SMALL WATERSHEDS

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ABSTRACT

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By

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Small watershed parameters are evaluated for their contributions toward a realistic definition of small watersheds. Hydrologic performance is selected as reflecting all the parameters in a working definition. The scope, results, applicability, deficiencies, and problems of small watershed research are examined. Small watershed hydrology is compared to that of large watersheds, and five general approaches for estimating runoff are evaluated. Policy formation is reviewed in terms of political maneuvering and citizen action. Basic water rights and water laws are traced. The special problems of urban watersheds are discussed. And, the financing of, deficiencies in, incentives for, objectives and methodology of, and the responsibilities for planning, developing, and managing small watersheds are studied as means for implementing policy.

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INTRODUCTION

Consider the small watershed. It is probably the most thoroughly researched, the most widely written about, and the most closely observed unit in water resources, which is logical since the small watershed forms the foundation of water resource development. Individually, small watersheds generate the surface runoff and ground water supplies that feed rivers and streams; collectively, small watersheds make up the major and minor river basins, each contributing its unique characteristics to the aggregate of basin resources. Any change in small watershed conditions effects a proportional change in the river basin regimen.

As an object of experimentation and research, the small watershed has been studied in depth; it has been surveyed, photographed, gaged, calibrated, synthesized, modeled, burned, denuded, eroded, plowed with and against the grain, sodded, cropped, reforested, paved, and even held pristine. It has been legislated upon. Yet, despite this massive research endeavor, the small watershed remains the unknown quantity in water resource development. The range in performance and in water yield and in response to treatment is as infinite and as unpredictable as the causal variables. Consequently, the small watershed defies sweeping, all-inclusive generalizations and all but the simplest of categorizations.

As an instrument in the decision-making process, the small watershed is curiously neglected. Considering that it bears the brunt of the research drive, that it has a propensity for public action at the local level, and that it has a susceptibility to management practices, the small watershed is conspicuously absent from the broad policy and planning spectrum. The recent emphasis on comprehensive planning threatens to completely subordinate small watersheds. This induced identity crisis leads to a needlessly fragmented, haphazard, and sometimes negative approach to small watershed activity.

To review current thinking on small watershed problems and to compile pertinent guidelines for policy makers, planners, designers, and administrators, four categories were set up for study: identification, research, hydrology, and policy, the latter category covering politics, planning, development, and management. These categories are highly inter-related and cannot be completely isolated. This results in a degree of repetition in order to maintain continuity. Attempting a comprehensive review precludes in-depth discussions on any given topic.

In studying small watersheds, several disciplines are encountered where specific references to small watersheds are not made in the literature, although the subject matter is relevant to small watershed work. The water quality and waste disposal phases of research, national politics and legislation, water law, water rights, and comprehensive planning are topics embracing general principles that can be applied to small watersheds.

CHAPTER 1

IDENTIFYING THE SMALL WATERSHED

The initial problem encountered in studying small watersheds is defining and identifying the subject. Apparently, everyone knows intuitively how to describe a small watershed: it is - well, you know, a small watershed. The term seems self-explanatory, and has become so commonplace that few authors go beyond titling their work as something dealing with small watersheds and throwing out an acreage in their introductory remarks to substantiate this usage.

Under this format, the small watershed is difficult to pin down. For example, PA 566 of 1954 sets the upper limits of a small watershed at 250,000 acres. The American Society of Civil Engineers defines small basins as drainage areas of up to 128,000 acres in extent.[1] The U. S. Bureau of Public Roads limits the small watershed to a more modest 20,000 acres.[2] Wisler and Brater suggest 6,400 acres.[3] The Soil

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[1]ASCE, Hydrology Handbook, 200

[2]U. S. Department of Commerce, Peak Rates of Runoff from Small Watersheds, 28

[3]C. O. Wisler and E. F. Brater, Hydrology, 248

Conservation Service has reduced the small watershed to a mere 2,000 acres.[4]

If a small watershed covers 2,000 acres, it cannot also extend over 20,000 acres, or 128,000 acres, or 250,000 acres. Arbitrarily setting a limiting acreage on small watersheds has muddied rather than clarified the waters.

What, then, is a small watershed? At what point does the small watershed become a river basin? (If the PA 566 criteria is adopted, more than 25 river basins in Michigan are technically small watersheds.) How do you recognize a small watershed? An adequate small watershed definition should satisfy a number of conditions: it should be universally applicable; it should be phrased in easily measured and understood watershed parameters; it should be flexible enough to incorporate new research discoveries; it should be sufficiently concrete for ready inclusion in legislative measures; and it should be logically derived rather than randomly adopted. Current small watershed definitions were formulated to meet the needs of the agency adopting them. The inevitable results of this approach are unrealistic and confusing variations within a single definitive parameter.

Watershed parameters fall into two major classes: natural and cultural. Under natural parameters, geometry, geology, and geography are the main subdivisions. Cultural parameters can be loosely broken down into land use, political

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[4]U. S. Department of Agriculture, _A Method for Estimating Volume and Rate of Runoff in Small Watersheds_, 1

subdivisions, ownership, and special interests. Most small watershed definitions try to incorporate one or more of these parameters. Size, the most easily determined of a watershed's natural features, does not provide a reliable working definition. The other parameters, both natural and cultural, will be briefly examined for their definitive potential.

Geographic features are altitude, latitude and longitude (or location), and orientation. Climate is a function of the geographic parameters. These factors play an important role in determining the hydrologic behavior of a watershed. They are easily established, but they are rigidly fixed, and with the possible exception of weather modification, they cannot be managed. Geographic parameters are not descriptive enough to base a small watershed definition on.

Another grouping of geographic features is found in surface features: soil and vegetative cover. These are readily observed parameters, but unlike the stable features of size, location, and orientation, surface features may change over night due to natural or cultural causes. Furthermore, the range of surface features on a given watershed may vary from bare rock to dense forest cover and attempting to describe small watersheds using this parameter would reduce small watersheds to even smaller mini-watersheds.

Geologic features include such diverse items as underlying strata, surface formations (hills, valleys, outcrops) glaciation history, and surface and underground drainage patterns. The first problem with using these parameters in

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small watershed definitions is the difficulty in determining them. Nor are these parameters flexible. Barring cataclysmic upheavals, geologic features change with the excruciating slowness of the natural erosion processes. Geologic parameters may be consistent throughout a drainage basin or may vary drastically on a few-acre tract. Their variability and undeterminability render them unsuitable for defining parameters.

Taken together or singly, natural watershed parameters are generally descriptive, subject to precise delineation, and easily measured. Most natural parameters are readily identified and understood by the general public. On the other hand, consistency and universal applicability are not assured. Reliable correlation among the various parameters is unlikely and meaningful statistical comparisons would require a complex reduction-to-common-factors system.

The second broad category of watershed characteristics, cultural parameters, are those man has superimposed upon the natural features, creating, for all practical purposes, artificial watersheds. In contrast to the well-defined and stable natural parameters, the cultural categories tend to be capricious and often imaginary aids to functional operations: political boundaries, administrative districts, real estate subdivisions, and planning units.

Cultural features may be logical, practical, and even necessary conveniences, but each governing agency, each manager, each subdivider, and each planner is free to draw his own boundaries subject only to local restrictions which vary from township to township, from county to county, and from region to region. A typical drainage district map shows the absurdity of defining a watershed in political administration or surveying terms. Water cannot respect political boundaries; the only imaginary lines it observes are contours.

Cultural features may also be studied through land-use patterns. Under this system, watersheds may be wild, rural, suburban, or urban. A wild watershed is one that has escaped man's handiwork, except for his infrequent trespasses for his recreational pursuits like hunting or hiking. Rural watersheds are wild watersheds that have been tamed for forestry, agriculture, or organized recreation. They are sparsely populated, yet show the marked effects of man's presence: clearing and building. The suburban watershed retains some natural features but these are rapidly being eradicated by the process of urbanization. The urban watershed, except for an occasional park, has lost any resemblance to its wild cousin. It is densely populated, paved, and polluted. The degree of watershed deterioration in the form of urbanization can be established visually from aerial photographs or in the field. But land use, aside from its cataloging function, is not an adequate parameter for identifying a small watershed.

Ownership, like land use, can better be used for describing rather than for delineating the extent of small watersheds. An entire watershed may be owned by an individual and held for private use. Private ownership might differentiate a small watershed from a river basin as it is unlikely that a single owner would acquire an entire basin, but there is no guarantee that a small watershed will be individually owned; it may be held by the government as a part of the public domain or as state or national forests or parks. Watersheds may also be under corporate or municipal ownership but the most likely case for both large and small watersheds is a conglomerate of owners representing all three classes.

Special interests are responsible for most watershed activity, and the extent of the watershed involved will vary with the activity. A watershed for upstream conservation protection or stabilization works would be much smaller than the watershed involved in a downstream flood control project. Likewise, there are optimum watershed sizes for developing and managing which will be independent of natural parameters. In all probability, such watershed areas will conform to political boundaries. Special interest groups will seek to maximize certain watershed parameters to the exclusion of others. The problem with defining a watershed in special interest terms is that they are mutually exclusive and the limits for one group's needs would be restrictive to another group. Under the special interest format, a watershed could be defined to include a certain area, a specific soil type, a predetermined population, or any number of variables, none of which are sufficient for defining a small watershed.

Cultural watershed parameters provide no better definitive base than do the natural parameters. They are useful for descriptive or inventory purposes. They are subject to change at will and while such changes might substantially change the watershed's behavior, the parameters themselves are too ambiguous and too arbitrary to be satisfactory for defining small watersheds.

The only remaining alternative for defining a small watershed lies in its performance or its function. Definitions can be phrased in terms of how a watershed reacts to changing conditions. The primary watershed function is water production; in this sense, the watershed becomes a catchment area and a hydrologic performance parameter is suggested. Many hydrologists consider a small watershed to be one on which the runoff characteristics and the resulting hydrograph are determined by overland flow rather than by flow in the river channel. Seemingly simple, this definition actually integrates most of the natural and cultural parameters previously rejected as being non-definitive in themselves. Runoff is determined to various degrees by watershed size, location, geology, surface features, land use, season, and precipitation. Hydrographs, in turn, are derived from runoff. Consequently, a hydrologic definition subtly includes both natural and cultural parameters. It can be universally applied without complicated adjustments to the independent variables. The end result - performance - is the limiting factor.

There are problems with a hydrologic definition, however. It is not as definite as might be desired for legislative use. Determining a hydrograph is not a task for the layman; it is

a technical problem that requires both hydrologic expertise and engineering judgment. It requires a detailed description of the watershed, and it is helpful, but not necessary, to have hydrologic measurements on rainfall and stream flow. Yet, in spite of these somewhat rigorous requirements, hydrologic performance is the most effective method for separating small watersheds from large watersheds and river basins.

CHAPTER 2

SMALL WATERSHED RESEARCH

Realistic watershed development and management is dependent upon realistic watershed research. Research can provide pertinent background data that is essential for planning. It is not sufficient to have an accurate description of a watershed. The most thorough tabulation of watershed parameters remains a mere inventory without the related research results required to establish performance predictions based on the complex interactions of the parameters.

Research should be conducted to fill the gaps in the knowledge of watershed parameters and their functions. Watershed research can be justified only if a new and widely applicable truth is discovered or if an accepted dogma is either reconfirmed or refuted. In order to accumulate meaningful results, the complete physical make-up of a watershed should be understood and the watershed should be completely instrumented in order to chart all water movement and storage. Finally, research should study quality aspects in their historical and environmental connotations.

