MEMORANDUM REGARDING RESEARCH

IN THE DEPARTMENT OF METEOROLOGY

Nevada Agricultural Experiment Station

February 23, 1940

-Projects-

Previously research work in this Department has been conducted under two projects.

Project 15 Adams Fund 1932-

"Timber and Snow Studies and Snow Surveying"
and

Project 44 Purnell Fund 1933-38

"Forecasting the Runoff of the Humboldt River, Nevada."

The evolution of these studies and the present trends of public interest and activity toward the interpretation of snow relationships make a summary of past and present research with plans for the future highly desirable.

The "Research Project Outline" proposed by the Office of Experiment Stations is followed:

1. Proposed Project Title. Snow, Snow Surveying and Forecasting of Runoff.

2. Objective. The conserving and forecasting of runoff for irrigation and power.

3. Reasons for Undertaking the Study. The data sought underlie all irrigated agriculture and much of hydro-electric development. They should be an aid in determining seasonal runoff and the probability of floods and drought. This study has now won the close cooperation of the U.S. Bureau of Reclamation, Forest Service, Weather Bureau, Geological Survey, Army Engineers, Soil Conservation Service with its Division of Irrigation, the Biological Survey for its Game Refuges, National Park Service, and Water Resources Board. To these organizations should be added irrigation districts, state divisions of water resources, municipal and private water and power systems.

The spiritual and physical values are great. Hostile groups have now united for the regulation of the level of Lake Tahoe; a severe drought was forexeen for Utah in 1934 and was met at a saving of over $5,000,000; the water users of the Humboldt River in 1931 accepted a forecast of 10 per cent of normal runoff and its drastic restrictions without question; and in 1939 the Director of Public Works of California in connection with the forecasts based on snow surveys issued "a warning to agriculturists, irrigation-and water-districts, the mining industry and power companies to conserve to the utmost their impounded water supplies."

On the other hand, as early as 1926 the Water Board of the Walker River Irrigation District saved the crops of the East Walker by a loan to the ranchers of reservoir water belonging by priority to others, and since this successful venture have allotted all waters on the basis of the snow cover and not merely on that of the storage on hand in the reservoirs.

The studies have fortunately preceded rather than followed public demand. As a result public confidence has been built up. The present trend is toward snow transport and sports. A study of the physics of snow has added much to safety. Practically the entire population of snow states is seeking knowledge and understanding.

4. Previous Work and Present Outlook on the Problem.

Previous work was scant and at the time was unknown to the Station. As early as 1901 a portable snow-measuring instrument for use in forests was designed in Russia and in the same year Charles E. Mixer in Maine cut snow cores to determine the probable size of spring floods in the Androscoggin Basin. In 1905 Robert E. Horton in New York, invented a sampling tube with scales for cutting and weighing cores of snow.

The beginnings of the present research date from 1905 on Mount Rose in the Sierra Nevada in the Far West, but observation was made in 1901 of the value of forests in conserving snow. The Nevada Agricultural Experiment Station invented the Mount Rose Snow Sampler and the Nevada or Percentage System of Forecasting runoff, now in almost universal use in North America. The project was undertaken originally to determine the effect of mountains and forests in conserving snow, then to forecast seasonal runoff in order to end strife and quiet alarm regarding the flooding of Lake Tahoe, finally to forecast water supplies and possible drought or floods.

Since this station has been the pioneer and leader in snow surveying, contributions to the research literature of the subject are mainly its own. The following list indicates the evolution and expansion of snow studies. All titles not specifically accredited to others belong to the Senior Project Leader and are marked J.E.C.

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5. Procedure

The present activity in the field of snow is best indicated by the Annual Reports of the Research Committee on the Hydrology of Snow of the American Geophysical Union, the Proceedings of the Western Interstate Snow Survey Conference, and the Transactions of the International Commissions of Snow and Glaciers of the International Association of Scientific Hydrology. These three organizations, spontaneously created from the research activities on Mount Rose and at Lake Tahoe, have united all organizations and individuals interested in snow and ice for mutual discussion of their problems from varying view points of climate and topography. The Senior Project Leader of the Station has been chairman of the American Committee on Snow, president of the International Commission of Snow and editor of the Western Interstate Snow Survey Conference throughout their respective periods, thus directing and coordinating the research along broad yet unified lines. The Junior Project Leader has been closely associated in the work.

