MEASUREMENT AND MANAGEMENT OF WATERSHED SNOW PACKS[1]

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Introduction

Water use has expanded so greatly in the United States during the past quarter century that demands for water in many places now exceed the readily available or most economically divertible or storable surface supply. This is especially the case in the West, where water utilization is more complete than elsewhere in our nation. Improved standards of living and technical discoveries involving increased water use in domestic, industrial, and agricultural processes will doubtless continue to magnify water use per capita in the future.

About one-sixth of the nation's present water supply now comes from groundwater. Out here in the West, our use of water in some places has simply outstripped nature's production rate of surface flow. We have turned, then, to mining the underground water supply. In Oregon this has been simple, and originally, at least, was not too costly. No license or fee is required. No accounting of the water used need be given to anyone.

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[1] Discussion prepared for annual meeting of American Society of Foresters in Portland, Oregon, October 19, 1955.

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Thus, increasingly heavy drafts are being made on water stored up for centuries in underground basins. The annual withdrawal rate dangerously exceeds the rate of replenishment in some groundwater basins. If those areas expect to stay in business, other water sources will have to be found, or the pumped amount will have to be reduced.

Future Water Needs

The nation's population is projected to increase around 35 percent by 1975. Water used by irrigation and for consumptive municipal uses will correspondingly increase. Non-consumptive water use in industry will greatly increase.

Here in Oregon, where agriculture and wood processing are mainstays of the state's economy, and where fisheries and recreation account for substantial annual income, water and its wise management seem certain to be a critical element in control of our future growth.

According to recent studies (Report to 48th Legislative Assembly for Oregon by Water Resources Committee) the water requirements of Oregon's two major water-using industries -- agriculture and wood processing -- can be expected to "increase from 5 to 10 times in the foreseeable future." Population projections indicate more than half again as many Oregon residents 20 years hence as today. Municipal water requirements are easily likely to double. Yet, the report says, "It does appear from the survey that 22 cities (in Oregon) of over 1000 population, using surface water as a sole or supplemental source of supply, will be unable to materially expand their water systems."

Sources of Water

What are the possible sources for the water we must have?

First, of course, are the precious sources of annually varying surface water supply which are found in the western mountainous areas. The precipitation there is usually twice, and sometimes three times or more, that on the valley floors a few miles away. The Pacific Northwest states are unusually well blessed in this regard.

Another important source is the groundwater. Groundwater supplies are not so readily evaluated as surface supplies and can readily be overused to a point which can irreparably damage the local economy.

The greatest, and an inexhaustible, source of all water is the sea. Nature's distillation processes have not thus far been duplicated by science at costs competitive with controlled runoff from watersheds. Cheap methods for converting saline water to fresh might be so developed as to make the sea a practical source for water to any user who can afford whatever costs per acre-foot may ultimately be involved. There are small plants all over the world now converting salt or brackish water to fresh, but only for the highest of all water use -- personal consumption. At present, the costs of converting brackish water might be as low as $20 per-acre foot, but for sea water it ranges from around $150 to $1,000 per-acre foot. Even if these costs could be remarkably reduced, as perhaps they might through superior technology, there would remain the truly expensive problem of transporting de-salted water to a point of use.

Conventional water-use projects in much the greater part rely on gravity flow for water transportation. Transport costs per acre-foot-mile therefore are reasonable. For instance, present "use cost" per acre-foot mile for delivering municipal water 30 miles to Medford, Oregon is 20 cents. But converted sea-water would have to be moved uphill, by pumping, in all cases and that would cost a great deal of money, probably far more than an irrigation water user, at least, could afford to pay.

A great deal of reclaimed or purified water is being used in our nation. In the U. S. Steel plant at Ceneva, Utah, where water is hard to come by, water is used, reused, and reused again. It is said that 70 million of the inhabitants of our nation use and drink water which has served a previous use for man.

But in the main, our future principal water supplies seem likely to continue to come, as in the past, from the watersheds. We technicians concerned with the best possible management of watershed resources must continue to learn all we can, rapidly, about their best management for maximum production and perpetuation of water sources in the watersheds.

Relative Watershed Values

It would be presumptuous for me to detail the numerous watershed values to technicians such as you foresters who are associated with them every day. You know them far better than I. However, speaking only as an observer who has roamed the western peaks and valleys for a few years, it is sometimes to be wondered if the water-productive capacity of watersheds has not been rather taken for granted. Enlargement and protection of the timber-production value, grazing improvement, mineral discovery and development, or enhancement of recreation and protection of wildlife and fisheries values are essential. These values are multiple in most all watersheds and are all, of course, related to the basic water production value.

However, water production is unquestionably preeminent in many western watersheds. Land without water is of little value. It lacks productivity and its inhabitants cannot establish permanent residence, as with the nomadic tribes of the high waterless Asian plains.

