to any conservation effort. These include: any capital equipment design costs, depreciation, and interest charges on invested equipment. There are also the costs of training and education, better supervision and attention, and the potential need for increased labor inputs. Some firms have also had difficulty with design problems, the need for more competent staff, and quality problems associated with newly introduced systems or processes which could not tolerate lower volumes of water. Plant officials must be cognizant of these costs prior to program inception.

## E. Water Conservation in Minnesota.

Water conservation decisions are made on an individual plant rather than on an industry wide basis. In Minnesota, the major stimulus for water use rate reductions is increasing costs of water supplies and, more importantly, of waste treatment. Random interviews were held with several different food processors in the state to get a rough approximation of what types of programs are being implemented. No effort was made to obtain a scientific sample or to get in touch with representatives of all types of firms.

Due to limitations in the survey technique, it is difficult to draw specific inferences about the status of conservation. Some plants had devoted a lot of time, effort, and money to conservation programs and felt it was worth the expense. Other firms contacted thought conservation was a good idea and were interested in any available information.

The most common source of information on new conservation technology or conservation "tips" were trade literature and contacts, sales representatives from equipment dealers and inspection tours of other processing plants. It appears that industry is more than willing to share ideas on conservation.

One interesting feature that developed from these interviews was that only one firm had attempted to measure the dollar benefits of conservation programs. Interestingly enough, this was the only firm that became interested in conservation because of a federally sponsored grant. The basic industrial assumption was that conservation was a good investment. Although firms knew how much water and energy was saved, they had not gone to the trouble of calculating the dollar value of their efforts.

The following presentation is a brief synopsis of some of the interviews held. The purpose is only to give a bare outline of some of the conservation programs in effect in the state.

F. Interview and Interim Report from Armor Energy Conservationist to the Minnesota Energy Agency.

In the early part of 1978, the Minnesota Energy Agency sponsored one full-time energy conservation position at Armor and Company, a hog processor, in South St. Paul. The purpose of the project was to illustrate that energy conservation measures could be instituted in a large meat packing plant which did not require engineering or a capital expenditure evaluation. The position was filled at an annual cost of $15,000 by a college graduate with no prior engineering or energy conservation expertise. During the first six months of the one year project, 55 energy conservation opportunities were successfully implemented for a projected annual energy savings of $24,662. These conservation applications included reductions in the use of hot water, lighting, power, and the repair of leaks and faulty valves.

The first step the conservationist took was to familiarize himself with the operations, utilities, and employees of the plant. This included an understanding of product flow within and between departments and the utilities, for their energy conservation importance and their safety ratings. An energy checklist was also created so that departments would be aware of which wastes to look for and which ones were priority wastes.

Another major step in the program was to set up procedures in which the conservation specialist could work effectively with management, supervisory staff, and plant employees. Energy waste inspections were instituted for all plant departments and are conducted at random times during the week, including night shifts and weekends. Inspection teams of varying memberships tour the plant, note conservation opportunities, notify appropriate department supervisors, and conduct follow-up inspections to insure wastes are eliminated. The conservation teams also leave florescent energy waste warning tags to identify specific energy wastes and conservation opportunities. The tags are used to alert area supervisors to waste, to show mechanics the location of items requiring repair, and to insure compliance with conservation projects already started.

The majority of the conservation effort in the plant was for "housekeeping" projects rather than for changes requiring capital expenditures. The conservation work did not include detailed energy or water use surveys by department or by operation. The major effort was spent on correcting waste rather than or measuring the degree of waste. Quality, production, and safety were operational factors that limited conservation implementation. Water use reductions in the plant resulted from changing to more efficient spray nozzles, turning off unnecessary rinses and washes, the elimination of water and steam leaks, turning off equipment when not in use, reduction of spillage, institution of faucet foot pedals, repair of faulty valves and the use of more efficient cleaning operations. The total estimated dollar savings for these water reductions is $22,533 per year. This savings is based on an estimated cost of 16 cents per thousand gallons of cold water and $1.32 per thousand gallons of water heated to an average temperature of 120 degrees F.

