BIBLIOGRAPHY

WESTERN SNOW CONFERENCE
This publication presents a complete summary of the technical papers and discussions that have been published under the auspices of the Western Snow Conference and its predecessor, the Western Interstate Snow Survey Conference. It contains 573 items published between 1933 and 1973. The summary for each published article is on a 3 x 5 card and includes an abstract, listing of authors and major subjects.

The Western Interstate Snow Survey Conference was created and organized to discuss and resolve problems in the field of snow surveying including: procedures, instruments, and the forecasting of streamflow derived from snowmelt. Dr. J. E. Church, Jr., Professor of the Classics, University of Nevada, and Meteorologist, Nevada Agricultural Experiment Station, developed procedures for measuring the depth and the amount of water in a snow sample. Average content was compared with the runoff for a period of months during the snowmelt season. This work was started in 1909 on Mount Rose, between Reno and Lake Tahoe, Nevada. By 1932 the work had spread to other localities in the Sierra Nevada Mountains, the high mountains of Utah, the Rockies, and the Cascade Mountains of Oregon and Washington.

In 1933, Dr. Church; Harlowe M. Stafford, Hydraulic Engineer, Division of Water Resources, State of California; and George D. Clyde, Head Civil Engineering, Utah State University, at Logan, organized a conference of engineers and scientists interested in the problems of snow surveying. This meeting to discuss mutual problems was held at the University of Nevada at Reno, Nevada. The Proceedings of the first Western Interstate Snow Survey Conference was published as a University of Nevada Bulletin.

During the fall of 1933 Dr. Church arranged with the American Geophysical Union, Section of Hydrology, to hold the Snow Conference meetings with that organization and to have the technical papers included with the Transactions of the AGU. This arrangement continued through 1947 when meetings became so frequent that the Western Snow Conference (name changed in 1943) began to lose its identity. In 1948 conference members voted to hold only one meeting per year, and to publish their own Proceedings. This arrangement has since continued.

Technical papers and discussions of the 41 Western Snow Conference meetings have been published in a variety of means and under the auspices of several organizations. The WSC recognized the need to locate, identify, and summarize the technical material developed over the years. This would be a valuable tool for researchers, scientists and others interested in the theories, procedures, and instruments used in snow survey and water supply forecasting through the many years since its inception. Consequently, the Western Snow Conference prepared and published this bibliography of the technical articles and discussions published by the Conference.

Work on this bibliography was initiated at the 1959 meeting in Reno. The next year Ashton R. Codd was appointed to head the work on this activity. Sample bibliography sheets were printed in the 1965 Proceedings, and the first draft was completed. Codd continued his work and presented a second draft to the Conference in 1968. W. D. Simons was appointed to review and edit the assembled material. A new style format was prepared in 1969 and subsequently adopted. This format contains title, author, standard data for bibliographic citation, and an abstract of less than 150 words for each paper or discussion. Cards in this original issuance are printed on sheets that can be filed in looseleaf notebooks or cut to size for use in a 3 x 5 card file. Abstract cards published in each years Proceedings will provide a means for keeping the Bibliography up to date.

In the upper right hand side there are three numbers. The first, a Western Snow Conference number identifies the sequence in which it was presented to the conference. Paper No. 1 is the first paper on the program at the first meeting. No. 2 is the second paper and so on. This is followed by the year in which it was presented. For example,
WSC 1-33 identifies the first paper presented to the Conference at the 1933 meeting; WSC 420-64 identifies the four hundred twentieth paper presented to the Conference and it was at the 1964 meeting.

The other two numbers; Catalogue No. and CRREL No. refer to the "Bibliography on Snow, Ice and Perma-Frost with Abstracts" prepared by the SIPRE and CRREL projects of the U. S. Army Corps of Engineers, Snow Ice Permafrost establishment and Cold Regions Research Engineering Laboratory at Hanover, New Hampshire. Many papers presented by Western Snow Conference members have been abstracted by the Library of Congress SIPRE Bibliographic project. Through the generous cooperation of the SIPRE and CRREL organizations permission was granted to the Western Snow Conference to use their abstracts and reference cards. In those cases where these are used, the SIPRE and Library of Congress catalogue numbers are shown in the upper right portion of the bibliography cards.

An alphabetical listing of subjects and sub-subjects has been developed from the key words shown on the right hand side of the card. These are also keyed to the WSC Paper Numbers. The subject index was prepared to emphasize snow and snow surveying and therefore is not identical with the Water Resources Thesaurus. A paper may be shown under several topical headings. In some instances, 334 of the listings are not shown on the cards. Of the over 450 topical headings some of the most popular ones are: Water Supply Forecasting; Statistical Analysis; Snowmelt and Runoff; and Weather Modification. These clearly indicate the topics of most interest to conference members.

A summary of the Bibliography: by years; paper numbers; and locations are shown in the following tabulation.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PAPER NOS.</th>
<th>PLACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1933</td>
<td>1-13</td>
<td>Reno, Nevada</td>
</tr>
<tr>
<td>1934</td>
<td>14-20</td>
<td>Berkeley, California</td>
</tr>
<tr>
<td>1935</td>
<td>21</td>
<td>Salt Lake City, Utah</td>
</tr>
<tr>
<td>1936</td>
<td>22-31</td>
<td>Pasadena, California</td>
</tr>
<tr>
<td>1937</td>
<td>32-42</td>
<td>Denver, Colorado</td>
</tr>
<tr>
<td>1938</td>
<td>43-61</td>
<td>Davis, California</td>
</tr>
<tr>
<td>1939</td>
<td>62-86</td>
<td>Los Angeles, CA &amp; Spokane, WA</td>
</tr>
<tr>
<td>1940</td>
<td>87-128</td>
<td>Stanford, California</td>
</tr>
<tr>
<td>1941</td>
<td>129-145</td>
<td>Sacramento, California</td>
</tr>
<tr>
<td>1942</td>
<td>146-148</td>
<td>Pasadena, California</td>
</tr>
<tr>
<td>1943</td>
<td>149-161</td>
<td>Corvallis, Oregon</td>
</tr>
<tr>
<td>1944</td>
<td>162-183</td>
<td>Berkeley, California</td>
</tr>
<tr>
<td>1945</td>
<td>184-190</td>
<td>Portland, Oregon</td>
</tr>
<tr>
<td>1946</td>
<td>191-195</td>
<td>Sacramento, California</td>
</tr>
<tr>
<td>1947</td>
<td>196-198</td>
<td>Portland, Oregon</td>
</tr>
<tr>
<td>1948</td>
<td>199-214</td>
<td>Reno, Nevada</td>
</tr>
<tr>
<td>1949</td>
<td>215-221</td>
<td>Denver, Colorado</td>
</tr>
<tr>
<td>1950</td>
<td>222-230</td>
<td>Boulder City, Nevada</td>
</tr>
<tr>
<td>1951</td>
<td>231-239</td>
<td>Victoria, British Columbia</td>
</tr>
<tr>
<td>1952</td>
<td>240-249</td>
<td>Sacramento, California</td>
</tr>
<tr>
<td>1953</td>
<td>250-264</td>
<td>Boise, Idaho</td>
</tr>
<tr>
<td>1954</td>
<td>265-278</td>
<td>Salt Lake City, Utah</td>
</tr>
<tr>
<td>1955</td>
<td>279-288</td>
<td>Portland, Oregon</td>
</tr>
<tr>
<td>1956</td>
<td>289-299</td>
<td>Penticton, British Columbia</td>
</tr>
<tr>
<td>1957</td>
<td>300-322</td>
<td>Santa Barbara, California</td>
</tr>
<tr>
<td>1958</td>
<td>335-346</td>
<td>Bozeman, Montana</td>
</tr>
<tr>
<td>1959</td>
<td>347-362</td>
<td>Reno, Nevada</td>
</tr>
<tr>
<td>1960</td>
<td>363-378</td>
<td>Santa Fe, New Mexico</td>
</tr>
<tr>
<td>1961</td>
<td>379-393</td>
<td>Spokane, Washington</td>
</tr>
<tr>
<td>1962</td>
<td>394-414</td>
<td>Cheyenne, Wyoming</td>
</tr>
<tr>
<td>1963</td>
<td>415-426</td>
<td>Yosemite, California</td>
</tr>
<tr>
<td>1964</td>
<td>427-443</td>
<td>Nelson, British Columbia</td>
</tr>
<tr>
<td>1965</td>
<td>444-456</td>
<td>Colorado Springs, Colorado</td>
</tr>
<tr>
<td>1966</td>
<td>457-474</td>
<td>Seattle, Washington</td>
</tr>
<tr>
<td>1967</td>
<td>475-493</td>
<td>Boise, Idaho</td>
</tr>
<tr>
<td>1968</td>
<td></td>
<td>Lake Tahoe, Nevada</td>
</tr>
<tr>
<td>YEAR</td>
<td>PAPER NOS.</td>
<td>PLACE</td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>1969</td>
<td>494-511</td>
<td>Salt Lake City, Utah</td>
</tr>
<tr>
<td>1970</td>
<td>512-527</td>
<td>Victoria, British Columbia</td>
</tr>
<tr>
<td>1971</td>
<td>528-543</td>
<td>Billings, Montana</td>
</tr>
<tr>
<td>1972</td>
<td>544-560</td>
<td>Phoenix, Arizona</td>
</tr>
<tr>
<td>1973</td>
<td>561-573</td>
<td>Grand Junction, Colorado</td>
</tr>
</tbody>
</table>