The thrust of most past research has been on sampling specific watersheds, then superimposing the results on

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watersheds having reasonably similar climatic and physiographic parameters. No matter how similar two watersheds may seem, however, each will have individual conditions and problems which are not duplicated and therefore cannot be legitimately studied on another watershed.

The ultimate objective of research in surface water hydrology is an understanding of the physical processes involved in the phenomenon of runoff from the time the raindrop hits the surface of the ground to the time it is available for use. Hydrologic research shares with other segments of watershed activities a joint interest in precipitation, water use, infiltration, aquifer recharge, water quality, and flood flows.

Research in surface water hydrology supplies data for the designers and operators of systems controlling, utilizing, or disposing of surface water. The principal stimulus for hydrologic research is in the continued expressed need of those engaged in water resources work.

In reviewing past research reports, the most successful watershed research in terms of predictive applicability and reliability appears to be that which relates structural or land-use techniques to reducing sedimentation. Measurements on stream loads before and after conservation practices are installed are easily and reliably measured. The cause and effect relationships are directly tied together without being influenced to any appreciable extent by watershed parameters.

The effects of applying similar conservation measures to changing peak discharges are not so easily determined.

When the research effort turns from quality to quantity, all the uncertainties and vagrancies of the hydrologic cycle are encountered. Measuring the effects of watershed management on water yield, for which peak discharge is an upper envelope, involves the combined effects of precipitation, soil moisture content, season, soil structure, geology, solar energy, ground water levels, and climatic conditions, all of which are more significant in determining water yield than are conservation measures.

A third area of research delving into land-use changes has been evaluating the downstream effects of upstream protective works. Here, the dominant role is taken by such factors as channel storage, overland flow, surface detention, drainage density, basin geometry, and the storm pattern, while surface measures have only a minor influence on runoff or on downstream flooding potential. It is difficult to outline the sphere of influence of a watershed as watersheds are not self-contained entities and what is done to one will affect the adjacent watersheds. Just how far downstream the consequences of management on a given watershed can be carried has not been established by research. To complicate matters, all the variables listed under water yield investigations are active in and must be considered in evaluating upstream - downstream relationships.

Water-related problems center about man - his knowledge, or lack of it, his institutions, and his objectives. Most watershed research has studied the water resources rather than the role these resources play in the socio-economic system. Granted, the study of water resources cannot employ traditional economic analysis because of valuation problems, institutional constraints and uncertainty. A group of economists working under Kneese have attacked the economic problem but there has been virtually no research attempt to correlate the significant systems of organized social action dealing with water resource development and management with the dynamics and interactions of these systems. As the demands upon a fixed water supply increase, an understanding of the mechanics of social systems is going to be vital in securing adjustments in water uses.

In surface water hydrology, three areas that should be considered as high-priority research areas are: studies of stochastic hydrology, applied research needed to provide reliable and practical methods of extending observed data to encompass the variability existing in hydrologic events, and methods to develop synthetic hydrology for the many areas where hydrologic measurements are not available. The aggregate investment in small structural works far exceeds the cost of the major water developments. Of particular need in small watershed research is a means for generalizing stream flow records and for better methods of analyzing and presenting results. Ephemeral streams are often the only source of water supply in arid and semi-arid watersheds. Research must develop general relationships for estimating runoff, water losses, and recharge in these regions.

Neglected areas in watershed research, in addition to surface-water hydrology, include ground water research, water quality research, the socio-economic spectrum, the patterns of precipitation that produce small-area floods, and understanding the thermodynamics of the hydrologic cycle. But the most glaring research gap is in the field of urban hydrology where until a year or two ago there was simply no research being done. The direction of research on small experimental watersheds has been toward agriculture, forestry, and wilderness preservation, none of which are remotely related to urban watersheds whose streams are little more than open (or enclosed) sewers, and whose open spaces are vast impervious seas of asphalt and concrete.

In April of 1969, the American Society of Civil Engineers published "Basic Information Needs in Urban Hydrology," which with its 1968 predecessor, "Urban Water Resources Research," identifies the major problems in urban hydrology and recommends studies and research projects for their solution. Among the salient recommendations were: all aspects of water resources research should be prosecuted concurrently with provisions for ample inter-communication and feed-back; the need for a national research program directed by a central body to stimulate, coordinate, and undertake urban water resources research; the acquisition of rainfall-runoff-quality data should be started as soon as possible to develop inputs suitable both for future use and for current management and operation of water works; and existing mathematical models for simulating the rainfall-runoff

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runoff-quality process should be continually tested and updated, starting with the meager data now available.

The recommended research plan begins with several pilot installations for measuring hydrologic events on catchments of about 50 acres in size being set up concurrently with model development and the analysis of time and space variations of rainfall. Subsequent phases include establishing a national data collection network, setting up regional models, defining regional storm patterns, developing storm drainage criteria for planning, design, and operation of facilities, and providing guidelines for local jurisdictions for operating existing facilities. Under this research format, potential benefits can be obtained in the comprehensive, multi-purpose development of urban water on a scale greater than that realized for river basins.

Water and Metropolitan Man, a research conference cosponsored by the Engineering Foundation and the American Society of Civil Engineers in August of 1968 listed eleven areas where urban research was needed: in communications, planning, social impact, management, legal and institutional aspects, regulation, data needs, precipitation, detention storage, design problems, and systems analysis.

Among the most critical research needs are determined efforts to find means and ways to link engineering systems to social systems in research designs. The goal is to learn how elements of engineering systems affect, relate to, or interact with elements of the social system. Research collaboration between social scientists and engineers should be directed to the following questions and needs:

1. How legal systems relate to and affect both engineering and social systems.

2. A rigorous definition of the responsibilities of each segment of the public and private decision making arenas.

3. Ways to consolidate water resource administration.

4. Criteria for preserving engineering, safety, and aesthetic values.

5. An understanding of motivating mechanisms.

To accomplish this, research will have to more clearly define concepts, words, and terms, so they are mutually understandable by social scientists, engineers, and other members of the urban water resources team.

Water quality has become a pressing national concern. Rapidly expanding populations require more of everything - especially of good water. The greater the urbanization of a region, the more pronounced is the interdependence of water supply and waste disposal with the ironic results that local water fronts become blighted, forcing municipalities to seek water supplies from more distant sources as Detroit has had to do.

The quality of water is influenced by usage, natural pollution, urban and agricultural drainage, solid waste disposal practices, recreational activities, and even political implementations. To date, most water quality research has been directed toward determining whether or not water can be made suitable for use at a reasonable cost. It seems that the research focus depends upon whether pollution by waste disposal is imposing an external cost on subsequent users, or is interfering with the optimum use of water resources, or is threatening the well-being of certain groups.

A survey of current water quality research indicates that deficiencies exist in:

1. improving treatment processes
2. translating theory to design
3. optimizing water quality management
4. developing stream use criteria
5. ground water quality management
6. improving marine disposal systems
7. storm drainage water quality

As is the case with most resources, accepted methods of exploitation are not questioned until a crisis - shortage, low quality or whatever - arises. Water research is seldom directed to revolutionary concepts while tried methods seem to be working. This is especially true in water quality where waterborne waste disposal has been accepted as a fact of life. Only when the public raises an outcry are researchers prompted into seeking remedial alternatives.

As an illustration of this public apathy problem, the February 23, 1970 edition of Newsweek carried an article on New York's Dead Sea, the site of the Metropolitan New York Sewage Treatment Plant's sewage sludge dumping grounds for the past 40 years. Suddenly, New Yorkers realized that they had a 20 square mile problem area 12 miles offshore. Why? The dumpings were beginning to wash up on their sandy beaches. No one was concerned that the dumpings had smothered seaweed and other vegetation on the ocean floor, or that fish in the area are afflicted with fin rot, or that mollusks taken within six miles of the dumping ground are unfit to eat, except for ecologists who are worried about the enormous quantities of wastes being dumped into the oceans. The Sandy Hook Marine Laboratory in New Jersey, after a fifteen month study, concluded that if waste disposal were stopped immediately, it would take at least ten years for the dead sea to regenerate itself. This situation does have research implications: waste disposal is of concern for small watersheds as well as for metropolitan areas. Other methods of waste disposal are little better than dumping at sea. Incineration pollutes the air. Converting sludge to fertilizer is not economically successful. Clearly, research must develop an improved basis for designing and implementing economical, esthetic and environmentally safe methods of waste disposal, or if complete pollution abatement is preferred, research must develop practical new waste-handling techniques.

Considering that about 70 percent of precipitation is lost to evapotranspiration, there has been little creative research in this area. Research has tried to measure how many inches of water plant A transpires annually, or how much water is lost per square inch of leaf surface area when the need is for research on managing precipitation in areas as diverse as weather modification, breeding plants that conserve water, the effects of chemically treating plants and their growing mediums to retard water losses, the timing of water applications, and, of course, continuing the most studied facet of evapotranspiration, land-use management.

Recent trends in watershed research have seen economic analysis become an integral element in the search for optimum water utilization; cross-disciplinary research become the rule rather than the exception; new disciplines developed using computers and requiring precise definitions, clear and accurate determinations of relationships, and specific quantitative data; an increased emphasis on recreation, water quality, and management of water-related land uses; the recognition of political, administrative, and institutional factors as significant causal forces, though the agencies which allocate water resources and protect their quality need more research attention; and a redefining of federal, state, and local roles as exemplified in the Water Resources Research Act of 1964.

Studies of political and financial structures; engineering problems and solutions; legal constraints, encouragements, and deficiencies; operational and maintenance requirements, and the time required to produce results through successfully implemented urban water resource plans should be undertaken to identify the common ingredients that can be used to expedite all phases of water resource activity. Last, but not least, there is a need for increasing the number of skilled professionals trained to carry on the research effort outlined above.

How is a research watershed selected? To begin with, the research team must have a research plan outlining their goals. Watershed selection will depend upon many things: the type of data to be obtained, the anticipated duration of the research project, the accessibility of the site, the ease of installing measuring devices, the ease of altering watershed parameters for study, and watershed stability, to name a few. To maintain control over research watersheds, the research plan should provide for avoiding unexpected ownership changes during the study period. Other guides for selecting research watersheds suggest that geology and soils should be as uniform as possible, not merely related, and that a single land-use or management practice should prevail throughout the watershed.

There are two types of research watersheds: experimental watersheds and representative watersheds. The essential difference in the two are the end results of the research effort. The experimental watershed is chosen and instrumented to study hydrologic phenomena - rainfall or runoff. On the other hand, a representative watershed is just what its name implies: a watershed chosen and instrumented to represent all watersheds with similar features instead of making measurements on every watershed. Experimental watershed research is aimed at discovering significant principles, relationships, and factors that can be incorporated in prediction schemes, helping to answer such questions as what will be the peak runoff from a watershed and how often can such a discharge be expected to occur? With representative watershed research, data is collected which can be applied more or less directly to watersheds where the data in question can not practically be gathered.

Watershed research is undertaken by many organizations, but these organizations can be loosely grouped into four categories. Government agencies, educational institutions, corporations, and foundations, and private groups or individuals may conduct or sponsor research. Many colleges and universities maintain experimental stations for watershed research. Notable are Utah State University at Logan, the University of Illinois at Urbana, and Colorado State University at Fort Collins. The United States Geological Survey, the Bureau of Reclamation, the Soil Conservation Service, and the Army Corps of Engineers are a few of the federal agencies that both conduct and finance research. Various foundations and professional societies provide scholarships and research grants, in addition to providing official organs for publishing research results. Water Resources Research, published by the American Geophysical Union, the Journal of the Irrigation and Drainage Division of the American Society of Civil Engineers, the American Water Resources Bulletin, the Journal of Forestry, and Agricultural Engineering are several publications that carry research articles relating to water resources, along with features on planning, developing, and managing them.