## G. Interview with French Fry Processor.

A large metropolitan french fry processor has reduced its water consumption from approximately 600 gallons per minute (gpm) four years ago to about 280 gpm presently. About 2/3 of its water supply is obtained from city supplies, the rest is furnished from private wells. Because the well water has too high of an iron content and harms machinery, well water is used only in the fluming operation which bring potatoes into the processing plant. The plant manager felt this plant was below average in its water use when compared to national average.

This plant processes institutional frozen fries. Most of the potatoes are trucked in from northwestern Minnesota. They use approximately 22 to 23 tons of raw potatoes per day. The plant operates 24 hours a day, seven days a week. The plant uses approximately 0.8 of a gallon of water per pound of french fries.

The following is a thumbnail description of the processing stages of french fry production. Potatoes are trucked to the plant and are stored in piles. The potatoes are then pumped into the plant with well water through a flume. The skin is softened with a lye and water solution, scrubbed off, and reclaimed for cattle feed operations. Potatoes then pass through several brush washers, are hand trimmed to remove damaged sections, and sliced into french fry strips. The strips are pumped and flumed to be inspected, graded, sized, and blanched at an average temperature of 160 to 180 degrees. The strips are again flumed to a drier to remove surface moisture and then oil blanched in a fryer. The final processing stages include: defatting, cooling, freezing, packaging, and shipping.

H. Conservation Steps for the French Fry Processor.

1. Water for fluming potatoes into the plant now comes from both fresh and recycled sources. Recycled water is screened and clarified. This measure has cut the fresh water requirements for this process by 60 to 70 percent.

2. Potatoes are now washed with scrubbing brushes and water rather than a total water wash. This has cut water use for washing from 120 to 40 gpm.

3. A high pressure cleaning system has been instituted in the plant utilizing hand gun, high-pressure nozzles which require far less water than the old large volume hoses without nozzles. The plant is cleaned at least once per shift. Cleanup now uses 2 to 3 gpm under 500 P.S.I. rather then the 10 gpm previously required.

4. Water is recycled from the cutting table and used for fluming potatoes to the shipping and grading process.

5. Blancher water is recycled for fluming strips from the inspection stage to the blancher.

6. Additives required in the production process are now pumped directly into the flume water between the blancher and the drier, rather than using a conveyor and water storage tank to add the additives.

7. Refrigerator cooling water is recycled within the refrigeration system.

8. Most processes are water metered and have pressure regulators which control the flow.

9. The water in the blancher will soon be controlled by a dextrose analyzer which will automatically control the volume of water coming into the blancher.

10. All the wastes in the plant are flumed. The water is screened and clarified, the wastes are removed for cattle feed, and the water is recycled in the plant for as long as it is of suitable quality to be used in the operations. It is then released into the municipal sewage system.

I. Interview With a Dairy Processor.

A large Minneosta dairy firm has instituted a water conservation systems in their plants. Their program is based more on housekeeping and common sense than on capital equipment. The major impetus for conservation has been the sharply escalating costs of municipal treatment of sewage. The plants have also been faced wth large increases in the costs of obtaining municipal water. Municipal water is mostly used as a backup and/or supplement to their own wells. The plants have also received a spin-off benefit from their conservation projects by increasing the efficiency of their operations and by increasing their product recovery (i.e., less product is going down the drain).

Within their conservation effort, the firm has introduced water saving, self-closing, regulated va[illegible] for nozzle heads. Also, cow water is reused for boiler feed water, condensers, refrigeration, and cleaning. Although pre-rinse and final rinse water is potable in their cleaning operations, cow water (water recovered from milk dehydration) is used in the intermediary stages. The in-plant compaign including employee education, posters, turning off hoses, fixing leaks, increased awareness, delegatory responsibility to supervisors.