This method of procedure is made possible by the wide extension of snow survey and streamflow forecast systems to all of the western states and provinces of North America and to the northeastern states and provinces including Newfoundland, and by the opportunities granted the Project Leaders of visiting practically all of the watersheds concerned. The purchase and distribution of reprints by more than twenty organizations has created a large field of understanding and cooperation. Complete files of Committee and Conference reports are submitted.

-Background Studies-

Certain broad facts have now been established which serve as a background for the study of the hydrology of snow. Briefly, these are as follows:

(1) Snow is much more efficient than rain in sustaining runoff even though the rain may be larger in total amount.

(2) Mountain snow at moderate altitudes is far superior in water production to lowland snow because of its relatively greater amount. Furthermore because of higher elevation and the consequently lower temperature, melting is retarded.

In the case of glacial streams fed by snow and ice, the autumn or low flow is relatively larger than in the case of snow only. On the other hand, the glacier stream like underground water may become seriously depleted by cycles of low precipitation accentuated in the case of the former by unusual melting and in the latter by excessive pumping. The long-range forecasting of supplies from glacier streams and underground water will ultimately be added to that of seasonal snowfields and rains.

(3) However, high-mountain snow may have little value except climatically. If the watershed is above 12,000 feet elevation, where low temperature and high winds prevail, evaporation may nearly exceed melting. Thus if quantitative measurements of the snowfields are made, the estimates may far exceed the runoff.

Also there appears to be an elevation as there is a latitude at which the maximum precipitation begins to lessen. This elevation has been detected though not yet determined for the Sierra Nevada.

(4) The conservation of snow by forests depends upon the relative power of the factors of interception and shading. Obviously the hardwood forest interposes but little interception to snow and rainfall in winter. Likewise it prevents drifting of the snow cover. On the other hand, it affords practically no protection against melting. The softwood forest intercepts snow and rain but provides shade against early melting. It also greatly reduces evaporation.

Both types of forest protect the soil from becoming windswept and if the depth of the snow is sufficient will provide frost-free soil at the time of winter or spring melting.

However, in the summer they intercept and transpire the intermittent rains to such an extent that the summer runoff falls below that of spring, though the precipitation is heavier. Thus snow, even if shallow, becomes the basic factor in runoff and floods.

-Immediate Problems-

The immediate problem basic to the solution of all others is accuracy of instruments and methods. Accuracy of method in turn depends upon further analysis of climatic and watershed factors, among the latter particularly the correction factors of soil moisture, precipitation during runoff, evaporation, snow density, and temperature. The mid-winter loss of a portion of the snow cover in the New England States forces the use of a quantitative rather than a percentage snow-survey and forecast system and thereby complicates the problem.

However, the accumulating store of snow-survey data now makes possible the analysis and comparison of snow-cover and runoff in widely situated and diverse watersheds over a period of years. Such analysis should indicate much more precisely than hitherto the potentcy of factors realized but not yet fully weighed.

The more specific groups of research are as follows:

I. EQUIPMENT

(1) Duralumin Sampler Tube. The substitution of duralumin for steel has brought several problems in the perfecting of the Mount Rose Snow Sampler. The hardening of its surface, the use of solder, and the replacement of the cutter in the field have now been solved. There remain, however, the adhesian of snow to the sampler and the question of durability.

Various types of enamel are being tried and a non-wetting metal is being sought.

Leaders, Philip S. Cowgill and John T. Ryan

(2) Short Cores. The problem of short cores in the Bow Basin, Alberta and the Androscoggin Basin, Maine should be studied. Similar trouble has been experienced in Australia. In the Bow Basin, powder snow may be the cause; in the other basin it may be an alternation of powder snow and crusts. Is the Kadel Sampler the only solution?