Every effort has been made to make this bibliography as complete and as free from error as possible. It is inevitable that some discrepancies may occur. It would be appreciated if such items be brought to the attention of the Western Snow Conference.
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SUBJECT INDEX

-A-

ABLACTION

Snowpack 143-41, 144-41, 261-53, 495-69, 496-69, 509-69, 530-71

AERIAL

Markers (Snow Cover) 260-53, 349-60, 379-62
Observations 379-62
Photography 260-53, 349-60, 408-63, 469-67, 496-69, 488-69

ALBEDO

Snow 500-69

ANCHOR ICE 219-49

ARTIFICIAL PRECIPITATION

(See Weather Modification)

AUTOBIOGRAPHY

Snow (Church) 221-40

AUTOMATIC DATA PROCESSING

Hydrologic Data 492-68, 493-68
Multiple Regression Formula
-Development 350-60
-Solution 350-60
Snow Survey Data 514-69
Weather Bureau Data 306-57

AVALANCHE

Countermeasures 223-50, 402-63
Controls 358-60, 359-60, 431-65
Forecasting 223-50
<table>
<thead>
<tr>
<th>Topic</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVALANCHE</td>
<td></td>
</tr>
<tr>
<td>Physical Properties</td>
<td>568-73</td>
</tr>
<tr>
<td>Research</td>
<td>242-52, 402-63, 423-64, 431-65, 568-73</td>
</tr>
<tr>
<td>Rescue</td>
<td>223-50, 298-56</td>
</tr>
<tr>
<td>Safety</td>
<td>223-50, 431-65, 502-69, 558-72</td>
</tr>
<tr>
<td>Statistical Evaluation</td>
<td>568-73</td>
</tr>
<tr>
<td>BASE FLOW</td>
<td></td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td></td>
</tr>
<tr>
<td>Abstracts</td>
<td>280-55</td>
</tr>
<tr>
<td>BLOWING SNOW</td>
<td></td>
</tr>
<tr>
<td>Particle Counter</td>
<td>507-69</td>
</tr>
<tr>
<td>Patterns</td>
<td>377-61</td>
</tr>
<tr>
<td>CALCIUM CHLORIDE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>107-40, 118-40, 230-50</td>
</tr>
<tr>
<td>CANOPY COVER</td>
<td></td>
</tr>
<tr>
<td>Measurement</td>
<td>286-55, 337-59</td>
</tr>
<tr>
<td>CHEMICAL ANALYSIS</td>
<td></td>
</tr>
<tr>
<td>Snow</td>
<td>346-59</td>
</tr>
</tbody>
</table>
CLIMATOLOGY

Climatic Cycles 124-40, 387-62
Limiting Factors 573-73
Statistical Analysis 366-61

CLOCKS

Recording New Escapements 134-41

CLOUDS

Icing Properties 318-57, 319-57
Cloud Seeding (See Weather Modification)

COMPUTERS

Operation and Procedures 350-60, 351-60, 503-69
(See Automatic Data Processing)

CONDENSATION

On Snowpack 344-59, 501-69, 531-71


CRYSTALS

Snow 87-40

CYCLES

Geologic 124-40
Precipitation 10-33, 387-62
DESALINIZATION 561-73

DENSITY

Forest Canopy Cover 337-59
Snow or Snowpack 187-45, 197-47, 500-69

DIGITAL COMPUTER

(See Automatic Data Processing)
(See also Electronic Computer)

DRY SNOW

Compaction 449-66

ECONOMICS

Snow Hydrology 428-56

 ELECTRONIC DIGITAL COMPUTER 329-58, 334-58, 350-60, 351-60, 417-64, 492-68, 493-68, 523-70, 524-70

ENVIRONMENT 544-72, 545-72, 562-73, 564-73, 565-73, 573-73

EQUIPMENT

Snow Survey 1-33, 5-33, 12-33, 52-38, 174-44, 379-62
Testing 397-63
Telemetering 541-71
EQUIPMENT
Water Measurement 559-60

EVAPORATION
Control 303-57, 353-60
Deterrents 303-57, 353-60
From Snow 9-33, 15-34, 217-49, 344-59, 501-69
From Reservoirs 303-57, 353-60, 561-73
Research 303-57
Tree Accumulation 15-34

FINANCING
Snow Survey Programs 3-33, 4-33

FISHERIES MANAGEMENT
Forecasting Lake Rise 418-64

FLOOD CONTROL
Prediction 42-37, 94-40, 115-40, 116-40, 117-40, 127-40, 348-60,
427-64, 463-67, 512-70, 513-70, 525-70, 551-72

FLOODS
Damage Reports 427-65, 551-72
Ice 119-40
Precipitation floods 200-48, 254-53
Routing Procedures 453-66
Snowmelt floods 200-48, 259-53
Spillway Design 200-48, 421-64, 429-65, 430-65, 453-66
Warning Networks 254-53, 487-68, 527-70
FORECASTING

Lake Rise Levels 7-33, 101-40, 139-41, 418-64

FOREST CANOPY COVER

Measurement 286-55, 337-59, 534-71

FOREST FIRE HAZARDS

Forecasting danger point 78-39

FOREST MANAGEMENT

Optimum Water Yield 179-44

FOURIER SERIES

Use in Forecasting Water Supply 309-57

FRAZIL ICE 118-40, 119-40, 219-41

FREQUENCY ANALYSIS 571-73

FROST

Forest Lands 140-41
Soils 114-40, 140-41, 160-43

GLACIERS

Ablation 202-48
Runoff 16-34
GRAPHICAL ANALYSIS

For Water Supply Forecasting

GROUNDWATER

Storage 196-47, 302-57, 543-71, 547-72, 552-72
(See Soil Moisture and Hydrograph)

HEAT TRANSFER

Balance (Arctic) 376-61
Exchange 243-52

HISTORY

Snow Surveys 1-33, 3-33, 92-40, 129-41, 156-43, 250-53, 335-59, 336-59, 511-69

HYDROLOGY

196-47, 288-55, 451-66
Basin Characteristics 122-40, 164-44, 289-56, 513-70, 516-70
Flood Hydrograph Development 162-44, 163-44, 167-44, 287-55
Groundwater 196-47, 270-54, 302-57, 537-71, 543-71
Planning 149-43, 150-43
Research 63-39, 473-67
Research Programs 199-48, 203-48, 204-48, 465-67
Small Watersheds 166-44
Statistical Studies 203-48, 451-66
Stream Measurement 268-54, 269-54, 284-55, 310-57, 360-60, 492-68, 493-68
Studies 470-67
War-time Efforts 149-43, 150-43

-10-
ICE

Anchor Ice 219-49  
Crusts 112-40  
Crystals, formation 239-51  
Frazil Ice 118-40, 119-40, 219-49  
Ocean Ice, Arctic 376-61  
River Ice 118-40, 119-40, 473-67  
Sheet Ice, Pressure, Reservoir 201-48