J. Interview With a Sugar Beet Processor.

The sugar beet industry in Minnesota operates an intensive water recycling program in its plants. In one plant, water use has been cut back to less than 100 gallons per minute. They operate a fairly enclosed water and waste water treatment system, with water being reused several times in plant operations, screened, clarified, pumped out to holding and settling ponds, brought back to sufficient quality, and reused again. The majority of water lost in the system is due to evaporation and percolation. Water is added to the system from rainwater that collects in the pond system, make-up water from a private well system and water from the beets themselves. Excess water from the recirculation system is used to irrigate alfalfa.

K. Summary.

The agricultural processing sector of the Minnesota agricultural economy puts a large demand on water resources for plant operation and for waste assimilation. These demands can often tax local water supplies and water-related capital equipment. As a result, the costs of obtaining and using water resources have been increasing dramatically. Many firms are now adjusting their use rates of water to compensate for increased costs and diminished supplies. This is being done through a combination of innovative technological measures and the institution of efficient water using procedures within the plant. General conservation techniques include: 1) the development of an organizational structure within the plant to accomplish conservation goals, 2) water surveys, 3) elimination of waste, 4) efficient cleanup operations, 5) dry conveyance of waste, 6) dry product transport, and 7) recycling and reusing as much water as possible.

Economic incentives for water reductions include decreased costs of water supplies, waste treatment, and energy. Other benefits are increased plant efficiency, less spillage, and diminished waste of product. Costs of conservation programs include design and equipment charges, the costs of training and education, the need for better supervision and attention, and the potential need for increased labor inputs. The advantages of water conservation programs must be weighed against the costs of these efforts.

Federal and state sanitary regulation and the current technologic need for water supplies and attitutdes are the major constraints on water conservation implementation. However, many food processing firms have felt that water conservation programs are worth the expense and the problems. A sound conservation effort not only decreases operating costs, but also can help prolong water supplies and increase the availability of water for other uses.

## V. DOMESTIC WATER CONSUMPTION.

### A. Problems of Water Supply and Use.

Water has generally been considered a free resource of unlimited availability. This attitude was not questioned in past years, but is one which cannot be afforded at present. Water supply problems are not always due to a lack of sufficient annual supply but rather to non-uniform seasonal availability and irregular regional distribution (Ruesink, 1978). Minnesota is considered a "water-rich" state but within its boundaries, areas of limited supply exist and demand conflicts arise. In addition to drought, water supply problems may occur because of community growth, facility obsolescence, and capacity constraints (Great Lakes Basin Commission, 1978). Water supply is limited by competing uses, water quality problems, and the cost of distribution and treatment (Sharpe, 1978).

This discussion of water supply is limited to municipal and domestic use. Domestic water consumption is only an estimated six percent of total water use in the United States. In Minnesota, residential water withdrawal was 7.3 percent of the state's total withdrawals according to Minnesota Energy Agency estimates for 1976. Even a dramatic cut in water use by households would add only a proverbial drop in the bucket of available water. The reason that domestic use can cause a supply problems is the high concentration of domestic, commercial, and industrial demand. Municipal systems which show high per capita use values usually also serve some industrial user (Feth, 1973).

A composite diagram of municipal water use and wastewater output is shown in Figure 5. Reduction of peak loads by shifting the time of demand or reducing excess demand for water, offers the potential for reduced energy. Consumption and reduction or deferment of enlargements to existing water works facilities (McPherson, 1978).

For reference in this discussion of domestic water use, the average daily consumption for a family of four is 255 gallons. The approximate breakdown of use categories is as follows.

| | |
|---|---|
| Dishwashing | 15 |
| Cooking, Drinking | 12 |
| Utility Sink | 5 |
| Laundry | 35 |
| Bathing | 80 |
| Bathroom Sink | 8 |
| Toilet | 100 |
| TOTAL | 255 Gallons |

Variations in this average use value tend to correlate with the age of the children in the family and the level of family income.

B. Reasons for Water Conservation

Water planning for the future traditionally has been concerned chiefly with the problem of acquiring and developing additional supplies. Water conservation in water supply planning is a relatively new idea, usually turned to only in times of shortage. In 1972, when wastewater flow reduction was included in the Clean Water Act, PL 92-500, water conservation became a formal part of water management policy (Lattie & Vossbrink, 1977). In 1978, the Presidents's message on national water policy proposed financial assistance for states to incorporate water conservation into planning activities.