McLaughlin (11) estimated the value of water produced in 1940 on watersheds of Oregon's Rogue and Klamath rivers at approximately $4.00 per acre. His estimate was based on the gross value of irrigated crops, power generated, and municipal water sold. Adjusting his estimate to 1955 values and capitalizing at 4 percent interest suggests a figure of about $225 per acre for the water-production value alone.

Following a procedure somewhat similar to McLaughlin's, suggests values for timber production alone on a sustained yield basis, for comparable total areas, equal to $170 per acre on Rogue river and $116 per acre on Klamath. This procedure employed an estimated growth-rate factor times current log prices at the mill.

At the higher watershed elevations, the per acre value for water production considerably exceeds the watershed average, since precipitation and snowpack are greatest there, whereas the timber value at highest elevations becomes less than the watershed average due to non-commercial species, thinner stands, slower growth, inaccessibility, etc.

More economic studies along this line are needed. However, additional studies would be unlikely to change the essential conclusion, that in watersheds which produce a substantial runoff from the annual snowpack, major portions should be managed primarily for the production of their water crop.

Watershed Features Important in Water Production

Numerous features additional to precipitation are recognized to affect water production. These include watershed size, aspect, topography, geology, and vegetative cover. However, of all the numerous features which affect water production -- its amount, delivery rate, and time of delivery -- our discussion today centers around snow.

The Mountain Snow Pack

The importance of snow in water production on western watersheds stems from the fortunate fact that precipitation falls mostly as snow. It stays on the ground for months, melting later to sustain river flow during much of the period of greatest demand for water from the streams.

There is thus provided in nature's mountain snow a water storage facility greater than any man-made storage ever conceived. However,

storage works built by man help to provide a means of regulating the runoff from snow melt to improve its distribution for agriculture, commerce, and industry.

Snow, as an enormous storage reservoir, materially and benefically alters the shape of the hydrograph from that which would otherwise be observed. If there were not any snowpacks, streamflows from western mountains would most often reach their annual maxima during the period December through March. These are the months of minimum water needs for agricultural and municipal use. Tremendous storage works would therefore have to be built to hold the amounts of water which are currently required to meet summer water needs. Western coastal streams, under a snowpack regime, usually reach their lowest flow stage for the year along in September or October. These streams would more than likely be as dry as toast by early July under a precipitation regime of rainfall only. The effects on western economy of such a situation would be disastrous.

On the debit side, from time to time, the western watershed snowpack provides the knock-out punch behind damaging snowmelt flood flows of summer or late spring. However, by means of snow surveys, the threat of this kind of a flood can usually be recognized considerably in advance and numerous precautions can be taken to minimize the damaging effects of such flows.

It is becoming more and more evident that activities directed toward the prevention of floods or the reduction of peak flows should include land treatment and watercourse structures on the headwaters of streams, thus complementing the flood-control activities on the main streams. Unquestionably, much can be accomplished toward the reduction

of damaging peak flows through proper watershed management, including conservative use of forest and range lands, and agronomic practices designed to reduce or retard runoff on cultivated lands.

A significant point relating to mountain snowpacks is the relatively small land area which produces the highest unit flows from snowmelt. For instance, 60 percent of the late summer flow of Oregon's Umpqua river comes from 10 percent of its drainage area.

If methods can be found to increase the amount of the snowpack or to reduce its rate of melt, the relatively small areas to be treated or managed would make such treatments more practical.

Snowpack Inventories

A first step in the search for watershed management practices aimed to improve both total water yield and its distribution is to make the best possible inventory of watershed precipitation and runoff.

At present there are very few precipitation gages in high mountains. A cheap gage which will operate unattended for long periods, and which will catch a true sample of snow is yet to be developed. An elaborate heated radio-transmitting gage has been developed and is in satisfactory use by the Bureau of Reclamation in California (1). The Corps of Engineers, with the Motorola Company, developed a radioactive gage, which records the water content of the snow at one spot and transmits the report of the reading by radio (5,6). This transmitter-gage costs in the neighborhood of ten thousand dollars. I know of but two such installations in the world.

The most commonly used precipitation gage in the high mountains is the so-called "stand-pipe" gage. It is not too expensive, but it

frequently caps over with snow and fails to accurately measure snowfall.

Snow stakes are seldom used as they have generally given way to snow surveys. A recent adaptation of the old snow stake is the so-called "snow stadia marker" for reading snow depth from the air (7). One hundred of these are in use now in the West. They are useful in estimating water equivalent of snow during early winter months when close accuracy of snow water determination is less important than later in the season.

Areas covered by snow are quickly estimated now by mapping from aircraft. Photography of snow-covered hills from fixed ground points is being used also for this purpose.

However, the reports of water stored on watersheds in the form of snow come on a wide-spread and accurate scale from the snow surveys conducted throughout the West by the Soil Conservation Service in cooperation with the U. S. Forest Service, Bureau of Reclamation, Corps of Engineers, National Park Service, Bonneville Power, Geological Survey, Bureau of Indian Affairs, each of the western states, and scores of other agencies. During this past winter 936 men participated in the progfam. These men traveled nearly 30,000 miles by foot, on skis or snowshoes, and an additional 23,000 miles by over-snow machines and aircraft, to measure 1,243 snow courses. They made use of 276 specially stocked shelter cabins in making their appointed winter rounds.