INfiltration

Forest Canopy Cover 184-48  
Infiltration Capacity 168-44, 184-45, 547-72  
Snowmelt 184-45

INSTRUMENTATION

Canopy Cover 286-55, 337-59  
Radiation 450-66  
Soil Moisture 94-40, 444-66  
Snow Pressure Pillow 431-65
LAND USE

Goals 565-73
Management 565-73

LOADS

(See Snow Loads, Roofs)

LYSIMETER STUDIES

Snowmelt 322-57, 509-69

-12-

MAPping

Snow Cover Areas
-by Aerial Observations 342-59, 380-62, 469-67
-by Satellite Photographs 381-62, 406-63, 498-69

MARKERS

Aerial 260-53, 379-62

MATRIC EVALUATION 564-73

Meteorological

Instruments
-Rainfall 416-64
-Temperature 416-64
Research Programs 199-48, 421-64
MODELS

Digital 525-70, 528-71, 546-72, 548-72
Snowmelt 500-69
Test Design Snowstorms 466-67
Test Snow Gage Shields 220-49, 234-51

MOUNTAIN SNOWFALL

Program 91-40
Stations 91-40

MOVIE FILMS

Avalanche 224-50, 242-52, 401-63, 402-63

MUNICIPAL

Water Supply 95-40, 393-62

- N -

NORMALS

Precipitation Data 26-36, 27-36, 128-40
Snow Course Data 11-33, 26-36, 128-40, 190-45
Streamflow Data 26-37, 27-36, 128-40, 190-45

NUCLEI

Ice Crystals 317-57
Silver Iodide 317-57, 452-66

-13-
OIL SHALE

Porosity of Residue 567-73

OVER SNOW VEHICLES


PHOTOGRAPHY

Forest Canopy Measurement Snow Line Snow Area by Satellite Photo Snow Cover Area Measurement 286-55, 337-59 41-37, 137-41, 342-59 498-69 177-41

PLASTIC

Snow Survey Tubes 396-63

-14-
POWER

Electric Power Development
94-40, 183-44, 196-47, 329-58, 365-61, 512-70

PRECIPITATION

Analysis

Artificial
(See Weather Modification)

Gages

-Design of
195-46

-Heated Orifice
305-57, 405-63

-Network
43-38, 47-38, 123-40, 435-65, 455-66, 514-70

-Operation of
194-46

-Radioactive
222-50

-Shielded Storage

PRESSURE PILLOW


Location Criteria
467-67

Research
431-65

Telemetry of Data
512-69

RADAR

Communications by
463-67

Snowpack Measurement by
433-65
RADIOACTIVE

Soil Moisture Probe 382-62, 454-66
Snow Gage and Snow Water Equivalent 222-50
Snow Water Equivalent by 382-62, 454-66, 499-69

RAIN GAGE

(See Precipitation Gage)

RAIN MAKING

(See Weather Modification)

RECORDER CLOCKS

Escapement 134-41

RESEARCH

Ice and Snow 161-43, 299-56
Infiltration 168-44
Soil Moisture 168-44, 169-44
Snowmelt Runoff 141-41, 178-44

RESERVOIRS

Evaporation 303-57, 353-60
Multipurpose, Planning 65-39, 300-57
Regulation of 40-37, 46-38, 65-39, 101-40, 139-41, 154-43, 179-44,
204-48, 226-50, 232-51, 300-57, 347-60, 365-61, 369-61,
512-70, 548-72

RIME ICE

305-57, 531-71

ROOF LOADS

103-40, 465-67, 466-67

RUNOFF

567-73
SAFETY

Ski Binkings 148-42
Snow Safety 105-40, 111-40, 224-50

SATELLITE

Photographs 381-62, 406-63, 498-69

SILVER IODIDE

Generators 368-61, 413-63, 452-66
Microbial Processes 566-73
Nucleation 317-59, 318-59, 413-63, 504-69
Silver Transformation 566-73

SNOW

Ablation 143-41, 144-41, 261-53, 469-69, 479-69
Accumulation 445-66, 462-69, 498-69
Analysis
- Chemical 366-59
- Physical Radiation 451-66
Avalanche Research 224-50, 242-52, 401-63, 402-64, 423-64
Classification 113-40, 236-51
Crystals 87-40, 236-51
Density
- Distribution 205-48, 325-58, 458-67, 499-69
- Lateral Sampling 173-44, 197-47
Drifting Snow 377-61, 466-67, 515-70, 536-71
Economics 215-49, 508-69
Fall Probabilities
- Intensity 445-66, 509-69
- Possibility 399-63, 532-71
- Studies 464-67, 573-73
Fence 572-73

Free Water Content 186-45, 293-56, 448-66, 499-67, 518-70
(See also Snow Quality)
  -Quality Measurements and Equipment 142-41

  234-51, 236-51, 434-56, 454-66, 476-68, 490-68, 491-68
  -Radioactive
    -Gage Comparisons 490-68

Hydrology 218-49, 299-56, 345-59, 354-60, 355-60, 356-60, 357-60,
  368-61, 428-65, 447-66, 453-66

Humanities 414-63

Line Measurement 408-63

Loads, Roof 103-40, 364-61, 465-67, 466-67, 518-70, 519-70, 520-70,
  521-70, 571-73

Measurements
  -Aerial and Photographic 41-37, 137-41, 349-60, 469-67

Oversnow Vehicles 104-40, 213-48
  -History 477-68
  -Performance 235-51
  -Vehicle Test Results 104-40, 362-60

Pressure Pillow
  -Location Criteria 467-67, 490-68
    514-69

Quality
  -Measurement 142-41
  -Equipment 142-41

Removal
  -Airports 403-63
  -Equipment for 113-40, 216-49, 292-56, 320-57
  -Roads, Highways 113-40, 216-49, 244-52, 292-56, 320-57, 400-63, 401-63,
    403-63

  299-56, 308-57, 324-58, 325-58, 368-61, 384-62, 387-63,
  422-64, 462-67
  -Chemical Analysis 346-59
  -Compression 449-66
  -Evaporation 385-62, 502-69
  -General Research 110-40, 161-43, 190-45, 198-47, 245-52, 293-56, 294-56,
    461-67, 475-68, 501-69, 507-69
  -Mechanical Properties 246-52
  -Physical Properties 161-43, 197-47, 507-69
  -Radiomicrowave Sensing 460-67
### SNOW

#### Settlement at Snowpack
475-68, 501-69

#### Snowmelt Research
481-68, 501-69

#### Sampler Tubes
- Anodyzing: 67-39
- Carrying Case: 133-41
- Comparison Tests: 53-38, 366-61
- Coupling: 54-38
- Duraluminum: 19-34, 53-38, 54-38
- Lateral Sampler: 173-44
- Plastic: 396-63
- Prairie Sampler: 366-61
- Steel Sampler: 53-38, 54-38
- Tests and Comparisons: 5-33, 53-38, 54-38, 135-41, 137-41
- Tube Defects: 137-41

#### Snow Sampling
- Accuracy Tests: 396-63
- Procedures: 68-38, 89-40

#### Snow Storm
- Models: 220-49, 234-51
- Storm Simulation: 220-49, 234-51, 377-61

#### Temperature
172-44, 462-67, 475-68

#### Thermodynamics
294-56

#### Trafficability
104-60

#### Transport Distance
572-73

### SNOW COVER

#### Accumulation
364-61, 535-71, 537-71, 539-71, 544-72

#### Analysis
138-41

#### Depletion
501-69, 529-71

#### Distribution

#### Hardness
236-51

#### In Forests
446-66, 530-71, 569-73

#### Melting
8-33

#### On Glaciers
312-57

#### Percolation
8-33, 9-33
SNOW COVER

Permeability 205-48
Photo Analysis 137-41, 177-44, 214-48, 252-53, 342-59, 406-63
Photo Mapping 342-59, 381-62
Photo Observations 469-69, 498-69
Radiation 244-52, 451-66
Testing Hardness 236-51
Thermal Effects 172-44
Water Equivalent 476-68, 569-73

SNOWMELT

Floods 116-40, 139-41, 240-52, 259-53, 272-54, 429-65, 430-65
Management 198-47, 446-66, 537-71, 553-72
Runoff Hydrograph (Simulation) 179-44, 186-45, 196-47, 233-51
Runoff Logging Effects on Hydrograph 15-34, 46-38, 343-59, 354-60