The principal difficulties in applying research results from one watershed to another seemingly identical watershed lie below the surface in the area of poorly defined soil and geologic formations as they relate to moisture storage and movement. All too often, the soil moisture and ground water are not measured, although they are important phases of hydrologic balances. The problem may arise from the initial selection of a watershed on which underground measurements are extremely difficult to perform. Considering the small size of experimental watersheds, incomplete basic data can lead to unscientific and unreliable results.

In addition to the problems in applying research results, there are several problems built into the research effort itself. To begin with, hydrologic research, to be at all useful, must extend over a number of years. Just to gather the basic data prior to any experimentation takes a minimum of one year. Financing small watershed research can be a problem which is also related to duration. The lapse of time between project implementation and meaningful results is discouragingly long. To the sponsor, watershed research may seem an open-ended effort.

Several factors complicate the staffing of research projects. Duration again is a prime consideration. Only the most dedicated scientists are willing to devote their time and talents to a single project extending over many years. The work is not glamourous; it is rather tedious and repetitious. The nature of hydrologic research tends to confine it to isolated areas, and once a research watershed is established, an individual can adequately collect data. Then, too, qualified personnel are in limited supply. Finally, there is the problem of applying research data. After spending years to collect and analyze data, the research team may find that their results apply only to the research watershed from which they were gleaned.

CHAPTER 3

SMALL WATERSHED HYDROLOGY

Small watershed hydrology is important for several reasons: the definition of a small watershed developed in Chapter 1 is phrased in terms of hydrologic performance; small watershed research is most likely to be centered about some phase of the hydrologic cycle; watershed planning, development, and management practices are applied to hydrologic phenomenon; and, reliable results in any of these fields will depend upon sound procedures for evaluating the dependable water supply. With increasing competition for water, and the greater need to control storm runoff, the need for greater accuracy in estimating water yields and peak flows becomes crucial.

The primary hydrologic function of a watershed is generating water. Water yield is determined by subtracting consumptive uses by vegetation, ground water underflow, and deep seepage from the precipitation falling on a watershed. Water yield is subject to the random distribution of hydrologic events, and all surface water development projects are subject to the uncertainties inherent in these events. In the past, the dependability of water resources has been based on records of stream flow using mass curve analyses, flow duration procedures, or flood routing methods. This approach, while tedious, is easy to follow and is easy to explain to the public. The problems with this approach are that a duplication of past events is all but impossible, the longer the period of record, the more restrictive it becomes, and the difficulties in applying data from one watershed to another. Stochastic hydrology is a means of circumventing natural vagrancies through manipulating statistical characteristics of hydrologic variables to solve hydrologic problems. Regardless of the approach, studies of hydrologic behavior are concerned with the volume and the time-distribution of rainfall and runoff.

Precipitation is the most significant variable in determining runoff. Precipitation may be either in the form of rain or snow. Rainfall results from frontal activity or from convection currents, the latter of which is of chief concern in small watershed hydrology. Convective storms, usually summer thunderstorms, are essentially local storms, covering areas of 500 square miles or less. Small storms can be defined with a gage density of one gage per ten to twenty square miles, and the point rainfall records so obtained can be applied in designing small watershed hydraulic structures, although point rainfall may not be adequate for predicting areal rainfall because of the extreme variations in intensity over a relatively small area. Rainfall intensities are generally highest at the beginning of a storm.

Precipitation varies with a number of factors, including temperature, geographic location, orientation, and season. Precipitation depths will, to a certain extent, increase with altitude, and they tend to be greater in headwater areas than in downstream areas due to the difference in elevation.

Precipitation data may be used in several ways. Point measurement applications (inches of rainfall) have already been mentioned. Recording stations produce mass curves, plots of rainfall accumulation over time, which can be used to estimate rainfall distribution at non-recording stations in the same general area. Intensity-duration-frequency curves can be constructed for use in design procedures. For design purposes, critical rainfall durations are related to concentration times of the watershed.

When converting rainfall to runoff, precipitation is the independent variable. Ways in which it may vary include total storm precipitation, basal area, maximum precipitation depths at various time intervals, duration of the total storm rainfall, rainfall distribution (or storm pattern), and direction of the storm's path across the watershed. Variables related to the watershed itself include antecedent soil moisture, vegetation crown spread, and watershed area, slope, and length. From these independent variables, the dependent runoff variables are peak runoff rates, total runoff volume, rise time, lag time, and the duration of runoff.

Surface water hydrology deals primarily with the volume and characteristics of runoff. Surface runoff results in a measureable inflow to a channel system and has definitely expressed fluctuations in discharge. These fluctuations are due to rapidly changing natural runoff factors: soil moisture, humidity, evaporation, and precipitation. Research indicates that peak runoff rates are most influenced by 15-minute rainfall depths. For short convective storms, runoff increases as precipitation increases, and decreases as crown spread of vegetation and soil moisture increase. A decrease of runoff with an increase in soil moisture seems contrary to common sense, but may be explained in having soil moisture condition normally dry surfaces to increase infiltration rates.

Overland flow may result from infiltration rate limitations even though the soil profile has unused storage capacity. Typically, this comes about from high intensity storms or low surface permeability. When surface soils become saturated, infiltration rates drop due to increased capillary heads in the soil profile. This type of runoff is typical of low-intensity, long-duration storms which produce only moderate runoff.

Considering runoff as a simple mathematical expression of precipitation minus losses, the problem becomes one of evaluation of losses: rainfall may be retained on vegetation and never enter the runoff process; it may evaporate during the runoff process; or, it may be retained in surface depressions. Infiltration and evapotranspiration vary with time, moisture content, porosity, and the permeability of the soil profile.

The general effect of natural surface storage is to delay concentration times and to decrease peak rates of discharge.

Watersheds differ greatly in their effective storage capacities. Some may quickly fill their storage capacities while others may never reach this condition. Interception, depression storage, and the soil profile provide temporary storages with high uptake rates but with limited capacity. Such storage retains water for later infiltration that might otherwise become surface runoff. Infiltration rates, depression storage, overland flow rates, ground water discharges, and soil profile storage will vary throughout the watershed. Of the losses, interception, depression storage, and soil profile elements will completely dominate shower and small storm runoff and will also be prominent in the early stages of runoff from large streams.

Precipitation which remains after deducting losses is responsible for the observed flow at the outlet of a watershed. It is best described by a hydrograph. A runoff hydrograph is a graph of discharge versus time and consists of base flow, a rising limb, a peak, and a recession limb, all of which depend on watershed characteristics and on the runoff producing storm. The ascending limb is determined by both storm pattern and watershed characteristics, while the recession limb is determined by storage depletion which is a function of watershed characteristics only. The recession curve begins when surface inflow to the channel system ends and is derived from three types of storage: stream, surface, and ground water.

A special form of runoff hydrograph is known as the unit hydrograph. It defines a unit storm having a total rainfall of one inch. The shape of the watershed is a direct indication of the shape of the unit hydrograph. Also affecting hydrograph shape are: size, slope, surface storage, drainage density, soil mantle, vegetal cover, and sub-surface drainage zones. The normal variation in the unit hydrograph as the drainage area becomes larger is a lengthening of the time base, a gradual increase in lag time, and a gradual increase in peak flow. Steepening watershed slopes will increase both the volume and the rate of peak flow. If rainfall is uniformly distributed over the watershed, the concentration time will equal the time to peak discharge, and a storm duration equal to the time of concentration will result in the maximum rate of discharge.

The hydrologic performance definition separated large and small watersheds by the effects of overland flow on the runoff hydrograph. Further comparisons of large and small watersheds show that runoff per unit area decreases with an increase in size; that the range in differences in runoff-producing factors on a small watershed at the beginning of any storm is small, while for a large watershed composed of many small watersheds, the runoff-producing factors may differ materially; and that a change in a single runoff factor will significantly affect small watershed runoff, but the net effect of a single factor on the amount and the rate of large watershed runoff is small.

Watershed performance is strongly time oriented; a brief thunderstorm will flood a small watershed but not a river basin, while a low-intensity rainfall extending over several days will have the opposite effect. In the small watershed, with its large ratio of overland flow to channel flow, the increased travel time due to lower velocity overland flow has an appreciable effect on the unit hydrograph shape. The channel system will modify the time distributions of inflows, delaying peak flows. Channel storage acts as a detention reservoir and tends to flatten tributary peaks while stabilizing the uniformity of mainstream hydrographs.

Because of the increased concentration times of large watersheds, peak runoff rates are not affected by short, intense rainfalls or by the time of occurence of intense rainfall with respect to the beginning of rainfall, and the cumulative reactions to rainfall in the preceding days or even weeks may be determining outflow. In the small watershed, the outflow hydrograph is very nearly equivalent to channel inflow hydrographs and the watershed's reaction to rainfall in the preceding 30 minutes will determine outflow.

These hydrologic differences, besides being useful for defining small watersheds, have ramifications in hydraulic design in that most of the procedures and formulae used in estimating runoff from large watersheds can not be used for small watershed problems. The many attempts, both theoretical and experimental, to establish working rainfall-runoff relationships for small watersheds fall into five general types: direct relationships, empirical formulae, hydrographs, infiltration theory, and statistical approaches.

Direct relationships require measurements of both rainfall and runoff for a given watershed. The maximum average rainfall intensities for each storm are plotted against the peak runoff rates. As runoff-producing factors vary from storm to storm, there is likely to be considerable spread for runoff from a given rainfall. Maximum runoff will result when soil moisture is high at the beginning of a storm, when vegetal cover is poor, and when peak intensities occur at the end of a storm. Minimum runoff will result when soil moisture is low, when plants are making rapid growth, and when peak intensities occur at the beginning of a storm.

Of the empirical methods, the rational method is the most widely used. It is an empirical derivation of runoff which takes into account rainfall intensity, ground cover imperviousness, and the watershed area. The method assumes that the difference between maximum rainfall intensity and the resultant peak runoff can be expressed as a constant. This method is the mainstay of most storm sewer design, but with the exercise of engineering judgement, it can be applied to small watershed runoff determinations. If the frequency of peak runoff rates is taken to be the same as the maximum rainfall intensity and as the maximum runoff conditions frequencies, the peak runoff rates will be high. The rational method is particularly valuable for use in areas where no runoff measurements are available.

The unit hydrograph for a storm occurring when runoff factors favor maximum discharge would have a short lag time and a sharp peak. When runoff conditions are adverse, the lag time will be longer and the peak flatter. This is due to the lag time being dependent on overland flow velocities which tend to be higher when runoff conditions are favorable. By multiplying the unit hydrograph ordinates by the rainfall depth, the hydrograph for any desired storm can be predicted.

The infiltration theory relates rainfall and runoff through such factors as rainfall rates, transmission velocities, infiltration rates, percolation rates, and soil moisture. Other aspects of infiltration have already been discussed. The weakness of this approach is in the variability of the factors involved.

Probability studies determine peak runoff rates by integrating the frequency of occurence of various watershed conditions with the frequency of occurence of various rainfall intensities and storm patterns. To compute probability curves, annual peaks are ordered and assigned recurrence intervals. Peak rates are plotted against frequencies on probability paper. A probability curve is reliable only if it is representative of past performance and of future expectations.

If probability curves for large watersheds are to be applied to small watersheds, they should be corrected for differences in rainfall factors between the two. Corrected peak rates can be plotted against watershed size on log-log paper. The areas of allowable application of the computed peak rates must be limited to areas having similar physiographic features to those of the gaged watershed.

It is important to realize when assigning return intervals for design purposes that a 10-year rainfall and 10-year runoff conditions are unlikely to occur simultaneously, and in assuming that both events have the same recurrence interval, the designer is actually using a 100-year return period for the basis of his design. This assumption results in structures that are over-designed and in turn, more costly.