The snow surveys in British Columbia are the responsibility of the Water Rights Branch of the Department of Lands and Forests of the Province. In California, the snow surveys are coordinated by the state engineer.

Foresters have contributed basically to the snow survey activity. It is well known, for instance, that without the support of the U. S.

Forest Service far fewer snow surveys would have been recorded than the users of the data needed.

Information secured by the snow survey includes data of snow depth, water content of snow, areal snow coverage, and, very recently, records are being gathered of water content of watershed soils beneath the snowpack.

The data are used for various purposes by numerous agencies, but in the main, the reports form the basis of estimates of the seasonal discharge of western rivers to flow from the watersheds during the summer months.

A gaging station network which currently reports the flows of main streams (so-called "index" stations) is maintained by the U. S. Geological Survey. There is need for a similar network on a current report basis in the small headwater tributaries.

The snow survey network is by no means complete or adequate. It is estimated that an additional 400 snow courses are needed in the West to provide the data needed to improve the accuracy of present forecasts, or to make possible the better forecasting of the small headwater streams. These required courses are being established as rapidly as funds come to hand.

The snowpack inventory is incomplete until the relative moisture content of mountain watershed soil beneath the snow is determined. Extensive use is being made of resistance units for this purpose in most of the western states.

Managing Watersheds for Maximum Snow Water Production

The ideal snowpack is one of maximum depth and maximum water content,

which melts at just the correct rate to minimize peak streamflows, yet sustains highest possible flow of streams during late summer. It is a common observation that such conditions most nearly prevail in the Alpine or sub-Alpine watershed areas where fairly dense timber thickets are thickly interspersed with small, winding open parks up to an acre or so in extent, or where thin timber stands result in minimum interception of snowfall, but shade the snow and provide protection from the wind. Under these ideal conditions heavy snowpacks accumulate, but their melt is delayed and snow lies in the numerous shaded places until well into July, or in cool seasons even into August.

There have been numerous approaches to proposals for increasing snow accumulation or controlling the melt. The creation of artificial glaciers has been proposed and attempted. Even could such glaciers be satisfactorily and cheaply built, it is extremely doubtful if the glacier melt rate would meet requirements for practical water use. Glaciers generally melt too slowly and do not provide water at required rates.

Some work has been done with use of chemicals or compounds applied on snow and ice surfaces, either to hasten or to reduce the rate of melt (8). These experiments have not so far shown much promise for use on other than relatively small localized spots.

Extensive cloud-seeding programs are being practiced in the West, with hopes by the sponsors of augmenting the mountain snowpack. The outcome of such operations is difficult to assess with our more commonly used evaluation methods. Thus it may be some time before we get a satisfactory picture of the results of such projects. However, some evaluators in this field have noted that cloud-seeding might have a counter effect

to that intended -- that is, it could reduce the precipitation (2).

Some experimental work on cropped lands having relatively shallow snow cover has shown that mechanical snow ridging aided in the conservation of the snow and resulted in increased soil moisture (10). We are not aware of such work being adapted to watersheds, although that would be interesting.

However, in watershed snowpack areas subjected to heavy wind drifting, fencing can be constructed to induce snow drifting in selected places where the subsequent melt will be long delayed (9).

There are continuing proposals for developing controls over snowpacks, mostly through timber management methods for reducing interception of snow by ground-covering vegetation, for reducing evaporation or transpiration losses, and for slowing the melt rate of snowpacks, all on timbered or vegetated watersheds (3).

It is also recognized that the water-producing capacity of watersheds can be increased by practices which reduce consumptive water uses by undesirable or uneconomic species of plants (4). It is recognized that in our efforts to increase or maintain the capacity of the watershed to produce water we must also produce water of acceptable quality.

Productive and excellent research work along these lines has been accomplished by the various western Forest Experiment Stations (12). A great deal more work should be done to find the best pattern of timber cutting and forest management for particular locations. The various possibilities of timber thinning, clear-cutting by blocks or strips, relationships of width to length, and orientation, require a great deal of research, especially as the results in one locality might not entirely apply elsewhere.

Conclusions

1. Snow is a natural resource of great value in western mountains.
2. Snow accumulation or snowmelt is not at present susceptible to much management by man, but might some day be.
3. Research into best management of watershed snow packs is necessary. Such studies should be pursued fully without delay in all western mountain areas.
4. As a natural resource, the snowpacks must be measured, inventoried, recorded, and estimates made of the resulting runoffs. Snow surveys provide an efficient and practical tool in this respect. Extensive snow survey records are available and should prove useful in estimating effects of the various watershed snowpack management practices which might be attempted or developed in widely separated areas.
5. It is urgent that more records of watershed flows be secured on the smaller streams near the headwaters of rivers. Snow inventories would be incomplete and lack full utility if not accompanied by detailed records of the flow of the rivers.

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