SNOWPACK

Augmentation 566-73
Collapse 502-69
Photography 41-37, 469-67
Physics 142-41, 144-41, 293-56, 294-56, 503-69
Plane (See Oversnow Vehicles)
Water Yield 354-60, 355-60, 356-60, 357-60
### SNOW SURVEY

#### Cooperative Programs
- 6-33, 21-35, 22-36, 29-36, 32-37, 92-40, 155-43

#### Courses
- **Aerial Markers**
  - 260-53, 379-62
- **Analysis**
  - 36-37, 37-37, 42-37, 323-58, 456-66
- **Location Criteria**
  - 34-37, 35-37, 70-39, 281-55, 437-65, 467-67
- **Maintenance**
  - 174-44
- **Markers**
  - 55-38
- **Networks**
- **Normals**
  - 26-37, 34-37, 35-37, 66-39, 341-58
- **Research**
  - 437-65

#### Description
- **California**
  - 352-66, 426-64
- **Eastern Snow Conference**
  - 335-59
- **Great Plains States**
  - 334-58

#### Economics
- **Benefits of**
  - 49-38, 85-39
- **Electric Power**
  - 50-38
- **Municipal Water Supply**
  - 237-51
- **California**
  - 437-65
- **Eastern Snow Conference**
  - 336-59
- **Great Plains States**
  - 344-58
- **California**
  - 49-38, 151-43, 183-44
- **Eastern Snow Conference**
  - 50-38
- **Great Plains States**
  - 237-51
- **California**
  - 49-38, 151-43, 183-44
- **Eastern Snow Conference**
  - 50-38
- **Great Plains States**
  - 237-51

#### Equipment
- **Office Forms**
  - 90-4-19
- **Sampling Tubes**
  - 5-33, 12-33, 19-34, 30-36, 33-37, 52-38, 71-39, 109-40, 190-45, 366-61
- **Sampling Tube Carrying Case**
  - 133-41
- **Tube Comparisons**
  - 367-61
- **Weighing Scales**

#### Forest Fire Hazard Predictions
- 78-39

#### Organizations
- 2-33, 21-35, 32-37

#### Plains Area Equipment
- 366-61, 416-64

#### Problems
- 13-33

#### Procedures

#### Questionaries
- 31-38

#### Safety
- 62-39, 63-39, 298-56, 559-72

#### Shelter Cabin (plans)
- 85-39

#### Training
- 298-56

#### Transportation
- **Airplane**
  - 275-54
- **Helicopter**
  - 313-57, 316-57
- **Oversnow vehicle**
  - 50-38, 104-40, 105-40

-21-
<table>
<thead>
<tr>
<th>Topic</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOIL ABSORPTION</td>
<td>24-36, 28-36, 184-45</td>
</tr>
<tr>
<td>SOIL MOISTURE</td>
<td></td>
</tr>
<tr>
<td>Forest Land Yield</td>
<td>152-43</td>
</tr>
<tr>
<td>Freezing Soil</td>
<td>497-69</td>
</tr>
<tr>
<td>Instruments</td>
<td>97-40, 444-66</td>
</tr>
<tr>
<td>Radioisotope Probe</td>
<td>382-62, 388-62, 454-66</td>
</tr>
<tr>
<td>Research</td>
<td>168-41, 169-44, 187-45</td>
</tr>
<tr>
<td>SOIL PERMEABILITY</td>
<td>28-36</td>
</tr>
<tr>
<td>SOIL PRIMING</td>
<td>24-36</td>
</tr>
<tr>
<td>Effect of Fall Streamflow</td>
<td>83-39, 84-39, 241-52</td>
</tr>
<tr>
<td>Effect of Shallow Springs</td>
<td>125-40</td>
</tr>
<tr>
<td>SOIL TEMPERATURE</td>
<td>47-38, 340-59</td>
</tr>
<tr>
<td>SOLAR RADIATION</td>
<td>244-52, 450-66</td>
</tr>
<tr>
<td>SPILLWAY DESIGN FROM SNOW SURVEY DATA</td>
<td>425-64, 453-66</td>
</tr>
</tbody>
</table>
STATISTICAL ANALYSIS

Snow Cover 214-48, 350-60, 351-60
Sample Size 185-45, 323-58

STREAMFLOW FORECASTING

(See Water Supply Forecasting)

SUBLIMATION 572-73

TELEMETERING

Precipitation Data 415-64, 431-65, 432-65
Telemetering Equipment 487-68, 488-68, 541-71

TEMPERATURE

Factors 14-34, 75-44, 240-52, 461-67, 462-67, 550-72
Water 398-63

TIME TRENDS 271-54

TRANSPORTATION

Airplane 276-54
Helicopter 276-54, 315-57, 316-57

TREES

Canopy Cover Measurement 286-55, 337-59
TREES

Snow Interception 383-62

UNIT HYDROGRAPH

117-40, 392-62

WASTE WATER RECLAMATION 561-73

WATER

Critical Resource 562-73
Diminishing Supply 562-73
Pollution 567-73
Pricing 562-73


WATER MEASUREMENT 360-60

WATER PLAN

Operation 302-57

-24-
WATER RECLAMATION
Waste 561-73

WATER REGULATION 563-73

WATER RIGHTS
Adjudication 563-73
Critical Flows 374-61, 375-61, 522-70
Forecast to Meet Usable Demands 145-41
Primary Water Rights Forecast 374-61, 375-61

WATERSHED
Basin Analysis 166-44

WATER SUPPLY FORECASTING
Coordinated Forecasts 251-53, 258-53, 479-68
Data Publication 253-53
Digital Computer 350-60, 351-60
Economics 505-69, 508-69, 509-69
<table>
<thead>
<tr>
<th>Topic</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evapo-sublimation</td>
<td>494-69</td>
</tr>
<tr>
<td>Forecast Made in KWH, Direct</td>
<td>47-38</td>
</tr>
<tr>
<td>Modified by Soil Moisture Data</td>
<td>188-45, 395-63, 444-66</td>
</tr>
<tr>
<td>Modified by Spring Temperature</td>
<td>175-44, 240-52, 496-69</td>
</tr>
<tr>
<td>Natural Lake Rise</td>
<td>7-33, 353-60, 418-64</td>
</tr>
<tr>
<td>Procedure Errors</td>
<td>278-54</td>
</tr>
<tr>
<td>Quantative Method</td>
<td>94-40, 95-40</td>
</tr>
<tr>
<td>Recession to Optimum Flow</td>
<td>145-41</td>
</tr>
<tr>
<td>Return Flow</td>
<td>457-67</td>
</tr>
<tr>
<td>Return Flow to Streams</td>
<td>457-67</td>
</tr>
<tr>
<td>Runoff Pattern Analysis</td>
<td>153-43</td>
</tr>
<tr>
<td>-Day to Day</td>
<td>46-38</td>
</tr>
<tr>
<td>-Month to Month</td>
<td></td>
</tr>
<tr>
<td>Snowmelt Degree Days</td>
<td>17-34, 158-43</td>
</tr>
<tr>
<td>Solar Radiation</td>
<td>494-69</td>
</tr>
<tr>
<td>Statistical Methods</td>
<td>35-57, 80-39, 156-43, 338-54, 479-68, 480-68, 523-70</td>
</tr>
<tr>
<td>Temperatures</td>
<td>494-69</td>
</tr>
<tr>
<td>Using Elevation Methods</td>
<td>95-40, 96-40</td>
</tr>
<tr>
<td>Using Mid-Winter Data</td>
<td>176-44, 193-46</td>
</tr>
<tr>
<td>Using Percentage System</td>
<td>100-40</td>
</tr>
</tbody>
</table>
WATER SUPPLY FORECASTING

Using Snow Surveys

Using Spring Precipitation
487-69, 557-72

Using Wind Travel Data
385-62, 397-63, 494-69

WATER TEMPERATURE
398-63

WEATHER

Control
(See Weather Modification)