(3) Ice Cutter. In the Merrimack Basin and vicinity ice strata to a thickness of 3 inches have been found in the snow cover by the Federal engineers investigating the causes of floods and an improved snow-sampler cutter capable of cutting cores of ice has been requested. This problem is especially difficult and will recur with the sampling of old snow in the study of the alimentation of glaciers.

Leader of (2) and (3), J.E. Church

(4) Spring Balance. Increase in accuracy and capacity is being sought for maximum depths of snow cover and maximum diameter of evaporation pans for snow and ice. Improvements are being made gratis by Leupold, Volpel & Co. of Portland, Oregon and Chatillon & Sons, New York City.

The latter has developed a balance with iso-elastic springs 99.8 per cent accurate. This may supplant the non-spring balance, too cumbrous for use in the field. Snow depths slightly in excess of 20 feet can now be sampled. It is desired to penetrate even to 30 feet. Evaporation pans 15 inches in diameter with contents of dense snow can now be weighed. Wider diameter is essential to simulate the unbroken snowfield.

Leaders, J.E. Church, John T. Ryan

(5) Seasonal Gages. The U. S. Weather Bureau is installing seasonal snow and rain-gages to supplement snow surveying. The use of calcium chloride to keep contents fluid has been recommended. However, there is serious doubt whether the gages have sufficient capacity for precipitation during a prolonged period and for the calcium chloride necessary to melt the entire catch. Material has already been assembled for this test.

Leader, Carl Elges

(6) Motor Snow Sled. The Tucker Motor Snow Sled has been brought to this department for test and suggestions. It is relatively light, inexpensive, and valuable for snow survey trips and emergency work. It should become an adjunct of national forests and mountain mail-carriers.

This sled is supported mainly and propelled by a revolving longitudinal cylinder, carrying a spiral fin. To increase buoyancy and thrust, particularly in powder snow, the load should be transferred from the cylinder to the lateral ski, thus permitting reduction in the diameter of the cylinder and corresponding increase in the width of the fin.

The cost of adjustments is being borne by the inventor and the manufacturer.

Leader, John T. Ryan

II. LAYING-OUT SNOW SURVEY COURSES

The measurements at many of the snow survey courses have now become sufficiently numerous to make possible a comparison of the individual measurements to the average of the whole number and of the course to the snow cover of the whole watershed. Moreover, the value of zoning the courses for altitude should be determined for seasons like the present when rain or above-normal temperature has diminished the lower portion of the snow field. Some analyses have already been made by forecasters, but the entire field should be covered. The analysis of the erratic Humboldt Basin, Nevada, is now under way.

Special attention should be given to watersheds where quantitative estimates of the water content of the snowfields are used. In these areas the measurements may vary from occasional samplings on the floor of the basin to a system of contour-line surveys. In the Androscoggin Basin a 300-mile circuit of single measurements with various exposure is employed supplemented by a vertical course up the rim to determine the factor of correction to be applied.

In the Merrimack Basin snow-survey courses are being laid out at the mean elevation of the snow cover. In Newfoundland the accessible portion of the watershed is surveyed and the same water-content is applied to the snow in the remainder.

The underlying study is therefore the relation of one portion of a basin to its whole or to other basins beyond.

Leaders, Carl Elges, J. E. Church, H. P. Boardman and other forecasters

III. FORECASTING RUNOFF; DISTURBING FACTORS

Since the major effect of snow in the United States has disappeared by the end of July, forecasts of runoff have generally been limited to the heavier runoff of the streams, i.e. the runoff of April through July. However, in Utah the period is extended through September and Los Angeles estimates its water supply by the year.

Accuracy in forecasting runoff is now being expected within 10 per cent of the normal, and in their enthusiasm some are seeking accuracy within 5 per cent or within the limit of stream-gaging error. A few forecasts fall far out. In one watershed, the St. Maurice of Quebec, the runoff seldom conforms to the snow-survey.