The questions, "What is water conservation?" and "Why does it warrant so much attention?" must be asked in light of the national

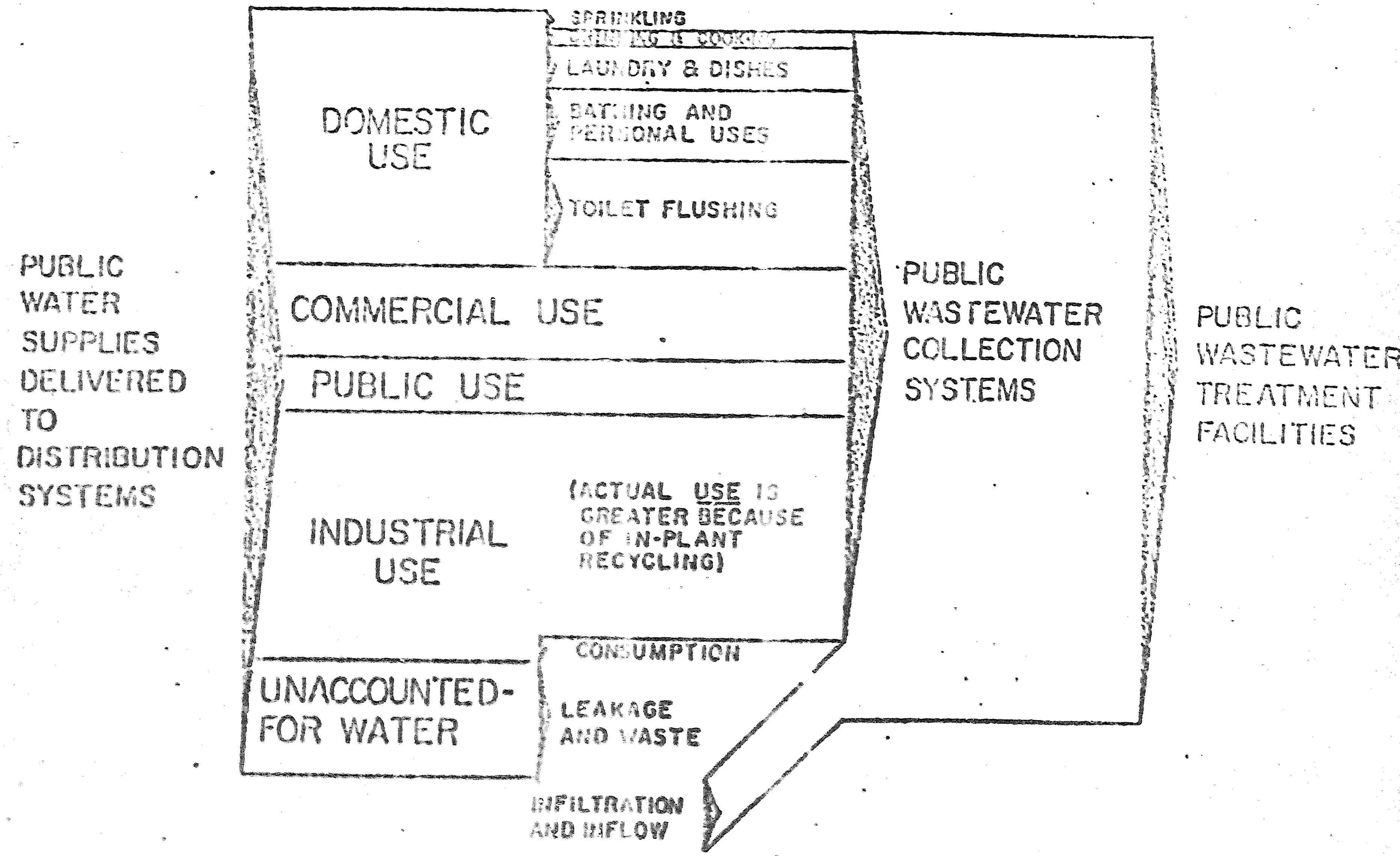



Figure 5. COMPOSITE PUBLIC WATER/WASTEWATER INPUT-OUTPUT BALANCE

interest it has gained. The term applies to a myriad of water management activities. Conservation generally means the protection of a resource from being used completely. Efficiency refers to the production of a desired effect without waste. With this difference in mind, a water conservation program for Minnesota should be efficient use/anti-waste rather than a purely conservation/anti-use campaign. Efficient water use is a tool which must be employed in managing Minnesota's water resources.

The benefits which are implied in a discussion of the water conservation are decreased demand and environmental preservation (Great Lakes Basin Commission, 1978). More specifically, if the demand for water on a public water supply system is reduced, the change will: 1) free presently developed supplies for other purposes; 2) prevent or delay the construction of costly water supply and treatment facilities; 3) decrease the amount of energy needed for pumping, treating, and heating water; and 4) reduce the required capacity for future wastewater treatment plants (U.S. Comptroller General, 1978).

In contrast to the seeming bandwagon of popularity which water conservation is receiving, opposition does exist to almost every option which can be proposed. People who are served by their own wells might argue that their water is free, in spite of the fact that energy bills may be reduced when less hot water is used and less water pumped. Municipal systems can be hurt financially if water demand drops. Minneapolis recently applied for a rate hike in December of 1978 because the water consumption dropped, thus reducing the amount of money paid to the water works.

Conservation measures must be appropriate for the individual supply and the circumstances. Implementation of conservation strategies might be accomplished with voluntary or mandatory participation. Two sets of conservation measures might be developed, one for drought conditions and one for normal precipitation. A water conservation program could include any number of the following strategies:

Figure 6. CONSERVATION STRATEGIES

Information/Education
Water Saving Devices
Metering
Pricing
Leak Monitoring and Control
Legislative Measures
Water Management Planning

Each of these items will be described and their feasibility will be discussed in the following section.