Satellite
381-62, 406-63

WEATHER FORECASTING

Long Range
266-54

WEATHER MODIFICATION

Cloud Seeding
506-66, 561-73

Computer Use for Controls
503-69

Economic Aspects
438-65, 505-69

Effectiveness
318-57, 483-68, 484-68, 486-68

Engineering
368-61, 442-65

Evaluation

Legal Aspects
412-63, 439-65

Methods of Procedures

Nucleation
317-57, 318-57, 368-61, 413-63

Project Skywater

Research
WILDERNESS AREAS 478-68, 554-72, 555-72

WIND

Data in Forecasting Streamflow 385-62, 397-63, 495-69
Direction 307-57
Movement 377-61, 385-62

Tunnel
-Drift Patterns on Models 377-61
-Rain Gage Shields Experiment 220-49, 234-51

WINTER SPORTS

Area Reporting Service 60-38, 61-38, 74-39, 75-39
Classification of Snow Surface 57-38, 58-38, 59-38, 73-39, 75-39
Equipment 74-39
Safety 93-40, 111-40

WINTER SURVIVAL 111-40, 298-56
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

AUTHOR INDEX

<table>
<thead>
<tr>
<th>Author</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALCORN, W. B.</td>
<td>39-37</td>
</tr>
<tr>
<td>ALFORD, DONALD F.</td>
<td>465-67</td>
</tr>
<tr>
<td>ALTER, J. CECIL</td>
<td>23-36, 102-40, 110-40</td>
</tr>
<tr>
<td>ANDERSON, HENRY W.</td>
<td>169-44, 304-57, 324-58, 325-58, 343-59, 354-60, 437-65</td>
</tr>
<tr>
<td>ANDERSON, JAMES A.</td>
<td>524-70</td>
</tr>
<tr>
<td>ARIAS, ENRIQUE S.</td>
<td>314-57</td>
</tr>
<tr>
<td>ARMSTRONG, RICHARD L.</td>
<td>568-73</td>
</tr>
<tr>
<td>ARVOLA, W. A.</td>
<td>394-63</td>
</tr>
<tr>
<td>ATKINSON, H. B.</td>
<td>114-40</td>
</tr>
<tr>
<td>ATWATER, MONTGOMERY M.</td>
<td>224-50, 242-52, 402-63</td>
</tr>
<tr>
<td>AYER, GORDON R.</td>
<td>336-59</td>
</tr>
<tr>
<td>BADGLEY, DR. FRANKLIN I.</td>
<td>376-64</td>
</tr>
<tr>
<td>BALDWIN, HENRY I.</td>
<td>58-38</td>
</tr>
<tr>
<td>BALL, HUBERT</td>
<td>347-60</td>
</tr>
<tr>
<td>BARNES, BERTRAM S.</td>
<td>157-43, 168-44, 200-48</td>
</tr>
<tr>
<td>BARNES, C. S.</td>
<td>230-50</td>
</tr>
<tr>
<td>BARNES, JAMES C.</td>
<td>498-69</td>
</tr>
<tr>
<td>BARRON, E. G.</td>
<td>360-61</td>
</tr>
<tr>
<td>Name</td>
<td>Pages</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>BARSCH, RAY E.</td>
<td>481-68, 513-70</td>
</tr>
<tr>
<td>BARTOS, LOUIS R.</td>
<td>569-73</td>
</tr>
<tr>
<td>BAY, CLYDE E.</td>
<td>114-40</td>
</tr>
<tr>
<td>BEAN, PAUL L.</td>
<td>94-40, 140-41</td>
</tr>
<tr>
<td>BEAN, PAUL W.</td>
<td>109-40</td>
</tr>
<tr>
<td>BEATTIE, L. A.</td>
<td>352-60</td>
</tr>
<tr>
<td>BELOTELKIN, K. T.</td>
<td>140-41</td>
</tr>
<tr>
<td>BENDTSEN, FREDERICK A.</td>
<td>109-40</td>
</tr>
<tr>
<td>BERGEN, JAMES P.</td>
<td>422-64</td>
</tr>
<tr>
<td>BERGGREN, W. P.</td>
<td>160-43</td>
</tr>
<tr>
<td>BERNDT, H. W.</td>
<td>531-71</td>
</tr>
<tr>
<td>BERTLE, FREDERICK A.</td>
<td>203-48, 228-50, 243-52, 429-65</td>
</tr>
<tr>
<td>BETHLAHMY, NEDAVIA</td>
<td>367-61</td>
</tr>
<tr>
<td>BETTER, FREDERICK</td>
<td>134-41</td>
</tr>
<tr>
<td>BILLONES, LOUIS</td>
<td>405-63</td>
</tr>
<tr>
<td>BISSELL, L. M.</td>
<td>275-54</td>
</tr>
<tr>
<td>BLACKWELL, S. R.</td>
<td>366-61</td>
</tr>
<tr>
<td>BLANCHARD, FRANCIS B.</td>
<td>237-51, 288-55, 310-57</td>
</tr>
<tr>
<td>Name</td>
<td>Pages</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>BONNER, J. P.</td>
<td>79-39</td>
</tr>
<tr>
<td>BORLAND, W. M.</td>
<td>359-60</td>
</tr>
<tr>
<td>BOUWER, HERMAN</td>
<td>547-72</td>
</tr>
<tr>
<td>BOWIE, MAJOR E. H.</td>
<td>6-33, 7-33</td>
</tr>
<tr>
<td>BOWLES, DUAIN</td>
<td>462-67</td>
</tr>
<tr>
<td>BOWLEY, CLINTON J.</td>
<td>498-69</td>
</tr>
<tr>
<td>BOYD, DONALD W.</td>
<td>364-61</td>
</tr>
<tr>
<td>BOYER, PETER B.</td>
<td>273-54</td>
</tr>
<tr>
<td>BRADLEY, DR. CHARLES C.</td>
<td>502-69</td>
</tr>
<tr>
<td>BRIGGS, PHILIP</td>
<td>546-72</td>
</tr>
<tr>
<td>BROWN, J. B.</td>
<td>162-44, 167-44</td>
</tr>
<tr>
<td>BROWN, JOHN WEBSTER</td>
<td>520-70</td>
</tr>
<tr>
<td>BROWN, ROBERT T.</td>
<td>492-68</td>
</tr>
<tr>
<td>BRUCE, J. P.</td>
<td>421-64</td>
</tr>
<tr>
<td>BULKLEY, ROSS V.</td>
<td>418-64</td>
</tr>
<tr>
<td>BURDICK, DR. RAYMOND T.</td>
<td>215-49</td>
</tr>
<tr>
<td>BURGY, ROBERT H.</td>
<td>301-57</td>
</tr>
<tr>
<td>BURNASH, J. C.</td>
<td>481-68, 542-71</td>
</tr>
<tr>
<td>BURNS, JOSEPH I.</td>
<td>321-57</td>
</tr>
<tr>
<td>BURTON, H. K.</td>
<td>23-36</td>
</tr>
</tbody>
</table>

-31-
BUSH, RICHARD H. 513-70
BUTSON, KEITH D. 252-53

-C-

CALLISTER, LELAND G. 374-61
CALVIN, LYLE D. 332-58
CANFIELD, GEORGE H. 155-43
CASTLE, GLENN H. 342-59, 415-64, 432-65
CAVADIAS, GEORGE J. 327-58
CHADWICK, DUANE G. 415-64, 500-69
CHAPMAN, E. G. 469-67
CHAPPELL, CHARLES F. 514-70
CHARD, A. E. 291-56
CHILDRETH, R. W. 173-44, 174-44, 189-45
CHRISTENSEN, E. G. 427-65
CHRISTIAN, FRANCIS G. 179-44
CHRISTNER, JERE J. 533-72
CHURCH, DR. PHIL E. 112-40, 136-41, 138-41
CLARK, R. H. 474-67
CLAWSON, MARION 206-48