In streams fed to any considerable extent by snow, the snow survey is the basis in forecasting. However, there are factors of varying effectiveness in modifying the snow percentage. These are in order of importance precipitation during runoff, initial soil moisture, evaporation, and possibly temperature. In the Percentage or Parallel System only the departure from normal of these factors need be considered. However, in the Quantitative System the full value of these factors must be determined for each basin. Wider discrepancies under the latter must therefore be expected.

(1) Precipitation during Runoff exercises a consistently increasing influence on runoff from snow eastward from the Pacific Coast. This is due to the relative increase in precipitation during the spring and summer months.

In the Sierra Nevada, where snow surveying has an ideal setting, the spring-summer precipitation is only 15 per cent of the annual. Here total lack of such precipitation reduces the expected runoff of streams 15 per cent of normal and Lake Tahoe 25 per cent.

The problem of determining the correction factor for the Humboldt Basin is made difficult by the spottiness of desert precipitation. The thunderstorm character of the summer rains in Arizona and east of the Rocky Mountains makes a study of precipitation and attendent runoff there desirable. In the Ruby Mountains of the Humboldt Basin, Nevada, a series of precipitation gages is being maintained at various altitudes to determine the effect of mountain rains. All brief rains that fall on dry soil are mostly wasted. However, it has been observed that the heavier summer rains on areas under irrigation and therefore moist appear in full volume in the runoff. From this observation has grown the habit of estimating the effective volume of such rains in the Humboldt by multiplying the depth of the rainfall by the irrigated area.

The weakness of summer precipitation as a factor on runoff in the upper Columbia and its apparent strength in the Bow and upper Missouri Rivers, which head in the same range as the Columbia but flow east, constitute a problem of first importance.

In New York State the snow cover is so small a portion of the annual precipitation that only the minimum runoff from the snow is forecasted, the maximum being dependent upon soil storage and summer rains. However, I am inclined to believe that this minimum is relatively large. The value of snow surveys in the East hinges upon this question.

In the Androscoggin Basin where snow surveys are quantitative, the surveys are made at frequent intervals and the precipitation during runoff is measured as a constituent part of the snow cover and the storage is computed like newly fallen rain.

Leaders, J. E. Church and Carl Elges

(2) Initial Soil Moisture. Soil moisture is a stronger factor on runoff in the Pacific Northwest and the Northeast where the precipitation is mainly heavier and better distributed throughout the year than it is in the West and Southwest. In the latter area the soil drains practically dry by autumn and freezing is insufficient to prevent the melting snow from percolating into it.

However, the spring priming of the soil must absorb a certain amount of moisture from the snow cover, dependent upon the character of the soil. Although this amount is fixed within narrow limits, its percentage relationship to the snow cover must depend upon the seasonal water content of the latter. The correction factor should be 0 at normal snow cover and increasingly high if the snow cover is thin, or *vice versa*.

For some reason this obvious factor has not yet been detected in the Sierra Nevada where the soil is shallow and the snow is deep, and although seen in the Humboldt Basin, Nevada, where the snow is shallow and the soil is deep, no exact measurements have been obtained.

The effect of the water table on the total seasonal runoff is being studied by measuring the water-level in wells.

Where the soil continues moist throughout the year, the problem of soil moisture is more complex. With the usual soil moisture, precipitation of 1½ inches will start runoff, yet in the Merrimack Basin after a summer of extreme dryness, precipitation totaling 6 inches scarcely affected the stream.

Measuring the moisture content of the soil has been proposed as an exact method. However, little has been done. Despite this uncertainty, quantitative forecasts in the Androscoggin are said to be accurate within 10 per cent and forecasts of soil storage for the following season are attempted. It is possible that except in extreme cases the moisture content of the soil does not greatly vary from season to season. The low autumn precipitation in the West this present season may provide convincing data.

Leaders, Carl Elges, J. E. Church and forecasters of the Pacific Northwest

(3) Temperature.

(a) Variation in temperature during melting affects the rate of melting rather than the total. This failure is probably due to the fact that temperature departures within the snow cover are small and the soil neither becomes dried out nor is infiltration capacity greatly overtaxed. Exceptions are chinooks which diminish the snow cover by evaporation and occasional high temperature that produces flood. The exact loss and gain due to temperature departure should be determined, for even the principle is still debated.