Formers of water conservation policy should recognize that water conservation is a management tool applicable at all times and in all areas of the country. To associate water conservation too closely with drought is a mistake. An even larger error would be to treat reduction in water demand as a separate issue unrelated to other significant natural resource problems, such as water pollution and energy consumption (Sharpe, 1973a). External influences in the form of federal legislaston, regional planning, and public pressure are promoting conservation of all natural resources to the point at which conservation must become a factor in a utility's overall planning (JAWWA, 1978).

C. Options for Programs.

For a long-term, continuing program, the goals are fairly broad; increased public awareness of the nature of domestic water supply system and the complexity of the problems they face in meeting the demand for water; recognition of the desirability of water conservation; understanding of economic and other costs and consequences of alternatives to water conservation; and perhaps other areas of concern to individual water supply regions (Lattie, 1977). These goals are important regardless of whether the move toward efficient water use is made for a water supply system or a community of private well owners. In order to implement a program, the amount of domestic water consumed must be known and consumers must be able to assess the economic impact of conservation measures. Specific objectives must be identified in order to be able to judge the success of the conservation strategy.

An example of a conservation program with a realistic scope was carried out in Dallas, Texax. The program was directed at the high-usage residential consumer during summer months. The objectives were:

1. To lower average residential consumption with respect to levels experienced in previous years under similar weather conditions.

2. To lower peak-hour and maximum-day demands on the treatment and distribution system (Rice & Shaw, 1978).

A basic and perhaps the single most effective tool used to promote general water conservation concepts is education and information. A large amount of printed material has been generated during the past few years describing domestic water conservation measures in the form of pamphlets, water bill inserts, and reprints of journal articles. A list of sample literature and the sponsoring agencies is provided in Appendix A. In most cases, the pamphlets describe water saving measures and devices which are easily installed. An example of the "helpful hints" to halt water waste is shown below in Figure 7.