-32-
<table>
<thead>
<tr>
<th>Name</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLAY, C. H.</td>
<td>418-64</td>
</tr>
<tr>
<td>CLENDENEN, FRANK B.</td>
<td>302-57</td>
</tr>
<tr>
<td>CLORETY, BERNARD S.</td>
<td>482-68</td>
</tr>
<tr>
<td>CLYDE, GEORGE D.</td>
<td>2-33, 4-33, 5-33, 11-33, 12-33, 28-36, 34-37, 51-38, 88-40, 97-40, 156-43, 171-44, 180-44, 237-51</td>
</tr>
<tr>
<td>COLBERT, JESSE L.</td>
<td>281-55</td>
</tr>
<tr>
<td>COLLINS, E. H.</td>
<td>17-34, 101-40</td>
</tr>
<tr>
<td>COLMAN, E. A.</td>
<td>279-55</td>
</tr>
<tr>
<td>CONKLING, HAROLD</td>
<td>33-37, 129-41</td>
</tr>
<tr>
<td>CONNAUGHTON, CHARLES A.</td>
<td>36-37, 110-40, 165-44</td>
</tr>
<tr>
<td>COOLEY, JOHN R.</td>
<td>563-73</td>
</tr>
<tr>
<td>COOPER, C. F.</td>
<td>469-67</td>
</tr>
<tr>
<td>CORLEY, J. P.</td>
<td>398-63</td>
</tr>
<tr>
<td>COULSON, C. H.</td>
<td>523-70</td>
</tr>
<tr>
<td>COURT, ARNOLD</td>
<td>307-57, 323-58</td>
</tr>
<tr>
<td>COWGILL, PHILLIP S.</td>
<td>52-38, 89-40, 105-40, 131-41, 132-41, 133-41</td>
</tr>
<tr>
<td>COX, LLOYD M.</td>
<td>476-68, 540-71</td>
</tr>
<tr>
<td>CRaddock, GEORGE W.</td>
<td>274-54</td>
</tr>
<tr>
<td>CRANDALL, DAVID L.</td>
<td>508-69</td>
</tr>
<tr>
<td>CRIDDLE, WAYNE D.</td>
<td>171-44, 176-44, 193-46, 233-51</td>
</tr>
<tr>
<td>CROFT, A. R.</td>
<td>187-45</td>
</tr>
<tr>
<td>Name</td>
<td>Pages</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>CROOK, Arthur G.</td>
<td>570-73</td>
</tr>
<tr>
<td>CROUGH, J. Carlisle</td>
<td>111-40</td>
</tr>
<tr>
<td>CROW, Loren W.</td>
<td>514-70</td>
</tr>
<tr>
<td>CULLINGS, E. C.</td>
<td>29-36</td>
</tr>
<tr>
<td>CUNDIFF, Stuart A.</td>
<td>225-50</td>
</tr>
<tr>
<td>CURRY, G. E.</td>
<td>435-65</td>
</tr>
<tr>
<td>DAI, Robert F.</td>
<td>306-57</td>
</tr>
<tr>
<td>DANIELS, Glenn E.</td>
<td>214-48</td>
</tr>
<tr>
<td>DAVIES, L. B.</td>
<td>453-66</td>
</tr>
<tr>
<td>DAVIS, Larry G.</td>
<td>504-69</td>
</tr>
<tr>
<td>DAVIS, Robert T.</td>
<td>298-56, 351-60, 389-62, 480-68</td>
</tr>
<tr>
<td>DEAN, W. W.</td>
<td>278-54, 316-57</td>
</tr>
<tr>
<td>DEIBERT, George</td>
<td>60-38</td>
</tr>
<tr>
<td>DELK, R.</td>
<td>554-72</td>
</tr>
<tr>
<td>DENNIS, Arnett S.</td>
<td>318-57</td>
</tr>
<tr>
<td>DEMBISKE, F. E.</td>
<td>320-57</td>
</tr>
<tr>
<td>DEVORE, George W.</td>
<td>37-37, 49-38, 88-40, 130-41</td>
</tr>
<tr>
<td>DIAMOND, Marvin</td>
<td>223-50</td>
</tr>
<tr>
<td>DOTY, Robert D.</td>
<td>501-69</td>
</tr>
<tr>
<td>DOUGHTY-DAVIES, J. H.</td>
<td>282-55</td>
</tr>
<tr>
<td>Name</td>
<td>Pages</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>DUCKER, H. P.</td>
<td>147-42</td>
</tr>
<tr>
<td>DUNCAN, D. L.</td>
<td>404-63</td>
</tr>
<tr>
<td>DUNCAN, WALTER W.</td>
<td>425-64</td>
</tr>
<tr>
<td>DUNFORD, E. G.</td>
<td>228-50, 243-52</td>
</tr>
<tr>
<td>DWYER, CARROLL H.</td>
<td>331-58</td>
</tr>
<tr>
<td>DYCK, G. E.</td>
<td>515-70</td>
</tr>
<tr>
<td>EAGLE, HENRY C.</td>
<td>83-39</td>
</tr>
<tr>
<td>EARL, KENNETH D.</td>
<td>275-54</td>
</tr>
<tr>
<td>EDGERTON, A. T.</td>
<td>460-67</td>
</tr>
<tr>
<td>EGGLESTON, KEITH O.</td>
<td>500-69</td>
</tr>
<tr>
<td>EISENLOHR, WILLIAM S.</td>
<td>253-53</td>
</tr>
<tr>
<td>ELLIOTT, ROBERT D.</td>
<td>249-52, 265-54, 317-57, 410-63, 503-69, 556-72</td>
</tr>
<tr>
<td>ELLIOTT, R. H.</td>
<td>117-40</td>
</tr>
<tr>
<td>ELLIS, JESSE D.</td>
<td>329-58, 392-62</td>
</tr>
<tr>
<td>ENGELMANN, R. J.</td>
<td>451-66</td>
</tr>
<tr>
<td>EWING, PAUL A.</td>
<td>59-38</td>
</tr>
</tbody>
</table>

-E-

<table>
<thead>
<tr>
<th>Name</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>FARNES, PHILLIP E.</td>
<td>351-60, 395-63, 418-64, 467-67, 510-69, 534-71</td>
</tr>
</tbody>
</table>

-F-

-35-
<table>
<thead>
<tr>
<th>Name</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farrow, Richard C.</td>
<td>35-37, 45-38, 84-39, 88-40, 121-40, 219-49</td>
</tr>
<tr>
<td>Felgenhauer, Harold</td>
<td>408-63</td>
</tr>
<tr>
<td>Fergusson, S. P.</td>
<td>19-34</td>
</tr>
<tr>
<td>Firth, J. H.</td>
<td>346-59</td>
</tr>
<tr>
<td>Ffolliott, Peter F.</td>
<td>495-69, 551-72</td>
</tr>
<tr>
<td>Findlay, Bruce</td>
<td>530-71</td>
</tr>
<tr>
<td>Fischer, Robert W.</td>
<td>393-62</td>
</tr>
<tr>
<td>Fisher, Elmer</td>
<td>122-40</td>
</tr>
<tr>
<td>Fisher, W. H.</td>
<td>512-70</td>
</tr>
<tr>
<td>Fittinger, Herman J.</td>
<td>195-46</td>
</tr>
<tr>
<td>Fletcher, Joel E.</td>
<td>444-66, 472-67</td>
</tr>
<tr>
<td>Ford, Perry M.</td>
<td>210-48, 268-54</td>
</tr>
<tr>
<td>Forsling, C. L.</td>
<td>6-33</td>
</tr>
<tr>
<td>Fowler, W. B.</td>
<td>531-71</td>
</tr>
<tr>
<td>Frame, S. H.</td>
<td>130-41, 146-42, 171-44</td>
</tr>
<tr>
<td>Fredericksen, D. G.</td>
<td>326-58</td>
</tr>
<tr>
<td>Freeman, D. B.</td>
<td>77-39, 88-40, 121-40, 126-40</td>
</tr>
<tr>
<td>Freeman, Ted G.</td>
<td>395-63, 426-64, 526-70, 570-73</td>
</tr>
<tr>
<td>Fulcher, Martin K.</td>
<td>256-53</td>
</tr>
<tr>
<td>Fuller, Edwin S.</td>
<td>162-44</td>
</tr>
<tr>
<td>Fulton, F. J.</td>
<td>474-67</td>
</tr>
</tbody>
</table>