(b) A study of the value of latitude as compared with altitude should also be made, for example the conserving capacity of the low Selkirk Mountains of Alberta, British Columbia as compared with that of the high Sierra in southern California, and their seasons of accumulation and runoff.

Such problems are complex because of the intermixture of the two factors of elevation and latitude. In the southerly Owens Basin the snow survey could be conducted as late as May 1, in the northerly Bow Basin as early as April 1, and in the Humboldt Basin, intermediate in elevation and latitude, as early as March 15.

Leader, J. E. Church

(4) Snow Density. The density of snow is admittedly a time factor in melting, though probably not affecting the total amount. Increase in the density of snow decreases its capillarity or ability to carry its water content. Consequently in the critical month of March even normal temperature has been found to cause runoff

from relatively deep snow if uniformly dense. However, if insulated by a top layer of newly-fallen snow, it is protected against the immediate effect of the sun.

The change in crystallization of snow throughout its life cycle from deposition to melting, to firn (i.e. granular snow), to glacier ice is now receiving international attention. The depth and density of snow are also important factors in determining flood probability. The question of melting snow therefore deserves detailed and, if possible, laboratory study. The relative resistance of new snow, old snow, and ice to evaporation and melting is still in dispute.

Leader, J. E. Church

(5) Evaporation

(a) From Tree Crowns. Much work has been done in the study of climate and evaporation in Alpine and Arctic zones and on the protection by forests against evaporation, particularly of snow. However, further study should be made of evaporation of snow in the crowns of trees to determine the factor of interception. This will be less in the case of dry snow than of wet, for the former will be readily shaken to the ground when the wind rises. Moreover wet snow and even wet ice are evaporated more rapidly.

A tree pan has already been developed for this study.

Leader, J. E. Church

(b) From Spray. A difficult problem is the determination of the effect of surf and spray on evaporation from large lakes and reservoirs. Floating pans are naturally insignificant. The lake or reservoir itself must be used for measurements. The inflow and outflow must therefore be accurately known. Two recording gages should preferably be used--one at each end of the lake--to determine and eliminate oscillation of the water level and should be connected with the lake at sufficient depth to be unaffected by wave motion. The net lowering of the lake at the close of the period of surf should represent the evaporation loss and when compared with the net loss during the preceding period of unbroken water may represent the loss due to wind acceleration or dissipation of vapor from the surf. The division of these two elements may require laboratory equipment. Possibly the comparison of evaporation loss from an adjacent pan and the loss from the lake itself may provide the factor desired, particularly if the temperature of the water is the same for both and the pan is exposed to the same wind movement and vapor blanket. Location on an island or on the lee side of the lake may be sufficient. The relation of wind movement over the surface of the lake and on the shore could be determined by recording anemometers, the lake-center station being carried on a barge duly anchored to the bottom or held by drag-anchors.

Flathead Lake, Montana, is well adapted for the purpose and is already equipped with the two lake-level recorders desired. A weather station could readily be established. Observers could be obtained from the towns on the lake. A cooperative committee under the chairmanship of W. A. Lamb, District Engineer, U. S. Geological Survey was organized in 1935 to undertake this work and the study of chinooks in Montana. W. E. Maughan, U. S. Weather Bureau, O. W. Monson, Montana Agricultural Experiment Station and the writer were the other members. The death of Mr. Lamb has temporarily hindered the work. Mf. Lamb's successor is suggested as chairman in his stead.

Leaders, A. H. Tuttle, W. E. Maughan,
O. W. Monson, J. E. Church

(c) Chinooks. Snow losses from chinooks (foehns) lie on the border line between evaporation and melting. The exact proportion to be assigned to each has never been determined. Chinook ravages appear to be centered on the eastern side of the Rocky Mountains in Alberta, Montana, and Colorado, and more opportunities for observation will be found there. Consequently preliminary plans were made in 1935 to study the phenomenon in Montana with supplementary studies in Alberta and Colorado.