Figure 7. <u>TEN TIPS TO HALT HOME WATER WASTE</u>

The public can save millions of gallons of water every day by following simple conservation practices. The American Water Works Association gives these ten basic tips to combat water waste in the home.

1. Check every faucet for leaks. A slow drip wastes 15 to 20 gallons a day.

2. Put a bit of food coloring in the toilet tank to see if it is leaking into the bowl. Leaky toilets are among the home's worst water wasters.

3. Do not use the toilet to flush away tissues, gum wrappers, cigarette butts, or other scraps. Every flush uses 5 to 7 gallons.

4. Do not shower too long or fill the tub too full. Five minutes for showering and about five inches in the tub is plenty.

5. Do not leave water running for tooth brushing, hand washing, vegetable cleaning or dish scraping. Use only what is needed, then turn it off.

6. Use dish and clothes washing machines with full loads only.

7. Do not let the faucet run for a cold drink. Keep a jug of water cooling the refrigerator.

8. Water the lawn and garden with good sense. Do it early or late, not in mid-day heat. See that the water goes where it should, not on sidewalks and driveways. Do not leave sprinklers on too long.

9. Never use the hose to clean off driveways and sidewalks. A broom is much better.

10. Wash the car from a bucket. Use the hose only to wet down before and rinse off afterwards (From the North Central Breeze, 1977.)

Water saving devices are generally inexpensive and long lasting. The key to their success is that they are installed without major disruption in water-use habits or lifestyle (Fletcher & Sharpe, 1978). The target appliances are all the major water users: toilets, faucets, showers, washing machines, and dishwashers. Figure 3 summarizes the devices which are used to reduce water waste.

Figure 8. WATER SAVING DEVICES

| Appliance | Device | Feature |
| --- | --- | --- |
| Toilet | Plastic bottle, plastic dam, ballcock | Displace water in the tank used for flushing |
| | Duel flush modification | One flush cycle for liquid wastes, one for solids |
| | Water saving toilets | 3.5 gallons/ flush |
| Faucet | Aerator | Even flow, reduced splashing, mix air with water |
| | Spray tap | Spray instead of single stream |
| Shower normally 5-10 gallons/min. | Flow control (orifice restrictor) | 3 gallons/minute flow |
| | Shower heads | 2-3.5 gallons/minute |
| Water Conserving Appliances | Smaller automatic dishwashers | Smaller load |
| | Washing machine | "Suds saver" |

Examples of the amounts of water which can be saved using waste conscious methods and water saving devices are shown in Figure 9.

An estimate of the effectiveness of these devices and education of consumers by voluntary installation is generally 9 to 10 percent

Figure 9. NORMAL WATER USE VERSUS WASTE CONSCIOUS USE

| | Normal Use | Water Conscious Use |
|---|---|---|
| Shower | Water running<br>25-50 gallons | Wet down, soap up, rinse<br>5 gallons |
| Toothbrushing | Tap running<br>10 gallons | Wet brush, rinse briefly<br>0.5 gallons |
| Tub bath | Full<br>36 gallons | Minimum water level<br>10-12 gallons |
| Shaving | Tap running<br>3-5 gallons | Fill basin<br>1 gallon |
| Dishwashing | Tap running<br>30 gallons | Wash & rinse in sink or pan<br>5 gallons |
| Automatic Dishwasher | Full cycle<br>16 gallons | Short cycle<br>7 gallons |
| Toilet flush | 5-7 gallons | Tank displacement or half flush devices<br>3-5 gallons |
| Hand washing | Tap running<br>2 gallons | Fill basin, rinse briefly<br>1 gallon |

(Compiled from American Water Works Association and the Office of Water Research and Technology, U.S. Department of Interior.)

reduction in water consumption (Consumer Reports, 1973). This result is direct, permanent, cost effective, and acceptable to consumers. Projections for utilization in California indicate that if all households are given bottles or dams for toilets and shower flow restrictors, and only 2 percent actually use them, the program will pay for itself in energy savings alone in 10 years (Sharpe, 1978a).