GARY, HOWARD L. 458-67

GAY, ROBERT W. 240-52

GAY, LLOYD W. 382-62

GEORGE, TOMMY A. 522-70, 571-73

GERDEL, DR. ROBERT W. 167-44, 172-44, 186-45, 205-48, 222-50, 244-52, 246-52, 377-61

GILES, GORDON G. 281-55

GILLETTE, HELBERT P. 124-40

GISBORNE, HARRY T. 78-39, 81-39, 110-40

GLEASON, CLARK H. 343-59

GOODELL, BERTRAM C. 135-41, 211-48, 217-49, 297-56

GOODRICH, R. D. 269-54

GOODRIDGE, R. S. 42-37, 64-39

GORNALL, J. C. 541-71

GRANT, LEWIS O. 229-50, 368-61, 411-63, 413-63, 433-65

GRAY, CARLETON H. 463-67, 487-68, 527-70

GRAY, DON M. 515-70

GREINER, EDWARD C. 486-68

GUMBLE, E. J. 185-45

-37-
HAEFFNER, ARDEN D.  529-71
HAFTSON, HAROLD D.  275-54
HALES, J. VERN  267-54
HALL, L. STANDISH  95-40, 130-41, 146-42, 162-44, 171-44, 179-44
HALVERSON, HOWARD G.  499-69
HAMBURG, GEORGE R.  309-57
HAMON, W. RUSSELL  476-68
HANES, FRANK  407-63
HARDING S. T.  162-44
HARLAN, R. L.  497-69
HARRINGTON, ARTHUR W.  250-53
HAUPT, HAROLD F.  509-69
HEADLEY, F. B.  10-33
HENDRICKSON, A. H.  168-44
HENNEBERGER, J.  555-72
HERZ, FRED  12-33
HERZ, WALTER J.  12-33, 148-42
HESPENELT, G. G.  352-60
HILDEBRAND, CARVER E. 322-57
HILL, LELAND K. 562-73
HILTON, ERIC 151-43
HIMMEL, JAMES M. 209-48
HINDERLIDER, M. C. 66-39
HINSON, H. B. 183-44
HOFFER, THOMAS E. 267-54
HOLECEK, G. R. 552-72
HOOVER, MARVIN D. 355-60
HOPKINS, GEORGE F. 123-40
HOPKINS, WALTER 335-59, 345-59
HORCIZA, E. 493-68
HORN, WILLIAM L. 565-73
HORTON, J. S. 285-55
HORTON, DR. ROBERT E. 84-39, 160-43, 184-45
HOTCHKISS, WILLIAM R. 558-72
HOUSTON, CLYDE E. 237-51
HOYT, W. G. 170-44
HUNSAKER, LEON M. 430-65
HUNTER, CLAUDE E. 37-37
HUNTER, HARRY I. 390-62, 424-64
<table>
<thead>
<tr>
<th>Name</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INGEBÖ, PAUL A.</td>
<td>286-55</td>
</tr>
<tr>
<td>JACOBSON, G. B.</td>
<td>212-48</td>
</tr>
<tr>
<td>JOHNSON, LYNN F.</td>
<td>350-60</td>
</tr>
<tr>
<td>JOHNSON, OLIVER</td>
<td>299-56</td>
</tr>
<tr>
<td>JOHNSON, RAY</td>
<td>391-62</td>
</tr>
<tr>
<td>JOHNSON, WALTER E.</td>
<td>121-40</td>
</tr>
<tr>
<td>JOHNSON, WILLIAM</td>
<td>372-61</td>
</tr>
<tr>
<td>JOHNSTON, C. N.</td>
<td>168-44, 169-44</td>
</tr>
<tr>
<td>JOHNSTON, ROBERT S.</td>
<td>501-69</td>
</tr>
<tr>
<td>JONES, GERALD W.</td>
<td>514-70</td>
</tr>
<tr>
<td>JONES, JAMES E.</td>
<td>12-33, 13-33, 19-34, 31-36, 88-40, 130-41, 154-43</td>
</tr>
<tr>
<td>JORGENSEN, DONALD J.</td>
<td>247-52</td>
</tr>
<tr>
<td>JUDSON, ARTHUR</td>
<td>423-64</td>
</tr>
<tr>
<td>KAHAN, DR. ARCHIE M.</td>
<td>441-65, 544-72</td>
</tr>
<tr>
<td>KEELER, CHARLES M.</td>
<td>449-66</td>
</tr>
<tr>
<td>KEHRLEIN, OLIVER</td>
<td>261-53</td>
</tr>
<tr>
<td>KEITH, H. A.</td>
<td>209-48</td>
</tr>
<tr>
<td>KELLEY, L. L.</td>
<td>428-65</td>
</tr>
<tr>
<td>Name</td>
<td>Pages</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>KENNEDY, DAVID V.</td>
<td>300-57</td>
</tr>
<tr>
<td>KENNEDY, J. M.</td>
<td>460-67</td>
</tr>
<tr>
<td>KENNEDY, R. E.</td>
<td>192-46</td>
</tr>
<tr>
<td>KERR, RAYMOND E. Jr.</td>
<td>303-57</td>
</tr>
<tr>
<td>KITTREDGE, JOSEPH</td>
<td>8-33, 165-44, 210-48</td>
</tr>
<tr>
<td>KLEIN, D. A.</td>
<td>566-73</td>
</tr>
<tr>
<td>KLEIN, GEORGE J.</td>
<td>235-51, 236-51</td>
</tr>
<tr>
<td>KOELZER, VICTOR A.</td>
<td>232-51, 277-54</td>
</tr>
<tr>
<td>KOHLER, KARL O.</td>
<td>166-44</td>
</tr>
<tr>
<td>KOHLER, MAX A.</td>
<td>313-57, 339-59</td>
</tr>
<tr>
<td>KRAMER, HARRY A.</td>
<td>254-53, 388-62, 398-63</td>
</tr>
<tr>
<td>KRICK, IRVING D.</td>
<td>239-51, 255-53</td>
</tr>
<tr>
<td>KRUNMES, PETER</td>
<td>145-51</td>
</tr>
<tr>
<td>KUEHL, DONALD W.</td>
<td>278-54, 390-62, 416-64</td>
</tr>
</tbody>
</table>

- L -

<table>
<thead>
<tr>
<th>Name</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA CHAPPELLE, ED</td>
<td>330-58</td>
</tr>
<tr>
<td>LAHLUM, LT. COL. A. H.</td>
<td>245-52</td>
</tr>
<tr>
<td>LANE, J. C.</td>
<td>544-72</td>
</tr>
<tr>
<td>LANG, WILLIAM A.</td>
<td>88-40, 130-41, 146-42, 171-44, 181-44, 237-51, 244-52, 335-59</td>
</tr>
<tr>
<td>LANGBEIN, W. B.</td>
<td>188-45, 268-54</td>
</tr>
</tbody>
</table>
LANYON, JOHN J. 362-60
LARSON, LEE W. 536-71
LEACH, T. A. J. 365-61
LEAF, CHARLES F. 448-66, 496-69, 529-71
LEAVER, ROBERT 46-38
LEE, CHARLES H. 25-36
LEMMON, DR. PAUL L. 286-55
LEUPOLD, NORBERT 122-40, 388-62
LEVIN, GERALD B. 226-50
LEWIS, GEORGE A. 12-33, 42-37, 74-39
LIGHT, PHILLIP E. 144-41
LINDGREN, R. E. 275-54, 425-64
LONBERGER, THOMAS E. 443-65
LOWDERMILK, DR. C. W. 9-33
LULL, HOWARD E. 356-60
LUND, GEORGE W. 483-68
LUPTON, FRANTZ R. 226-50
LUTES, D. A. 521-70
MAC CREASY, PAUL B. JR. 319-57
MAC LEAN, DAUGHT A. 208-48
MAC VICAR, J. D. 113-40
MC ANDREW, DONALD W. 464-67, 571-73
MC CALLISTER, JOHN P. 391-62
MC FARLANE, W. T. 121-40
MC KAY, G. A. 366-61, 416-64, 530-71
MC LAUGHLIN, W. W. 48-38, 92-40, 155-43
MC NUTT, J. J. 39-37
MC QUEEN, ALEXANDER 6-33

MADSON, B. A. 166-44
MAGNUSON, MARVIN D. 364-61, 383-62, 399-63
MAHONEY, DAVID G. 430-65
MALONE, GEORGE W. 4-33
MALSOR, ROY E. 468-67
MANN, A. S. 435-65
MANSFIELD, C. W. 222-50
MARSDEN, MICHAEL A. 480-68
MARTIN, JOHN T. 348-60