There are innumerable published methods for estimating runoff. The United States Geological Survey has developed one; the Bureau of Public Roads has developed one; the Soil Conservation Service has developed several; the Bureau of Reclamation has developed one. Each method was designed to meet the needs of the developing agency and may or may not have wider applications. *Water Resources Research*, *Agricultural Engineering*, the *Journal of Forestry*, the *Journal of Hydrology*, the American Society of Civil Engineers *Journal of Hydraulics* and *Journal of Irrigation and Drainage*, are continually publishing new variations on standard methods for estimating runoff. The problem with most of these permutations lies in their high degree of technical specialization and in their use of complex mathematical expressions which render them useless for practical design problem solving.

Urban watersheds are a unique class of small watersheds. Hydrologic losses on urban watersheds are no different from those on natural watersheds: interception, depression storage, and infiltration. But here, all similarities cease.

The hydrology of urban areas is complex and incompletely understood. The process of urbanization brings about many hydrologic behavioral changes. Generally, urban drainage systems include storm water inlets to capture surface flows for transmission to the underground drainage network.

Most urban hydrology studies evaluate the effects of urbanization on storm runoff - the increasing peak discharges, and the decreasing lag times, with scant attention paid to low flow changes. The sewage effluent discharged to small creeks is directly proportional to the population increase on the watershed. Sewage disposal into a stream will augment low flows, but will degrade quality unless effluent treatment is high. For some streams used for sewage disposal, only the initial flood surge becomes heavily polluted, and as the storm runoff continues, it can be stored for future use. Streams with flat gradients or with combined sewage outlets will remain in a polluted state throughout the storm duration, and storm runoff must be wasted.

Urban drainage system design problems include accounting for losses from the patchwork of pervious and impervious areas, each of which contributes to the runoff process in a different way, and the fact that individual runoff inputs must be determined at each inlet and then must be routed and combined in the sewer system. Most methods in general use for predicting urban runoff merely supply a peak rate, while knowledge of the entire runoff hydrograph is essential for properly routing and combining inlet flows.

Like those for rural watersheds, the response of the urban inlet hydrograph to rainfall patterns is rapid and slight changes in rainfall intensity show almost simultaneous changes in the hydrograph. Using unit hydrographs to synthesize total runoff hydrographs requires deducting losses from the total precipitation to determine effective precipitation. Depression storage losses may be accounted for with an initial deduction, and infiltration losses may be accounted for with a constant-rate deduction during the remainder of the storm. Hydrographs from successive time periods are then computed and superimposed at appropriate lag times to form the total runoff hydrograph from the urban watershed.

CHAPTER 4

POLITICS AND THE SMALL WATERSHED

Politics, according to Webster's Seventh New Collegiate Dictionary, may be defined as the art or science concerned with guiding or influencing governmental policy. Policy, in turn, may be defined as a definite course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future decisions. Adapting this general definition to small watersheds in more specific terms, we have: small watershed policy refers to action by the various governmental branches at the federal, state, or local level that shapes the development and the allocation of small watershed resources. As stated, the definitions of politics and of small watershed policy pose a number of questions concerning the nature of policy formation. For instance, who is responsible for policy formation? Who guides and influences the policy makers? Do the various branches of government work with or against each other?

There are two viewpoints to consider when creating functional policies. First, there are the relationships between individual actions in setting objectives, planning, implementing, and managing water resources. Ideally, there should be a continuous flow and feed-back from area to area. Second, there are the motivations of the various units planning or taking action. The conceptual purposes of the acting units may be completely divorced from the anticipated individual actions. Neither viewpoint should be singled out as the exclusive determinant in policy formation; rather, both viewpoints must be integrated in balanced amounts if policy is to be effective.

The definition suggested for small watershed policy divides policy formation into two categories: the development of and the allocation of watershed resources. Both spring from a common background of initial research and planning, but their objectives are quite different. Policies for developing (or exploiting) water resources are aimed at increasing the quantities abailable for use, while policies for allocating water resources are aimed at metering a given supply among competing uses.

Policies for water development and allocation are primarily concerned with the laws, regulations, and the administrative structures that enable groups and individuals dealing with water to make their decisions. It is important to remember that the agencies responsible for developing and allocating both ground and surface waters are generally self-supplying farms, industries, corporations, and non-profit organizations.

In determining the direction of policies, prime attention should be given to those elements that are most directly manipulated to secure the desired ends. Institutional changes are perhaps the most significant variables in water resource policy that are subject to control. The structure, function, and performance of water institutions become means to achieving objectives rather than objectives. Implementing water policy requires the programming of water institutions instead of programming the water resources themselves.

Basic water development policy, whether for river basins or for small watersheds, is essentially a function of water law, covering such topics as the riparian and appropriation doctrines, water reservation for future development, the control and treatment of pollution, establishing and regulating water institutions, and co-ordinating ground and surface water development. Water law is primarily an extension of property law and is concerned with the right to divert water for use or the right to use water in place.

The power of the various levels of government to engage in the control and regulation of water-related activities is determined by the constitution. Federal water policy flows from a gradually broadening interpretation of the powers delegated under the commerce clause. The federal government also creates and administers policies involving international and interstate relations through treaties and compacts. The constitutional powers reserved to the states are the primary source of water policy, the bulk being water law in the form of either legislation, administrative regulation, or judicial decisions. Although enabling legislation by the state governments gives zoning powers to local governments who adopt ordinances affecting water use and control, most water law has been enacted as state law.

The three forms of water law are not mutually exclusive, but are closely related. A statute, as enacted by the state legislature, may be set up to accomplish one of several goals. It may formalize a common law tenant, it may update an unrealistic common law rule, it may clarify an ambiguous common law application, it may make an exception to common law, or it may even supplant common law with a comprehensive set of regulatory codes. Administrative regulation is the delegation of legislative powers to executive agencies with technically oriented staffs who administer the law. Judicial decisions are necessary because statutory and common laws are not always explicit, may be contradictory, and may contain oversights and ambiguities. In such circumstances, the courts must determine the intent of the law makers or the most equitable applications to litigants. The courts' decisions then become precedent for cases with similar problems.

Inherent in political maneuvering are several hazards to sound water resources programs and policies. Political pressures result from public decision making being placed in the hands of men who must rely on popular elections for their status. Decisions on water resources involve issues of value judgments in addition to scientific and technical determinations. Individuals, including Congressmen, have motivations shaped by their backgrounds, their aspirations, and the organization with which they are identified. These motivations result in personal value preferences that may or may not reflect the interests of the people affected by their decisions. Besides the political pressures for re-election and of personal value preferences, there is a tendency for decisions on unrelated programs to become politically wed by trading support for other programs.

Hand-in-hand with political pressure, and a by-product of it, is the pork-barrel phenomenon. The nature of the pork-barrel phenomenon is the construction of uneconomical projects whose sole function is to retain the loyalty of the voters. The project-by-project approach to water resources problems is ideally suited to pork-barrel projects. Public works are seldom the subject of party differences and are favored, if not demanded, by constituents. A form of Congressional courtesy exists that regards as poor taste the public questioning of the economic justifications for another Congressman's project. The checks and balances don't seem to function in this area; presidents recognize the political nature of Congressional interests in pork-barrel projects and tend not to oppose them. They can, and do, impound or decline to spend all the funds allocated for pork-barrel projects.

Governmental agencies are not immune from political pressure, but it is pressure of a different nature. Agencies have differing objectives and as a result, they tend to reflect and promote different values. They have, too, preferred solutions that are not necessarily the most efficient means of reaching project goals or of developing project resources. The pressures in this case come from a universal characteristic of organizations for self-perpetuation with its attendant growth in power and prestige plus augmented status (and income) for its workers. This growth tendency contributes to worker loyalty as do selectivity in recruitment and the agency's socialization processes. Instead of political pressure, agency employees are subject to peer group pressure.

Sustained organizational growth has a detrimental effect on decision-makers. When an individual is charged with the sole responsibility for making decisions, he is likely to feel a strong ethical commitment to the decision. When a decision becomes a staff responsibility and is subject to hierarchal review, the individual feels less responsible and becomes detached from the decision-making process.

The most prominent phase of policy formation is the legislative process. In Congress, specific areas of water resource activities are assigned to specific committees. In each house, the Committees on Interior and Insular Affairs are responsible for: irrigation and reclamation projects, desalination, national parks wildlife and stream pollution control, water-based outdoor recreation, collection of basic data on surface and ground water, and the recent legislation dealing with comprehensive river basin planning and watershed research. The House and Senate Public Works Committees handle the navigation and flood control programs of the Corps of Engineers and the research and construction grant programs for the water pollution abatement programs of the Federal

Water Pollution Control Administration. The Banking and Currency Committees of both houses have jurisdiction over the federal assistance programs for planning and constructing public water supply and sewerage facilities. The House Agriculture Committee and the Senate Agriculture and Forestry Committee handle the Agriculture Department's watershed protection program. Legislation on weather data and research on weather modification by the weather bureau is processed by the House Merchant Marine and Fisheries Committee and the Senate Commerce Committee. The Senate Commerce Committee would also handle legislation dealing with hydraulic research undertaken by the Bureau of Standards. Finally, the Appropriations Committees of both houses play a significant role in water programs of all agencies because they review the Administration's budget requests and make their own recommendations for funding.

Despite this conglomeration of committees (1289 water-related legislative measures were introduced during the 89th Congress and were referred to 13 House committees and 11 Senate committees), the fractionalized policy approach, and the pork-barrel projects, Congress has passed some significant water resources legislation. Of interest to small watershed operations are the Watershed Protection and Flood Prevention Act, and the Water Resources Planning Act.

Public law 566, the Watershed Protection and Flood Prevention Act, is an approach to solving local watershed problems. It was designed to bridge the soil and water conservation gap existing between the Soil Conservation Service's work with the individual farmer on land treatment measures, and the Corps of Engineers' large downstream dams. To qualify, a watershed must be limited to a hydrologic unit of less than a quarter of a million acres (390 square miles). The most important features of the act are:

1. Authorization of co-operative efforts by the federal and state governments, individuals, and local communities to solve flood prevention and watershed management problems.

2. Provisions for cost-sharing.

3. Provisions for co-ordination of watershed development efforts.

4. Placing the initiative on the local residents and landowners to implement the program.

5. Provisions for technical assistance by the Department of Agriculture in planning and executing watershed programs.

1956 amendments significantly broadened the scope of the act by:

1. Permitting the inclusion of non-agricultural purposes.

2. Raising the capacity limitation to 25,000 acre-feet per structure.

3. Requiring plans and estimates for engineering evaluation.

4. Requiring cost allocations to various project purposes.

5. Providing federal payment of all flood prevention costs.

6. Requiring local sponsoring organizations to bear a

portion of agricultural water management measures and the full costs of other measures, excluding flood control.

7. Assigning the local sponsoring organization the responsibility for securing engineering services.

8. Making the act applicable to water users.

9. Making available 50-year federal loans of up to five million dollars.

10. Exempting from review by Congress and other federal agencies projects involving less than $250,000 in federal costs and with no structures exceeding 2,500 acre-feet of retention capacity.

11. Eliminating the 45-day waiting period allowed for Congressional review.

12. Extending the provisions to the non-contiguous states and Carribean territories.

In 1958, one amendment authorized the Secretary of the Interior to make surveys of fish and wildlife development in proposed watershed project areas and to make recommendations to the Secretary of Agriculture. A second amendment authorized payment by the federal government of portions of costs allocable to fish, wildlife, and recreational development in a watershed program. A 1960 amendment added several non-profit organizations to the list of local sponsoring organizations. A 1962 amendment specifically added recreation as a purpose for cost-sharing and authorized fund advancements for the early purchase of project lands threatened with encroachment.