Essential equipment consists of snow sampler and evaporation pans supplemented by a weather station recording wind, temperature, and relative humidity. A precipitation gage should be kept to measure precipitation if any occurs. A stream-flow gage would show the response of the streams. The main point to determine, however, is the total loss from the snow-field and the loss from the pans. The loss from the pans will represent evaporation. The total loss from the snow-field minus the loss from the pans should represent melting. Since evaporation losses at such times are heavy, the pans should be unusually deep or preferably be refilled during the progress of the chinook. Because of the suddenness and rapidity of the phenomenon, observers should be resident near the snow-field.

Leaders, O. W. Monson, R. L. Parshall, J. E. Church

IV. FLOOD CAUSES AND FORECASTING

~~(2) In the~~ (1) In the Northeastern States

The two essentials for flood are excessive water or deficient soil capacity to absorb it. The Northeastern states possess both of these characteristics in abundance. Being exposed to the interaction of warm moist winds from the sea and a cold air mass from inland, this region suffers heavy and prolonged rains, but its soil is shallow and the underlying shale is impervious, acting like a slate roof on the watershed. Mainly, moreover the soil is moist from recurrent rains and therefore has lessened infiltration capacity. The result is expressed by Carroll F. Merriam of the Pennsylvania Water & Power Company in the following terms for the

Susquehanna, one of the large basins in the area: "we have approximately 10% of the total flood damage of the entire country in a drainage area that is not much more than 1% of the total."

Snow has an acknowledged influence in intensifying floods, depending upon its depth and density. Dr. Robert E. Horton has observed that floods do not occur when the snow is deep, for it possesses sufficient capillary capacity to hold the rain and thus serves like alluvial soil. The warmth of the rain may modify somewhat its melting power.

(a) Snow Density and Temperature. The capacity of snow of various depths and densities to hold rain and melt-water should be measured and tables prepared. Mr. Merriam urges that the transformation of the crystalline structure of snow be studied to determine whether there is a critical temperature and density of snow at which it suddenly releases its water content or facilitates passage of the rain. Such studies should be conducted under actual conditions of snow and weather concurrent with floods and in the region where opportunity of observation is abundant.

(b) Frost in the Soil. Obviously frost in the soil destroys the latter's absorptive power completely and leaves snow and vegetation, except of course lakes and reservoirs, as the sole deterrents of water movement. A study is being made of the protective power of forests and their litter against the entry of frost into the soil. Deciduous forests are believed to be more efficient than the conifers, but neither provides sufficient protection.

On the other hand, frost is rarely found in the soil when the snow cover is deep. It has been suggested by E. S. Cullings that frost regularly enters the soil in the autumn but is gradually melted by earth-warmth if sufficient insulation against further entry of frost is provided by the snow cover.

Mid-winter melting may permit the re-entry of frost without sufficient time for dissipation before the spring runoff occurs. Wind-swept land will naturally freeze deep. Floods therefore may be accentuated in the lower areas of a watershed where the snow is shallow and frost prevails.

Surveys of both snow cover and frost are desirable to determine the minimum possibility of flood.

(c) Shelter from Melting. Though the deciduous forest may slightly reduce the entry of frost, it is poorer than the conifers in sheltering the snow against melting. However, it permits more snow to reach the ground and more evenly.

(2) In Michigan-Wisconsin

The shading off of precipitation amount and intensity in Michigan-Wisconsin reduces somewhat the flood source of this area, but its surface and subsurface pockets of lakes and glacial soil impound much of its water. Thus floods are reduced to a minimum.

(3) In the Far West

In the Far West a study is being made by the U.S. Army Engineers to determine what floods are possible under maximum provocation. For this, the maximum capacity of the snow cover has been taken as a basic factor. Such snow floods would be stupendous and flood-detention works unusual in size and cost.