Direct energy savings from water use reduction include reduced pumping costs, reduced water heating costs, and reduced operating costs for wastewater treatment. Because hot water use is the second greatest consumer of residential energy (after home heating), conserving hot water can reduce energy consumption significantly (Fletcher & Sharpe, 1978). Indirect energy savings are decreased production of chemicals used in treatment processes and savings from not constructing additional water and wastewater treatment facilities (Great Lakes Basin Commission, 1978).

Pennsylvania State University and Gettysburg College installed shower flow controls at costs of $15,000 and $5,000, respectively, to yield estimated total savings of $100,000 and $13,000 per year. Calculations have also shown that the hydraulic life of sewage treatment plants can be extended where a modest conservation program requiring water-saving toilets in new construction is initiated (Sharpe, 1978b). Sewer overflows were the reason that the Washington Suburban Sanitary Commission ran the successful Cabin John pilot study in 1972, which demonstrated that water conservation could overcome sewer limitations (Bishop, 1975).

Water use reduction by people using individual aerobic septic systems does not result in appreciable cost savings, but operational problems associated with wastewater surges from home applicances are substantially reduced (Bernnett, 1975). When planning for construction of an on-site system, changes in design characteristics could be made to accommodate the estimated seven percent reduction in sewage flow due to water conservation practices (Fletcher & Sharpe, 1978).

Metering of water consumption is a third possible strategy in the development of a water conservation program. Without total metering of water consumption in a community, only a flat rate for water use can be charged. The recent federal position paper on water conservation appears to place heavy emphasis on pricing as a means to achieve reductions in water demand. Any pricing scheme other than a flat rate would be based on metered use (Sharpe, 1978a). The other pricing schemes and their effect on water use will be discussed later in this paper.

The initial cost of meter installation may be high and reduction in water use only temporary (Fletcher & Sharpe, 1978). The cost effectiveness of moving to the metering of all unmetered supplies is a difficult management consideration. Water use may be divided into required and discretionary use categories. Most sources agree that metering and even restrictive rate structures have little effect on required water use (i.e., that water needed to sustain life and manufacture goods). On the other hand, discretionary use is sensitive to metering and somewhat sensitive to price structure (Cornell, 1978). One author concludes the following points to be considered in line with metering:

1. Metering may not always be justified.
2. Metering is less justified holding other things constant in communities with declining populations than in communities with stable or growing populations.
3. The correct choice of pricing is crucial to the success of metering, an incorrect choice possibly turning potential efficiency gains into actual efficiency losses (Coelen, 1975).

Metering in growing municipalities is important in controlling growing demands on the capacity of municipal water supplies. It also allows water rates to be charged equitably--those larger or peak users on a system could be charged more for their water according to the conservation perspective. All water pricing schemes except for the flat charge require metering. In Minnesota, 23 percent of all municipalities use the flat charge rate structure (Gardner, 1977). In addition to those consumers, roughly 20 to 25 percent of the state's domestic water is self-supplied, thus unaffected by water pricing.

Water pricing options are the flat charge, uniform pricing, declining block, inverted block, peak load pricing, and seasonal pricing (GLBC, 1978). The pricing structure which is simple to administer and creates an incentive to conserve is uniform pricing. As water use rises, so will the water bill. Block pricing sells units of water at a gradation of cost. The inverted block raises that cost with every step increase in consumption, thus encouraging conservation.

In order to make pricing an effective municipal water conservation tool, rates would have to be raised significantly above current levels. Consumer resistance to such rate increases will definitely occur. However, W. E. Sharpe (1978a) states that "the altering of rate structures to a more equitable basis, the use of marginal cost of the pricing where possible, and making customers pay the true cost of the water they are served are reforms long overdue in the water business."