Public law 89-80, the Water Resources Planning Act, is an act to provide for optimum natural resources development through the co-ordinated planning of water and related land resources with the co-operation of all affected federal, state, and local agencies. To accomplish this task, Title I of the bill establishes a water resources council, composed of the Secretary of the Interior, the Secretary of Agriculture, the Secretary of the Army, the Secretary of Health, Education and Welfare, and the Chairman of the Federal Power Commission, to maintain a continuing study and to prepare a biennial assessment of the adequacy of necessary regional water supplies and to maintain a continuing study of the relation of regional or river basin plans to larger regions and of the adequacy of administrative and statutory means for co-ordinating policies.

The council shall establish principles, standards, and procedures for participants in planning. It shall review plans for efficacy in achieving optimum use, the effect on other programs, the contribution of a plan to obtaining national goals. After its review, the council shall recommend modifications or transmit the plan to the President for Congressional authorization. The council may hold hearings, acquire and equip offices, use the U. S. mails, employ civil servants, procure consultants, maintain a motor pool, and incur other expenses necessary to carry out the provisions of the act.

Title II of the act established River Basin Commissions. The request for presidential authorization must include the area to be served by the Commission, be in writing, and be concurred in by the Council and by a third of the states in which the basin is located. The Commission will be the principal co-ordinating agency for federal, state, and local activities, will prepare and keep current a comprehensive plan for resource developments, recommend long-range priorities, and undertake the studies necessary for plan preparation. Commission membership shall be a chairman appointed by the President, one member from each federal department determined to have an interest, one member from each state within the basin, one member from each interstate compact or international commission with jurisdiction in the basin area. The Commissions must submit annual reports to Congress. The powers of the Commissions are parallel to those of the Council.

Title III sets up financial assistance to the states for comprehensive planning with $5,000,000 for each of the ten years following enactment of the bill. Funds will be allotted on the basis of population, land area, the need for planning, and the financial need of the applicant state. Programs submitted by the states must provide for comprehensive planning to meet the needs of all water and water-related purposes, full co-ordination with statewide planning agencies, designate a state agency to administer the program, provide for periodic report filing, set forth administrative procedures, and provide for fiscal control. The federal share of the state cost is limited to between 33-1/3 and 66-2/3 percent, and is based on the average per capita income of the states and the nation for the three most recent years having data available. Payments are made quarterly.

Title IV covers miscellaneous items such as administrative appropriations, Council rules and regulations, delegation of functions, utilization of personnel, and employee benefits.

This legislation was designed to help tie together the piece-meal, unintegrated portions of the national water problem and provides a broad approach to the over-all water problem.

On the state level, water resources legislation is usually organizational, regulatory, or enabling. Three Michigan statutes, Act 200, Public Acts of 1957, and Acts 20 and 253, Public Acts of 1964, are typical of the three types of state legislation.

Act 200, Public Acts of 1957, is an act to provide for the creation by two or more municipalities of an intermunicipality committee for the purpose of studying area problems and to provide authority for the committee to receive gifts and grants. Section 1 defines municipalities, Section 2 sets up organizational procedures and lists problems that can be studied as sewers and sewage disposal, water drains, parks and recreation, and ports. Section 3 lists employment and agreement-making powers. Section 4 authorizes funding. Section 5 allows services as a part of municipality financial support. Section 6 authorizes grants being accepted by the committee to further its objectives.

Act 20, Public Acts of 1964, is an act to regulate the impoundment and utilization of surplus water, to prescribe the powers and the duties of the Water Resources Commission and the several boards of supervisors, and to provide penalties for the violation of the act. Section 1 titles the act "Surplus Waters Act of 1964". Section 2 defines terms. Section 3 authorizes water surveys. Section 4 requires all local units to join in planning requests. Section 5 describes optimum flow determinations. Section 6 details hearing and order procedures. Section 7 outlines plan implementation. Sections 8 and 9 deal with grants, use of county funds, and fees. Section 10 apportions increased flowage. Sections 11 and 12 set up restrictions, rules, and regulations relating to existing acts. Section 13 describes procedures for optimum-flow redeterminations. Section 14 makes violations of the act's provisions misdemeanors, and Section 15 removes the act from within the jurisdiction of river management districts.

Act 253, Public Acts of 1964, and as amended by Act 119, Public Acts of 1966, is an act to enable local units of government to co-operate in planning and implementing co-ordinated water management programs in shared watersheds. According to Section 1, the act is known as the "Local River Management Act." Section 2 defines terms. Section 3 sets up watershed councils. Section 4 outlines council membership. Section 5 details the duties and powers of watershed councils. Section 6 details potential council functions. Section 7 allows the petitioning for forming river management districts' governing bodies. Section 8 defines a river management district's governing body. Section 9 lists areas eligible for possible river management boards. Section 10 defines district powers. Section 11 outlines procedural rules for boards. Section 12 allows the executive secretary of a watershed council to serve as executive secretary of the river management board. Sections 13 through 17 detail minimum stream flow determinations and stream gaging stations. Sections 18 through 20 list other acts, rules, and regulations which are not affected by the act.

Water rights and water law are closely related. While neither has developed a special body of material dealing exclusively with small watersheds, water rights and water law are not dependent on the size of the watercourse or the area of its watershed. The power to create property rights and the police power to regulate them are the sources used in state regulation of private water rights. State water allocation laws have traditionally assigned water to individuals as property in the form of rights to divert or store water and to apply it to beneficial use.

Water rights deal differently with two classes of water: overland flow and stream flow. The landowner's rights and interests vary considerably in surface and stream flow. To begin with, the landowner "owns" surface water diffused over his land and may capture it and use it on his land or sell it to others. Ownership of land adjoining or traversed by a natural water course, that is, riparian land, confers certain rights of use, but not of ownership of the flowing water.

There are two rules concerned with surface water rights. The civil law rule holds that each piece of land is subject to the natural flow across it so that a landowner may not prevent water from coming to his land nor may he collect it so it flows from his land in unusual quantities nor may he change the direction of natural drainage. The common enemy rule holds that the landowner may protect himself against surface water as best he can, building dikes to keep it off his land or drains to remove it from his land.

Water rights also vary from state to federal jurisdictions. At common law, the title to land under tidal waters was held by the Crown as a public trust. This doctrine was carried to the colonies and title was taken by the federal government. The English common law rules that fresh water lakes belong to the riparian owners and prevails in most United States jurisdictions. Where states hold title to the land under navigable waters, it is held in trust for all state inhabitants for the protection of navigation and other public uses. A riparian owner's title, if any, to the submerged lands under navigable waters is a qualified one, and is held subordinate to the public right of navigation in the waters flowing over submerged lands.

The riparian doctrine as applied in the United States seems to derive from the 1804 Code of Napoleon, but it has been reshaped primarily through state appellate court decisions. In the mid-1840's, natural wants of riparian owners were defined as those necessary for survival and artificial wants as those increasing either comfort of prosperity. Prior to 1874, the natural flow interpretation of the riparian doctrine permitted a riparian to take water for artificial wants only if the flow was sufficient to supply the natural wants of all downstream riparians and if his use did not substantially diminish the flow or impair its quality. In some states, a riparian may use all the available water for his natural wants even though it exhausts the entire flow. The reasonable use interpretation of the riparian doctrine dates from 1874 and holds quantity and quality of flow to be subject to the question of whether or not the water use is reasonable and consistent with an exercise of the same right by others.

Briefly, the provisions and restrictions of the riparian doctrine hold that the fact that one riparian initiated his use before another does not determine or affect their respective rights; riparian rights attach to natural lakes or ponds regardless of their origin; the laws of the state in which the riparian land is located govern the rights of the riparian owner; the riparian rights of land owners adjacent to lakes correspond to those of landowners adjacent to flowing water courses; ownership of a portion of a stream or lake bed does not confer the right to use the entire surface, but courts have held that riparians can use the entire surface if such use does not interfere with the reasonable use of the water by others; in navigable waterways, riparian rights are subject to public use and the riparian owner has no rights that the government must recognize, nor must the government pay for losses caused by its operations within the stream bed.

Where municipalities are involved, according to the courts, they can not, through the purchase of riparian land, use water anywhere but on their riparian holdings. Extensive municipality water use, then, is not within the scope of riparian rights. However, the courts may allow non-riparian use if no immediate damage is done to downstream riparians or if damages are awarded to "balance the equities."

Riparian rights can be lost or altered in a number of ways. As property rights, they can be bought and sold, either outright or through easement. The reasonable use rule tends to make a riparian's rights ambiguous, requiring definition by the courts. Many municipalities, water resource districts, and governmental agencies hold condemnation powers which can be employed to acquire water rights from riparians for non-riparian uses. Even after the United States has permitted a private right to become established, the right may be destroyed by the exercise of federal power with no damage payments required. Finally, certain public rights may be acquired against riparians through their express or implied dedication of water to public use, and prescriptive rights may be acquired by or against riparians through long-continued adverse or unlawful use of a water course or access to a water course.

The Water Resources Planning Act attempts to co-ordinate federal, state, and local water resources activities. In his statement at the hearings on this bill, Michigan's Attorney General, Frank Kelly, summarized the division of jurisdiction between the federal and the lesser governments. He said, in part, that there are things which the federal government can do for all of the states much better than the states can do as individuals, and there are many things which the states can do alone since these tasks can be done more efficiently and more heterogeneously than by the federal government. When it comes to water resources, no two states are alike and thus, each state should be allowed, within its territorial limits, to deal with these resources in a way that best suits its needs, its geography, and its economy. In other words, required governmental action should be accomplished at the level closest to the problem and best able to deal with it on the basis of intimate knowledge and of existing circumstances.

The areal extent and functional scope of interest in water resources become progressively broader up through the levels of government from local to national. Prior to local government action is private action which is usually typified by single-purpose objectives, more stringent economic limitations, more restrictive legal restraints, and strong emphasis on profits, with less consideration for long-range conservation of physical resources and for meeting competitive water demands.

Local government action is the initial attempt to accomplish by joint effort what can't be done by individuals. Basic objectives remain largely single-purposed, and economic limitations determine the extent to which physical needs can be met. Water resources activity at the state level usually includes responsibilities not found in local or private efforts simply because the states have greater administrative potential and are in a better position to evaluate the composite effect of local efforts on the problems of broader regions. State activity is directed to guiding local government activity, to programming basic data requirements, and to enacting and administering state laws.

A state may establish regulations dealing with its local streams and also with United States waters within the state if jurisdiction over the navigability of its waters has not been assumed by the federal government. If a state law conflicts with federal law, the state may be prevented from applying the conflicting law to the particular waters which give rise to the conflict. Nor can the state require the United States to obtain permits or licenses prior to beginning water control structures construction in navigable streams. Should a state adopt a development pattern that meets local needs but does not fit a broader federal development plan, the state must alter its plan.

As each successively higher level of government is engaged in water resources activity, increased attention is given to long-range resource considerations, multi-purposed development, and greater sophistication in applying economic concepts to realistically fulfill local needs. The federal government engages in water resources activity when no other effective and adequate means exist or when the national interest requires it. The role of the federal government should be in providing leadership, co-ordination, physical and economic information, investment, and an environment conducive to comprehensive development. National policies should be directed toward resolving local and regional problems.

Generally, financial limitations, the absence of political responsibility to other areas, or the inability of lesser government units to reach workable compromises have forced adoption of existing federal policies. Over the years, numerous expressions of Congressional policy, in separate, single-purpose acts, which along with executive directives, have attempted to provide solutions for most water problems in federal programs. This patchwork policy process has seldom completely satisfied any one water group because the water-oriented public has specific interests in certain problems rather than a general interest in comprehensive approaches.