On the basis of the observed limitation on the power of the various weather elements in winter and spring when floods occur, the snow cover at the higher elevations would never be suddenly melted by either temperature or rain. Abnormal melting in the central Sierra Nevada may occur below 7,000 feet elevation but losses above this elevation are relatively small. Therefore, the feather edge of the snow fields below this elevation should be assumed as the danger factor. A quantitative survey of such snow should be made with sufficient study of soil moisture beneath it to estimate the net release of water from the snow. To this must be added the rain that can fall upon it and the net runoff that can be expected from the snowless slopes below. Of course, the heavier the snow cover the greater usually is its expanse on the lower slopes. But its depth above 7,000 feet is likewise greater and therefore more resistant to melting.

The flood problem in all of its phases is vital to human welfare and contentment. The snow surveys can readily be extended to provide requisite data for final conclusions.

Leaders, J. E. Church, Walter J. Parsons

V. SPECIALIZED STUDY OF ENTIRE FORECAST SYSTEMS

(1) Humboldt Basin, Nevada, (Present Project 44)

Typical plateau conditions: shallow, windblown snow, deep alluvial soil, summer rains as heavy as winter snow, heavy diversions above main points of gaging, few stations for measurement of precipitation and stream flow.

Present projects: (a) Analysis of annual snow surveys to improve their representativeness and accuracy; (b) Establishing stations for continuous measurements of stream flow; (c) determining normals; (d) estimating effect of summer precipitation on the stream flow; (e) measuring the intensity of mountain rainfall with altitude (Lamoille Canyon, Ruby Mountains); (f) conducting well measurements to determine the effect of ground storage on streamflow, thus providing a factor for modifying the snow cover percentage; (g) making annual forecasts and perfecting methods.

Leader, Carl Elges

(2) Yakima Basin, Washington

A typical Cascade Range basin, midway in character between the Humboldt Basin, Nevada, and the basins of the central Sierra Nevada, where snow is deep and stable.

Winter precipitation consists of rain and snow. Forecasts have long been based on precipitation and reservoir storage. Data and cooperation proffered by the U. S. Reclamation Service. Some analysis has already been made of runoff in the Skagit Basin which provides power for the city of Seattle, and a snow-survey system has been established in Lake Chelan Basin by the Washington Water Power Company. These three basins are adjacent to each other and represent both slopes of the range. A joint study of the three should serve the entire Cascade Range.

Leaders, H.P. Boardman, J. E. Church

(3) Snake River Basins

A volcanic basin with a large return flow below diversions. The feeders are numerous and diverse. Some variation between date of irrigation needs down stream and the date of snow-melting at the source. For example, the snow cover above Jackson Lake continues to accumulate until April, whereas forecast of available snow is desired at American Falls as early as March 1. Much material is now available for analysis.

James C. Marr, J. E. Church

(4) Feeders of the Colorado River

The Colorado River Water-Conservation District, Grand Junction, Colorado, requests that some research be done on the distribution of the snow cover in Western Colorado. It is felt that present snow courses "are very close to the lower boundary of the areas which really contribute the major part of the runoff." Aid has been promised.

Leader, J. E. Church

(5) Minor Tributaries of the Upper Missouri

The water of the upper Missouri is provided mainly by a fan of streams flowing from the Continental Divide but runs in a channel too deep to be utilized readily on the bench lands. The latter must be served if at all, by minor streams. The present forecast is adapted for the storage at Fort Peck Dam. Some investigation should be made of the possibility of providing snow surveys and forecasts for the smaller areas as well.

Leader, J. E. Church

(6) Comparison of the St. Maurice Basin, Quebec, with the Androscoggin Basin, Maine

To these should be added the Humber Basin, New Foundland. The snow surveys for the two latter are quantitative, that of the St. Maurice has been by typical courses and the percentage system of forecasting. The results in this basin have been very discordant. Midwinter melting creates a problem both in snow sampling and forecasting. Is quantitative forecasting inevitable here? The solution of this problem is essential to determining the limits of snow surveying.