Another application of metering is in leakage detection both in the home and in the water supply system. Average water loss in a water supply system is 10 to 14 percent but many may register 30 to 40 percent "unaccounted for" water consumption (DeArment, 1975). The cost effectiveness of a leakage detection program depends on the estimated amount of water loss due to leakage, the time the leak would go unnoticed without a detection program, hydrological conditions, local water rates, and the cost of finding and repairing the leak versus the value of the lost water. In a large portion of Minnesota where ground water is the source of supply, the leaked water re-enters the aquifer. Although cost of treatment and pumping is lost, leak detection may not be considered useful in this situation (U.S. Comptroller General, 1978). Once undertaken, a leak detection program is a regular component in water waste reduction because it is implemented by the water works and does not rely on a high level of public interest as do the eductional approaches (McPherson, 1978).

D. Conclusions.

A report of this nature can only look at existing theory, methods, and the relative success of water conservation programs in order to make recommendations for Minnesota. The effectiveness of a water conservation strategy, composed of any number of the elements described, depends upon consumer acceptance. "At the consumer's level, education, income, inconvenience, and total costs are the major variables affecting domestic water conservation and installation of flow reduction devices" (Shaefer, 1975).

Examples of success stories in nearby states are seen in Illinois and Madison, Wisconsin. These moves toward waste reduction differ in that one was initiated at the state level and the other by the municipality. In Illinois, a low key approach was adopted by the state. Steps taken in their program are:

1. Three regional conference - quick methods of conserving water and material to get started including: descriptions of leak detection and repair, water saving devices, and a list of manufacturers.
2. Distribution of pamphlets on water conservation.
3. Communication with retail associations such as the hardware retailers (GLBC, 1977.)

Other activities which are presently being carried out or considered are:

1. Setting an example in state agencies.
2. Estabalishing community demonstration programs in four or five small communities.
3. Amending state plumbing codes.
4. Developing curriculum materials on wise water management for elementary schools.
5. Adopting new legislation for water management in critical areas (GLBC, 1977.)

Another example of a low key approach which might be appropriate for Minnesota includes the following water conservation elements:

1. Code requirements for water saving toilets in new construction.

2. Distribution of water saving devices for retrofit in existing homes, possibly at no charge to customers.

3. Industry, commercial, institutional, and in-house conservation programs.

The resource conservation ethic, energy costs, and waste treatment limitations should act as incentives in Minnesota without regard for water price considerations. Contingency plans for water shortage periods should be developed by municipalities, outlining public information programs, and the priorities for limitation of discretionary water use.

APPENDIX A.

| | |
|---|---|
| American Water Works Association<br>Denver, Colorado | 5 Basic Ways to Conserve Water<br>Be a Leak Seeker<br>25 Things You Can Do to Prevent Water Waste<br>By the Dawn's Early Light (sprinkling)<br>Water Conservation at Home/Why to - Where to - How to<br>The Story of Water Supply |
| State of California<br>Department of Water Resources<br>Metropolitan Water District of Southern California<br>Los Angeles, CA | Water Conservation<br>How Saving Water Saves Energy |
| Denver Water Department | 44 Ways to Be Water Wise<br>Film - Water Follies |
| East Bay Municipal Utility District<br>Oakland, CA | Project Water<br>EBMUD Water Conservation Education Program |
| Illinois<br>Interagency Water Management/ Conservation Committee<br>Springfield, IL | Water Conservation |
| Illinois Dept. of Transportation<br>Division of Water Resources<br>Chicago, IL | Wise Water Use, A Curriculum Supplement for Teachers<br>Wise Water Use is Good for the System |
| Madison Water Utility<br>Madison, WI | Water Conservation at Home - A Guide to Effective Water Use Indoor - Outdoor |

| | |
|---|---|
| Missouri<br>Department of Natural Resources | Making the Most of Water |
| National Water Well Association<br>Worthington, OH | Water Conservation in Your Home |
| U.S. Department of Agriculture<br>Soil Conservation Service | Water Conservation Tips for Stretching Water for Yards and Gardens |
| U.S. Department of the Interior<br>Geological Survey | Water and Industry<br>Water Use in the United States |
| Technology Transfer<br>Office of Water Research and Technology | Water Research Capsule Report<br>Water Conservation Devices<br>Residential Water Conservation |
| Washington Suburban Sanitary Commission<br>Hyattsville, MD | A Customer Handbook on Water<br>Water Saving |

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