Federal powers may be exercised in three ways: affirmatively, negatively, and permissively. Affirmative action is taken in improving channel and harbor facilities and in dam construction. Negative action lies in the prohibition of interference by lesser units with the navigable capacity of water. And permissive action consists of the federal government licensing activities which it may prevent, or delegating activities to others which it is empowered to undertake itself.

The needs for water and its use patterns are generated at the local level. People who are not close to the local picture may not be concerned with preserving or expanding the economy of already established communities. Water flowing in a river basin cannot be divided into local waters, state waters, and federal waters for separate treatment. However, the individual responsibilities of each unit must be involved in water resources work and federal participation in joint action should not be allowed to intimidate the lesser units into a federally dominated association.

Authorizing joint agencies for co-ordinating mechanics is one method of avoiding the subordination of either state or federal governments while safeguarding the legitimate role of each. Greater co-ordination between the various levels of government can be achieved through comprehensive revision, correlation, clarification, and updating of statutes relating to water resources; the use of interstate compacts and river basin commissions; the use of watershed associations; and co-operation among federal agencies. One of the chief barriers to effective federal-state harmony in water policy is the multiplicity of federal agencies having conflicting objectives and policies with which the state must deal. There are more than thirty federal agencies active in some phase of water resources work, although only three of these actually construct water resources works: the Corps of Engineers, the Bureau of Reclamation, and the Soil Conservation Service. Another factor tending to weaken state-federal liaisons is the lack of water policy co-ordination within the state government due to the single purpose approach to inter-related resource problems and from fragmentation of administrative functions into separate agencies.

Moving back to the local scene, it is at once obvious that while the small watershed may be ignored in the political give and take of policy formulation, citizen involvement more than compensates for this neglect. Local projects have become rallying points for affected citizens and their response can make or break a project. To what extent a local pressure group can influence national policy is hard to say, but there is no doubt that when policy is implemented at the local level, public action has often been grossly underestimated. Civic action can stall and in some cases stop water programs which agencies, administrators, and politicians have endorsed as necessary.

There are four areas in which the concerned citizen can and should involve himself: as a member of an organized group, as a member of a governing unit doing water resources development, as a voter, and as the person who pays the bills for water resources projects. If the citizen pays for projects through direct assessments, higher taxes, or higher water rates, it is in his own interest that he understand the problem at hand and hopefully can be won over to supporting the offered solution. As an individual, the public-spirited citizen can express his views at public hearings, in letters to newspaper editors, and in related activities which do not require group membership or backing.

In organized groups, citizen participation can come in many ways. He may spearhead the initial drive to form a group nucleus when action is needed. He can participate actively in a functioning group. He can contribute his financial support in addition to his time. Or if he is not inclined to active participation, he may simply lend his moral support as a passive member. Of the groups formed for local action, the most effective are watershed associations, drainage districts, and soil conservation districts, all of which are legislatively sanctioned. National groups supporting water resources programs include the American Geophysical Union, the American Society of Civil Engineers, the American Water Resources Association, the American Water Works Association, the National Association of Soil Conservation Districts, the National Reclamation Association, the National River and Harbors Congress, and the National Waterways Association, to name a few. Conservation groups such as the Sierra Club can also be quite vocal in water resources problems.

One of the healthiest characteristics of water resources organizations is the variety of operational arrangements possible. Resource developments have been planned, funded, built, and managed by private corporations, individuals, local governments, state agencies, and federal units. There are functional relationships between the organizational level, the type of agency, and the water-related responsibility. Generally, local governments operate water supply and sewage treatment facilities; special districts handle reimbursible functions such as irrigation and conservation; state agencies are responsible for non-reimbursible functions like recreation;

federal interests are in flood control and navigation; and private efforts tend to be power oriented.

The public is an unpredictable variable in water resources. They are not likely to act unless the issue is controversial and is viewed either as a personal threat or as a decided benefit. Motive and motivation are everything in water resources development. Only the individual who can be motivated to accomplish something for his own or the general welfare can help to attain water resources goals. The responsibility for generating public support for water resources programs falls to the administrators, and the only way to win this support is by keeping the public informed on a continuing basis, by keeping abreast of public sentiment, and by allowing that the citizen has a valid role to play.

Successful citizen action requires the satisfaction of several independent variables. There must be a real resource problem about which a substantial portion of the public must be concerned. Dynamic leadership is necessary either in a board of directors or in an executive director of a formal organization or in a prominent local member of the community power structure in an informal group. Unless the federal, state, and local agencies are willing and able to carry out the public's preferred programs, citizen action will go for naught. The secret of successful public action is positive thinking in support of realistic programs.

In summation, sound public policy requires improved techniques of engineering, economics, and systems analysis to develop economically efficient systems. Public decision-making in the realm of public interests must be concerned with individual-group relationships among those affected by a decision. A well-rounded national water resources policy must reflect a consensus of the people. Policy must be infused with a moral relationship between man and nature and between man and man. Such relationship patterns illuminate the issues requiring value judgements and help to represent all parties in the decision-making process. Water resources policy has been and will be determined by public viewpoints formed from social, political, and economic forces. The problem is achieving a national understanding of water use problems so these forces can be used to keep policy abreast of the changing environment within which water resources activities are undertaken.

Several forces counteract and tend to delay policy changes. Inertia makes moving from status quo to a position with untried results difficult. Agencies, to keep the favor of the people supporting them, tend to maintain existing policies endorsed by their supporters. Finally, present beneficiaries do not want to sacrifice any of their present benefits while future beneficiaries do not want to be deprived of the benefits they see others receiving.

Some water resources policy has changed a great deal over the past few years due to the need to provide for such activities as federal participation in municipal water supplies and in pollution control, activities not previously covered by federal policy. Unfortunately, water policy growth has not yet provided a uniform federal policy governing comprehensive water and water-related developments, nor adequate coordination of the objectives of various agencies. In contrast to the new policy areas, the policy framework for flood control, irrigation, power, and navigation has remained untouched in spite of changed conditions and advanced knowledge which strongly suggest adjustments. Situations allowing policies to become frozen and totally unsuited to the times must be avoided. Understanding the motivating mechanics of policy changes should encourage the adjustments needed to revitalize existing policy.

CHAPTER 5

SMALL WATERSHED PLANNING

Planning is the first phase of putting policy into practice. Planning must intimately link basic data, its projections and synthesis, and research into a coherent outline for effective water development and management. The most basic planning concept requires a look at the anticipated future needs, a cataloging of available resources, and a method of utilizing the resources to meet these needs. The planning process is one of discussion, compromise among shifting and conflicting alternatives, and consensus based on facts. It is an unending series of decisions, each made more complex by the decisions made earlier. In spite of these self-imposed restrictions, planning must be flexible. It must provide for shared responsibilities, encourage local initiative, and envision long-range plans. Planning is only one step in the total process of controlling, protecting, conserving, and utilizing water resources; it is not an end in itself. It is rather, a broad series of recommendations to the governments involved and final decisions on implementation must be the duty of the policy-makers.

There is an urgent need in almost every region to adopt an orderly procedure for water resources development, from river basins down to small watersheds. While the river basin, where the entire complex of resources is naturally intermeshed, is the smallest geographical unit that will permit truly comprehensive planning, small watersheds are the most feasible units for conservation, development, and management of renewable resources. Despite confinement to an area, whether regional or local, planning requires consideration of pertinent physical, economic, and social factors outside of the study area. Comprehensive planning must also recognize the effects and the jurisdictions of existing compacts and interstate (or international) agreements which may also authorize planning operations.

The planner should be aware that the area for which he is planning has a particular social, economic, and political structure which changes very slowly. The planner's task is not to fit society to his plan but to design a plan to fit the existing society. The planner and the political authority responsible for sanctioning planning strategy must evaluate where and to what extent resistance is likely to be encountered. The basic planning objectives, too, are a product of the political and social values prevailing in the area's social structure, and once objectives are adopted, they set the operational strategies and final decisions of the actual plan. While basic objectives are among the least changeable factors of planning, they do change with time as they are an ideological product of a society that is also changing with time.

The objectives of planning are many. Planning should, of course, produce plans that can be carried out. Integrated and co-ordinated development and management of water resources should be fundamental to a plan. Plans should account for all purposes served through water development, giving full recognition to non-revenue producing purposes. Planning should promote the conjunctive use of ground and surface water sources. Planning should take advantage of multi-purposed uses, reconcile competitive or conflicting uses, and establish responsibilities for carrying out its resolutions. Planning can outline the extent of upstream protection measures required to offset unsound, unregulated urban, industrial, and agricultural developments on flood plains subject to periodic innundation. Planning must be multi-disciplinary, involving engineers, geologists, economists, lawyers, geographers, sociologists, politicians, and administrators.

Goals and objectives of water resources planning should be established by Congress and should be both multi-purposed and nationwide in scope. Unfortunately, despite the recognition of the needed range in planning objectives, under national guidelines, most planning remains economically oriented. Economic efficiency is the most common goal, but also economic in nature are such concepts as security, progress, and prosperity, though they are admittedly more difficult to measure and to date, no procedures for including these concepts in traditional planning have been developed.

Once broad objectives for the national interest in water resources are established, planning groups translate the administrative and legislative guidelines into criteria for developing specific water resources plans through engineering, economic, and institutional considerations.

Questions for planners to answer include such items as the effect of reservoirs on channel stability, the relationships between water use and water quality, the effects of well fields on river flow, the increase in pumping head caused by drawdown and the effect of drawdown on recharge, and the flood danger to new land uses. These questions suggest that water resources planning can no longer be limited to the traditional route of engineering design and construction.

To achieve optimum comprehensive planning of water resources, it is necessary that mechanisms for such planning be created and implemented. Consideration must be given to the agencies that will enforce the plan: their powers, objectives, functions, policies, and philosophies, along with the laws under which they operate. It is essential that legislation required to facilitate planning and its subsequent translation into reality be initiated at the earliest possible time, for legislation can require years to enact if the process does not work smoothly. The political mechanisms for carrying out planning should provide for maximum participation by the private sector and local, state, and federal agencies.

Now that Congress has committed the nation to comprehensive river basin planning, the role of planning at the small watershed level may diminish. There are several relationships that may arise between small watershed planning and river basin planning: they may be entirely independent, they may be in direct conflict, they may be closely related, or one may completely dominate the other.

Solutions to water problems undertaken privately or by local governments prior to comprehensive planning may not conform to the broad planning objectives. Conversely, comprehensive planning may be too broad to adequately consider pressing local problems, may be too slow in attempting to solve local problems, or may propose solutions which do not satisfy local needs. It is possible for a small watershed to be completely submerged by a major development project. Small watersheds that fall outside of the limits of a regional planning unit could be planned and developed independently, and small basins immediately downstream of major developments will have slight, if any, operational relationship to an overall plan. With a lack of communication, planning could proceed on the local and regional level simultaneously with no co-ordination and yet be fairly compatible. Perhaps the most realistic approach is to have the regional planners adopt a comprehensive master plan, considering local problems in generalities, and then to have the local planners, assuming there is such a body capable of doing the job, detail solutions to problems at the small watershed level.

Sooner or later, the water requirements of a watershed are likely to exceed the supply and choices must be made for priority of uses. Where water resources are initially scarce, the allocation of available resources will govern planning, but even in cases where scarcity is anticipated, priorities should be assigned during the planning process. Competition among users as a class for the same water and among users in the same class as to who gets the water and where it is to be used can generate major problems. In setting priorities, the planner should determine if the water requirement is an essential one, if there is a satisfactory substitute for the water requirement, if competing uses have greater economic merit, if there are water rights which must be taken, and if they must be compensated for, or if there are legal constraints on the requirement such as rules and procedures for allocating, developing, and managing the water which may have been established by compact or statute. Priorities should also be studied for their long-range impacts to make allowances for future changes in demands or use patterns.