Leader, J. E. Church

Conclusion

The basic problems mentioned above should be carried forward as data and cooperators can be obtained. The enlistment of the latter will depend upon the opportunity to make personal contacts. This in turn depends upon availability of funds for travel. The trips of 1935 to the watersheds of the West and of 1939 to those of the Northeast were fruitful in viewpoint and potential assistants. The journals of these two trips are being included with supplementary publications.

It is hoped that research funds can be obtained from Congress or Federal agencies to supplement the present fund of $15,000 granted annually for determining "irrigation water supplies." This might facilitate closer cooperation between the Division of Irrigation and the Nevada Agricultural Experiment Station, which jointly made the trip of 1935 possible. Its pioneer experience and favorable location make the Station a natural research center in snow studies.

6. Probable Duration. Since the snow studies are just emerging from their pioneer stage and represent various phases, the project should be made broad and its tenure indefinite. Its length of life seems coextensive with human interest in snow and ice.

7. Financial Support.

The following financial items are approximate, representing the average for recent years, except that until the present year the Senior Project Leader served at half salary.

Salaries			
Senior Project Leader	$3,900		
Junior Project Leader	1,800		
Clerk	1,200		
		$6,900	
Office Expenses		300	
Travel		600	
Field Equipment		150	
Labor		450	$8,400

The Humboldt Basin Snow Survey

The snow surveys in Humboldt Basin cost about $800 each year, of which the Experiment Station has been paying about $100. The remainder is borne by the U. S. Forest Service, Bureau of Reclamation, and the Nevada State Engineer. These surveys are necessary for the Humboldt Project.

A hydrographer is hired by the Nevada State Engineer to do the hydrographic work under the direction of the Station. This service is costing about $1,600 per year.

8. Personnel. The leaders of the project are J. E. Church and Carl Elges. The former is the inventor of the essential principles of snow surveying and forecasting of stream flow, the latter is a graduate of the School of Civil Engineering of the University of Nevada with the degrees of B.S. (Civil Engineering) and M.S. (thesis in snow surveying).

Other members are employed only on special assignments, as in the improvement of apparatus.

9. Departments Involved. No other division in the Experiment Station contributes directly to the work. However, there is a background provided by the Department of Range Management and Agricultural Economics.

10. Regional or National Cooperation. Although this project has never formed a part of a formal coordinated program, it has received informal cooperation from various Federal, state, municipal, and cooperate agencies which have benefitted from results of the studies and desire to see them expanded and improved. The American Geophysical Union has provided a center for the discussion and publication of problems. Formal cooperation has been planned, as stated in 5, but awaits further development. However, informal cooperation because of its breadth and spontaneity may maintain the vitality of the snow studies better than narrower control.

J E Church

J. E. Church, Meteorologist

Carl Elges

Carl Elges, Assistant Meteorologist

February 23, 1940.

P.S. The rapidity with which studies of snow and ice phenomena are expanding is vividly set forth in the following letter from Dr. Robert E. Horton:

Voorheesville, N.Y.

Feb. 17, 1940

Dr. J. E. Church,
University of Nevada
Reno, Nev.

Dear Dr. Church:

You will, I think, be interested to know that Dr. Nichols has designated Mr. W.U. Garstka, Soil Conservation Service, Columbian Bldg., 5th St., Washington, D.C., to take charge of studies and investigations of hydrologic phenomena under frozen conditions, including, in particular, frost depth, winter moisture content of soils, infiltration under winter conditions, snow cover, and runoff from snow cover. As I understand it, Mr. Garstka is a soil technologist, not a hydrologist, but he is well informed, energetic and enthusiastic.

A start has already been made, largely through the activities of the Advisory Committee of which you are a member but specifically through the Executive Sub-committee, in that arrangements have been made to have records of frost depth and soil-moisture kept at all regular field experiment stations of the Soil Conservation Service, Research Division.

Mr. Garstka is anxious to learn all he can and get all the literature and information he can bearing on cryologic phenomena, and I suggest that you get in communication with him - in fact, I think it would be well, if it could be brought about, to have him appointed a member of the International Commission on Snow and Ice.

Yours truly,

Robert E. Horton
Consultant, S.C.S.

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