Conflicts are inevitable during the planning process. While private conflicts can be resolved by common law or statute law in the courts, the broader planning conflicts are best resolved by diplomatic negotiations to prevent future animosities that could generate delays in plan implementation. The migratory nature of water can create jurisdictional and operational conflicts exemplified by the conflict between storage and maintaining stream flow. Using stored water to improve water quality through low-flow augmentation is opposed by water users who want impounded water kept available for higher uses. The growing conflicts in water uses imply a need for more objective means of weighing competing water uses, a need for a drastic overhaul of water law, and a need to encourage water rights holders to pay what water is worth. When conflicts do occur, the following criteria are generally used for evaluating the position of the competing uses: aesthetic and ecological considerations (or the effects on environment and the balance of nature), technical performance, legal precedent, and cost-benefit relationships. The ultimate resolution of conflicts and designation of priorities are dependent upon related economic, social, and managerial decisions made in the best interests of the overall region.

Among water uses, domestic and municipal use take the highest priority and planning must assure them a minimum supply at all times. Other non-consumptive uses, if deterioration of quality is not considered to be a consumptive use, are industiral uses, navigation, power generation, and recreation. Irrigation is the major consumptive use of water. While technically not a water use, flood control has a direct bearing on most other water uses. Changes in priorities will result from population shifts, urban growth, improved living standards, and water use changes.

Other problems facing planners are the scope of their planning efforts, which may or may not be well defined; resolving and balancing federal, state, and local interests; protecting the water rights of the landowners within the planning area; eliminating jurisdictional overlapping in both physical and planning limitations; generating initiative for implementing the plan; helping to establish the necessary procedural and legal authorizations for implementing the plan; continually updating the plan to meet changing conditions; compensating for water losses through evaporation, natural consumption, seepage, and conveyance; planning development so as not to alter the watershed regime to an extent that will void estimates of usable water supplies; and considering topographical restrictions that might preclude effective control of the entire region originally programmed for planning.

The planning of any water resources development is certain to encounter questions of a legal nature and the more comprehensive the plan, the more serious and numerous the legal complications may become. Some of the legal phases of proposed projects that should be evaluated early in the planning process are those of constitutionality, adequate legislative or corporate authority, and legal processes required to plan, construct, operate, and maintain the project. Other legal problems may be found in clearing the way for project financing and construction, some of which (land and easement acquisition) are subject to agency control, and some of which (injunctive actions by opposition) are not. Contractual law will be of importance as planning progresses to construction phases.

Planning incentives are derived from various sources. On the grass-roots level, they stem from the individual's desire to protect or conserve his lands or as a local group effort to solve a local water problem. When activity at the local level fails to develop, incentive may be imposed from higher authorities, usually with an attempt to encourage participation by the people most immediately concerned with the problem. In contrast to the strictly remedial nature of local efforts, imposed incentives may be directed toward preventative measures. But perhaps the greatest incentive is that of financial reward. The economic gain philosophy permeates the entire planning network from the national level where water resources investments are designed to augment the GNP to the state level where stimulating regional economies is of prime interest, to the local level where communities seek increased tax bases and individuals wish to save money by avoiding flood or erosion damage or want to increase their incomes with additional acreage under production or with recreational developments. The form of economic incentive may vary from cash grants to cost-sharing programs to tax relief to low interest loans, but whatever their form, economic incentives are very powerful.

A recent development in the planning of water resources is a methodology of problem solving known as systems design or systems analysis. Four related steps make up this approach: identifying design objectives, translating objectives into design criteria, using the design criteria to create development plans for specific projects, and evaluating the consequences of the plans so produced.

Breaking the process into more detail, the first step is to consider the variables affecting the problem and its solution. Each variable should be studied sufficiently to determine its degree of importance in varying the system. Next, the formulation of objectives define what is to be accomplished in the project. Once objectives are established, they are used to measure how a plan meets them. Now, all the possible alternates are listed. Unfortunately, many alternatives will be more apparent after the project is completed than when it is on paper. With the alternates set down, the planner then tries to visualize and analyze the consequences of acting upon each alternative. The consequences will vary when considered by different disciplines and political, social, legal, engineering, and economic viewpoints will usually not be in accord on project consequences. The problem is to determine which alternate reflects the consensus of the region concerned with development, given the choice of objectives including both economic and non-economic values. Evaluation of the alternates must be made on a sound economic basis to select the plan (that combination of structures, level of development, different water uses, and operating procedures) that will best achieve the objective. If alternates are viewed as being mutually exclusive, a preservation-at-any-cost philosophy may develop that will obscure the fact that water resources can be used for many purposes. One of the most difficult parts of evaluation is value judgements, the intangibles, and the uncertainties. As many terms as possible should be expressed as costs or benefits, reflecting or varying from market values to meet the objectives. The final step is to consider the active restraints which may be physical, political, ideological, social, or a consequence of local custom. In contrast to conventional techniques, physical, legal, and institutional constraints are examined in terms of their costs. Having followed the outlined procedure, the planner can now make his decision on the best course of action to program.

The planning approach is essentially the same for comprehensive river basin studies or for small watershed projects. In fact, there are some planners who maintain that the problems of small watersheds are, except for scale, the same as the problems of the river basin, and that the small watershed can be used as a model for river basins. While the hydrologically dissimilar functioning of river basins and small watersheds refutes this view, the basic planning elements can work in both planning situations.

Initially, an inventory to provide raw data on resources is required. The basic objective of a water resources inventory is to estimate the maximum yields that can be attained without risking quantitative and qualitative deterioration beyond program limits. To be inventoried are: natural, capital, human, structural, and institutional resources. A national policy statement should set up general planning objectives. A master plan is helpful whether the planning area is the entire region or a small part of it. Neither level can effectively function without enabling legislation. Co-operation among various units on any given level and among the different levels is equally vital. Public education regarding the need for planning, its objectives, and its implementation will help insure success at any level, and finally, local action is needed in support of the planning effort.

CHAPTER 6

SMALL WATERSHED DEVELOPMENT AND MANAGEMENT

In a watershed, management has already begun when the first tree is planted or uprooted; management doesn't wait until a watershed is completely developed. Consequently, development and management can not be completely divorced for discussion and certainly not in practice. Total watershed development and management requires the successful culmination of a complicated chain of events that reaches back to research studies. Watershed development is built on careful planning which in turn is built on realistic evaluations of human needs. The watershed factors to be developed must represent real-life requirements and their planning must demonstrate engineering practicality, economic justification, and financial feasibility. To ensure social acceptance of proposed developments, the planners must give a high-level presentation of the engineering facts to convince public agencies that the development is necessary and feasible, and to assure private owners that they stand to benefit from the proposed work.

A watershed is more than land and water, infiltration and runoff, elevation and slope, soil and rock; it is also insects and bacteria, roads and fences, farmsteads and cities, and wildlife, livestock and people. The water resources of a watershed become only one facet for development and management. The other resources, the timber, the minerals, the land, the fish and wildlife, may be of equal or greater value. Total development must be approached on a systems basis with consideration given to all the resources and values involved. As in planning, many disciplines have interests in and valuable contributions to make toward the solution of development and management problems.

Concepts of the purposes of water resources development range from the view that water should be developed to satisfy specific human needs to the view that water is a means to achieving a higher standard of living. Regardless of the philosophical approach, the process of development requires the postponement of benefits now for the sake of future benefits, and is of necessity, a long-term process. To the public, long-term policies are unpopular because of the sacrifices that are required during the initial phases of development. Another concept of resource development views it as a means for improving upon research data and hypotheses. Observations on the response of hydrologic parameters can be used to verify the original hypothesis with the feed-back being used to gradually improve the original assumption.

Full watershed development requires that arid lands be irrigated, floods be controlled, water power be harnessed, water be available for industrial uses, fish and wildlife habitats be preserved, navigation be maintained, and that the quality of water be preserved for municipal and domestic uses.

Multi-purposed water development is an attractive goal, but water supplies are limited and it may not be possible to have optimum quality and quantity for all uses. Water resources development is a compromise between competing uses and between regional and small watershed needs. The benefits of water development can not be confined to those living on the watershed selected for development, nor are the needs for development confined to the residents of a single watershed.

It is very unlikely that watershed development will be introduced on a virgin watershed. Developers will be faced with a variety of conditions, most of which came into being without the benefit of organized planning, that will prevent development from reaching its highest level of fulfillment. The level of water resources development has two parts: the level of water usage development and the level of water facilities development. The level of water usage development is determined by the extent to which the watershed's water supply is being used, and the level of water facilities development is determined by the extent to which non-water resources have been committed to developing water for use. Obviously, the extent of proposed development will be a function of existing development.

Water resources development is essentially the systematic exploitation of water, that is, making the water available for use. Any form of resource exploitation involves disturbing the established equilibria; unbalancing by exploitation may have far reaching effects upon the sustained yield of the resource, upon its quality, its quantitative and qualitative variability, and possibly upon its location. The utilization of water resources deals with slowly responding equilibria and the resulting transients may be of great significance to effective management.

The physical manifestation of exploitive development is construction. Water resources development requires the drilling of wells, pipelines to transport and distribute the water, treatment plants to purify it before and after use, structures to control and regulate it as overland flow, in streams, and in lakes, channel improvements to facilitate its flow, land treatment to protect its quality, and harbor facilities to realize its navigational potential. It is not surprising that this heavy emphasis on construction has led to an engineering approach to water problems that extends from planning through development and management.

The rate and scope of developing water resources falls to two quite dissimilar groups consisting of the builders and the producers. The builders draw up, construct, and supervise projects while the producers operate and maintain the project facilities upon their completion. The qualifications of the two groups differ widely. The builders need formal technological training, experience in technological applications, sustained drive or motivation, the ability to organize informally into development teams and the ability to motivate and direct the producers. Producers must also be technologically experienced, but they should be motivated to discard traditional technology and to change existing structures, and should be able to co-operate with other producers.

There are a number of constraints operating in water resources development. Land and water were among the first resources for which laws and institutions were established in ancient times, and today these laws and institutions are resistant to change. Institutional factors are among the most serious contributing to resource abuse. As a renewable resource, water will usually be utilized at a rate that provides maximum yields now and will allow similar rates on a sustained basis. In terms of development, this may dictate that water be imported to meet local needs. Technological progress (or the lack of it) may effect data accumulation and evaluation, development, extraction, parametal manipulation, and the reduction of resource losses.

Developers may choose to develop either ground water or surface water. The choice depends upon many factors. Surface supplies are usually stored near the water source while underground water is usually developed near the demand area. Ground water storage has several inherent advantages. Its storage space does not require major investments, full and empty stages do not present risks, there is no lumpy investment, and water losses are much lower. There are difficulties with ground water supplies: recharge operations may be complicated, the long-term behavior of percolating formations is not fully predictable, and clogging effects can be detrimental to quality. The limitation to underground supply comes from recharge being subject to the percolation capacity of the field and generally, large flows can not be absorbed. Water development will usually begin with ground water since it can be obtained with the least cost, least delay and the least risk. During the initial period of ground water development, time is available to collect surface flow data, conduct investigations, and to prepare designs to ensure adequate conservation and regulation of surface systems. Extended use of ground water on a scale significantly greater than sustained yields, while exhausting the ground water supply, enables the local economy to expand to a position where it can afford to import water when the need arises.

Financing of watershed developments will vary depending on the initiative and on the responsible agency. The individual who makes improvements on his own will pay his own way. Under the Soil Conservation Service program, assistance is available for conservation practices and wildlife preservation measures. Drainage districts finance improvements through assessment of all land owners within the district. Watershed associations may have the power to tax. On the larger scale, water distribution and sewage collection systems are financed through revenue bonds as are treatment facilities. Federal grants are available for municipal projects. When it comes to flood control, the federal government will pick up 100 percent of the bill for design and construction.

The history of watershed management dates back to 1867 when a legislative committee in Wisconsin pointed out the relationship between watershed cover and watershed stream flow, a relationship that remains the foundation of watershed management. In the national forests, watershed management has been practiced since 1897 when Congress allowed the Department of the Interior to reserve public forests to secure favorable conditions of water flow. In 1911, the Weeks law authorized co-operation between states to protect the watersheds of navigable streams. In establishing the Soil Conservation Service, Congress stated its policy to be the preservation of natural resources, flood control, prevention of reservoir impairment, and maintenance of river navigability through permanent control and prevention of soil erosion. A year later, in 1936, the Flood Control act divided flood control responsibilities between the Department of Agriculture for treatment of upstream watersheds and the Corps of Engineers for main stream projects. The 1944 Flood Control act established the first experimental watersheds.

The fundamentals recognized in these acts have endured and the water resources aspects of watershed management are still considered as the art and science of managing the land, vegetation, and water resources of a drainage basin for the development, use, control, and protection of the watershed for man's benefit. Any shifts in the approach to watershed management over the past 30 years have followed from the growing seriousness of certain water problems and the appearance of new ones, changes in the possibilities for dealing with water problems through improved technology, and changes in political philosophies. At any particular time, the approach to water management will be governed by four factors: concepts of the purposes of water resources development, perception of the problems and potential for development, the available technology, and social guides.

Current thinking treats management of water resources as a planned intervention into natural equilibria or equilibria established by prior development, with a view to intercepting water for human uses while causing a new equilibrium to be formed in the resource. Adding an economic flavor, water resources management becomes concerned with establishing the quickest and the least expensive way to change existing resource parameters into those prescribed by the demand function (or the comprehensive plan) while considering conservation and budgetary constraints. In either case, dynamic management does not confine itself to studying initial and desired states, but also investigates the transients between the two states.

Water resources should be managed to get maximum use and to take advantage of their full economic value. This requires: (1) development of the nation's water resources in an orderly phasing that will allow optimum use of available supplies now and in the future, (2) consistent policies uniformly applied to all concerned, (3) adequate planning and development instrumentalities which will bring about participation or representation of all classes of water use, (4) procedures which will provide the most favorable co-ordination of all planning and development agencies and eliminate unwarranted duplications,

(5) research, investigations, and experiments in the field of water and related resources, (6) utilization, in most cases, of natural geographic boundaries as logical areas for comprehensive planning and development of water resources, and (7) establishment of priorities for different and conflicting uses.

There are two principal dimensions to watershed management: protection of the watershed by stabilizing the soil, thereby preserving and improving water quality, and treatment of the area to improve water yields. Positive watershed treatments are likewise grouped into two categories: vegetation management and mechanical and structural measures. Vegetation management includes fire protection, phreatophyte removal, timber-cutting management, plant-type conversion, seeding of burned areas, strip cropping, reforestation, improving ground cover on water-spreading grounds, range management, and the use of wetting agents to increase infiltration. Mechanical and structural measures include contouring, channel stabilization, headwater dams, adequate road drainage, protecting water quality at construction sites, gully plugs, adequate sanitary facilities, and evaporation suppression. These measures must be fit into a management equation defined by space-time, quantitative, flow-rate, mineral, and biological quality parameters.

The choice of boundaries for a management basin will often be a decisive factor in shaping water resources development policy and in determining efficiency in the exploitation of the resource. The best approach to water resources management is from the most fundamental level that can be established. This is the small watershed where the overall problem breaks down into its constituent parts. The small watershed lies at the base of all water yields, and the management measures applied to it will determine how much water it will catch and hold for use.

Water yield is not the only goal of small watershed management. Protection, stabilization, and conservation have already been mentioned. They are instrumental in managing water production and also in flood control, another management goal. In terms of land use, other management goals could be the increase of agricultural production, the provision of recreational facilities, or the adaptation of the watershed for urbanization.

As was the case with research, the major water resource management problem is in the urban watershed. Urban water management consists of water supply development and distribution, surface drainage collection and disposal, and waste collection and disposal. Urbanization drastically changes the local water regimen, resulting in the loss of base flow and in greatly increased storm flows. Rapid urban runoff adds sediments, oils, fertilizers, salts, and nutrients to the pollution loads of area streams. The traditional approach to urban water management generates problems by treating urban water utilities services as unrelated entities and as optional government services which implies that the service could be provided by the people themselves, that the municipality is an effective service area, that local government may elect to provide service or not as it sees fit, that initiative rests with the local citizens, and that intermunicipal arrangements are strictly a matter of local concern.

Much preferred to the traditional approach is that of an essential utility concept which holds that water is a need which people can not provide for themselves and thus it is a government responsibility, that the service should be provided under monopoly conditions over a guaranteed franchise area, that the state will regulate the operation, that rates should be based on the service rendered, and that fixed responsibility for quality, type, and continuity of service is necessary. Under this concept, municipal water, sewage, and drainage administration should be consolidated in all urban areas and given an independent revenue base which should derive from user charges and not from general revenues.

The primary forces to be managed in urban areas are the activities of man, specifically his generation of waste and his inclinations to develop areas not consistent with sound planning. Where control of people instead of natural forces is the issue, the traditional management method of stopping, confining, or treating with engineering cures instead of with preventives must be abandoned. The principal urban management problem originates with expanding populations requiring more water and more waste disposal area, and at the same time, more open areas and more recreational water. Thus in metropolitan areas, watersheds and water recreation areas can not exist separately but become the recipients of ever-increasing waste discharges.

The urban area that gets its water supply from a major river is far removed from small watershed treatment, although its supply is affected. Outside of urban areas, understanding cover-stream flow and soil-stream flow relationships is fundamental to management. It is not necessary to go far from a river's banks to find that ground water is the main source of water supply and that watershed characteristics are causally important. Even if surface water is the main supply source, everything that happens to the watershed affects the supply, and by knowing the interactions of meteorologic and topographic conditions, the forested areas, the soil cover, and the farming methods used on a watershed, the manager can develop ways of improving the rainfall-runoff relationship.

Efforts to conserve and utilize water resources must recognize that water and soil are inseparable in resource management. Above any other consideration should be that of what happens to or in the soil which receives precipitation. No matter how much new land is put under irrigation, there is no excuse for losing productive agricultural land through poor land management in relation to water. The costs of land erosion, carrying away topsoil, clogging streams, filling reservoirs and harbors, and of removing sediment from water supplies are liabilities that need more attention.

There is no single approach to water management. All management approaches are heavily slanted by law and by historical precedent, with little emphasis given to economic considerations in allocating water between uses and users. But flexibility is a necessary characteristic as the approach being used currently may be constantly required to change due to such crises as drought, flood, intolerable pollution, or severe economic depression. Should the resources of the given management basin be insufficient to meet the demands, a broader base will be required, or if basin resources are excessive, management basins could be subdivided.

Management alternatives will change mainly with technological improvement. The technology available depends in part on the locality and sometimes technological applications will be inhibited by cultural factors. Advances in technology have helped to broaden the range of choices in problem solving, but at the expense of increasing the pressures on available resources by introducing new potentialities. Technology can't increase the average quantity of water beyond a certain point, but it can ensure that an average quantity will be available under all conditions.

If too much emphasis is given to technology and physical engineering, too little is given to human engineering and sociology. Social guides or human behavior that condition water resources development are found in laws, administrative arrangements, and public policies, or they may be tacitly accepted without formal expression. The problems with social guides relate to the problems of values, intangibles, and the lack of standardization in agency procedures, compounded by a lack of factual data on the social structure and on its functioning. Management constraints will arise mostly from the human element of the development equation; they may be connected with the professional, motivational, and organizational limitations of project development groups, with institutional and legal problems, and with fund limitations.

Other important management constraints are due to planning limitations, to the lack of authority to implement management measures, and to the lack of authority to prevent unplanned, inefficient, or detrimental exploitation of resources. The effects of this lack of authority may be seen in Soil Conservation Districts, for example, when all of the land owners in a watershed do not participate in a project. The principal weakness in the administrative framework for watershed management stems from a lack of leadership in the executive branches of government which filters down to the local level, and from the lack of an agency to evaluate in depth total development proposals instead of the individual facet evaluation now used.

Wise management and planned manipulation can completely change ground water flow regimes; it can adjust water flow availability in space and time to meet demands; it can change the relation between ground and surface water, increasing the availability of the latter as the availability of the former declines; and it can institute qualitative changes that will continue on their course for many years.

CHAPTER 7

SUMMARY

Small watersheds are difficult to define because of the variety of natural and cultural parameters involved. Hydrologic performance expresses the effects of most of the parameters and a small watershed can be defined as a watershed whose sensitivity to high intensity, short duration rainfalls and to land use is not surpressed by channel characteristics, or, in terms of hydrographs, a watershed whose hydrograph is determined by overland flow rather than by channel flow. The time of rise and the shape of the hydrograph are the distinguishing characteristics: small watershed hydrographs will have a short lag time, a rapidly rising limb, and a sharply defined peak. The application of a performance definition can be extended to all areas of small watershed activity.

Research is the source of small watershed performance data and is also the means of testing the reliability of proposed development and management measures. Research has been concentrated on the physical aspects of agricultural watersheds, and while the results have been useful, a much broader research program extending to social and political fields must be established.

Small watershed hydrology is in a developing stage.

Large watershed hydrology can not be directly applied to small watersheds. Hydrologic calculations are hindered by the lack of rainfall and runoff measurements for small watershed events. This data is necessary for the derivation of most predictive methods used in estimating runoff. Empirical formulae do not require measured data, but they are deceptively simple and can be unreliable when used indiscriminantly by those unfamiliar with their proper application and with the area being studied. In terms of design, this can lead to over-designed facilities (providing excess flow capacity or excess storage capacity) and excessive construction costs. Failure to evaluate both rainfall and runoff conditions can also lead to excessive runoff estimates.

Small watershed policy can only be inferred from legislation, water law, water rights, and administrative actions that have been designed for broader applications; the small watershed is the subject of very little direct policy creation. At the present time, small watershed activities are authorized and carried out under a nebulous national policy which filters down to the local level through state legislation and administration.

Small watersheds can be planned, developed, and managed under the same principles and procedures used in comprehensive river basin studies, providing that appropriate modifications are incorporated. Multi-purposed considerations are not as demanding in small watershed work, although use-conflicts will occur and priorities must be established. The primary goal of small watershed planning, development, and management is high quality water yield. Watershed conservation, protection, stabilization, and land use controls are used to secure the objective.

In all phases of small watershed activity, the urban watershed needs more attention than it has received. Research on urban problems is almost non-existent. Urban hydrology is poorly understood at best. Generally, the effects of urbanization are an increase in peak flows, a shortened concentration time, and a decrease in water quality. Lowering of ground water tables is another serious effect of urbanization, and results from a combination of increased water consumption and decreased infiltration recharge opportunity. Urban planning, development, and management considerations dealing with water usually stop at supply lines; to date, the major water interest in urban areas has been assuring a source of potable water. As with wild and rural watersheds, the solutions to urban problems must be multi-disciplinary, must begin with research, and must consider both the water and its related land resources.

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