-43-
<table>
<thead>
<tr>
<th>Name</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARTINELLI, M. JR.</td>
<td>358-60</td>
</tr>
<tr>
<td>MARWITZ, J. D.</td>
<td>433-65</td>
</tr>
<tr>
<td>MAXWELL, L. M.</td>
<td>352-60</td>
</tr>
<tr>
<td>MEADOWCROFT, N. F.</td>
<td>162-44, 166-44</td>
</tr>
<tr>
<td>MEIER, MARK F.</td>
<td>312-57, 447-66</td>
</tr>
<tr>
<td>MERRIELL, F. C.</td>
<td>66-39</td>
</tr>
<tr>
<td>MERRYFIELD, FRED</td>
<td>122-40</td>
</tr>
<tr>
<td>MEYER, C. B.</td>
<td>164-44</td>
</tr>
<tr>
<td>MIDLING, GEORGE W.</td>
<td>128-40</td>
</tr>
<tr>
<td>MILLER, DAVID H.</td>
<td>383-62</td>
</tr>
<tr>
<td>MILLER, DONALD L.</td>
<td>391-62</td>
</tr>
<tr>
<td>MILLER, ROBERT W.</td>
<td>315-57, 333-58, 379-62</td>
</tr>
<tr>
<td>MILLIGAN, CLEVE H.</td>
<td>309-57</td>
</tr>
<tr>
<td>MITCHELL, W. BRUCE</td>
<td>369-61, 420-64</td>
</tr>
<tr>
<td>MOLER, MURRAY M.</td>
<td>511-69</td>
</tr>
<tr>
<td>MOLNAU, MYRON</td>
<td>533-71</td>
</tr>
<tr>
<td>MONDRILO, GEORGE</td>
<td>294-56</td>
</tr>
<tr>
<td>MONFORE, G. E.</td>
<td>201-48</td>
</tr>
<tr>
<td>MONSON, O. W.</td>
<td>80-39, 81-39, 82-39, 121-40</td>
</tr>
<tr>
<td>MOONEY, MARGARET L.</td>
<td>483-68</td>
</tr>
<tr>
<td>MOORE, ROBERT E.</td>
<td>392-62</td>
</tr>
<tr>
<td>MORELAND, RONALD E.</td>
<td>539-71</td>
</tr>
<tr>
<td>Name</td>
<td>Page Numbers</td>
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<tr>
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<tr>
<td>MORRIS, EDWARD A.</td>
<td>412-63</td>
</tr>
<tr>
<td>MULVANEY, ROBERT J.</td>
<td>563-73</td>
</tr>
<tr>
<td>MUNSON, SPENCER M.</td>
<td>5-33, 11-33, 12-33</td>
</tr>
<tr>
<td>MURPHY, THOMAS D.</td>
<td>434-65</td>
</tr>
<tr>
<td>MURRAY, WILLIAM E.</td>
<td>272-54</td>
</tr>
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<tr>
<td>NAKAYA, UKITIRO</td>
<td>87-40</td>
</tr>
<tr>
<td>NARAIN, D.</td>
<td>466-67</td>
</tr>
<tr>
<td>NEMANISHAN, WALTER</td>
<td>549-72</td>
</tr>
<tr>
<td>NEYMAN, DR. J.</td>
<td>247-52</td>
</tr>
<tr>
<td>NICHOLSON, ROLAND I.</td>
<td>401-63</td>
</tr>
<tr>
<td>NIEDERHOF, C. H.</td>
<td>151-43</td>
</tr>
<tr>
<td>NIKLEVA, S. N.</td>
<td>573-73</td>
</tr>
<tr>
<td>NORUM, D. I.</td>
<td>515-70</td>
</tr>
<tr>
<td>NOUJAIM, DR. A. A.</td>
<td>552-72</td>
</tr>
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<td></td>
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<tr>
<td>OBEDEKOFF, W.</td>
<td>516-70</td>
</tr>
<tr>
<td>OGILVIE, JAMES L.</td>
<td>561-73</td>
</tr>
<tr>
<td>OLSEN, HARRY</td>
<td>157-43, 175-44</td>
</tr>
<tr>
<td>Name</td>
<td>Pages</td>
</tr>
<tr>
<td>----------------------------</td>
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<tr>
<td>OPPENHEIMER, JACK C.</td>
<td>439-65</td>
</tr>
<tr>
<td>ORD, MELVIN J.</td>
<td>488-68</td>
</tr>
<tr>
<td>ORVILLE, CAPT. HOWARD T.</td>
<td>265-54, 296-56</td>
</tr>
<tr>
<td>-P-</td>
<td></td>
</tr>
<tr>
<td>PACKER, PAUL E.</td>
<td>357-60</td>
</tr>
<tr>
<td>PAGENHART, T. H.</td>
<td>304-57</td>
</tr>
<tr>
<td>PARKER, GLENN L.</td>
<td>27-36</td>
</tr>
<tr>
<td>PARSONS, WALTER J.</td>
<td>115-40, 118-40, 162-44, 342-59</td>
</tr>
<tr>
<td>PAULSON, JOSEPH B. JR.</td>
<td>163-44, 214-48</td>
</tr>
<tr>
<td>PEAK, GEORGE W.</td>
<td>283-55, 385-62, 397-63, 494-69</td>
</tr>
<tr>
<td>PEARSON, GREGORY L.</td>
<td>375-61, 415-64, 559-72</td>
</tr>
<tr>
<td>PEASLEY, PHYLLIS</td>
<td>217-49</td>
</tr>
<tr>
<td>PECK, EUGENE L.</td>
<td>267-54, 271-54, 375-61, 419-64</td>
</tr>
<tr>
<td>PEDERSON, CLARENCE</td>
<td>128-40, 231-51, 258-53, 376-61</td>
</tr>
<tr>
<td>PENTON, V. E.</td>
<td>382-62</td>
</tr>
<tr>
<td>PERKINS, R. W.</td>
<td>451-66</td>
</tr>
<tr>
<td>PETERSON, E. N.</td>
<td>196-47</td>
</tr>
<tr>
<td>PETERSON, NED R.</td>
<td>490-68</td>
</tr>
</tbody>
</table>
PHILLIPS, H. BOYD 309-57
PHILLIPS, J. E. 50-38, 64-39
PIERCE, ROBERT S. 356-60
PILLSBURY A. F. 167-44
PIPER, ARTHUR M. 196-47
PIES, ANTHONY 525-70, 543-71
POLOS, ANTHONY 251-53, 258-53
POTTs, HARRY L. 41-37, 42-37, 177-44, 211-48
POULSON, WAYNE 68-39, 73-39
PRICE, E. B. 157-43
PRIEST, JOHN E. 382-62

- Q -
QUALE, BOYD E. 267-54
QUICK, M. C. 517-70, 525-70

- R -
RAIMUNDO, A. L. 394-63
RAMSEIER, RENE O. 449-66
RAND, J. L. 388-62
RANTZ, S. E. 384-62
RAPP, DR. ROBERT L. 438-65
RAUSSEPP, WALTER 289-56
RECHARD, PAUL A. 536-71, 569-73
REEDY, O. C. 40-37, 42-37, 65-39
REID, JAMES E. 528-71
REYNOLDS, ROBIN R. 300-57
RHEA, J. OWEN 504-69
RHODES, FORREST L. 61-38, 197-47, 198-47, 218-49
RICE, R. M. 325-58
RICE, R. C. 547-72
RICHARDS, H. B. 338-59
RIESEL, HERBERT S. 430-65
RILEY, J. PAUL 500-69
RINKER, LYMAN E. 56-38, 86-39
RITER, J. R. 171-44, 237-51
ROBERTS, KENNETH L. 109-40, 135-41
ROCKWOOD, DAVID M. 329-58, 378-61, 414-63, 422-64, 453-66, 524-70
ROGERS, S. M. 346-59
ROMPEL, JOHN 510-69
ROWE, P. B. 169-44
RUGEN, OTTO N. 127-40
RUSSELL, S. O. 516-70, 525-70
RYAN, JOHN T. 54-38, 70-39, 104-40, 130-41
SACHS, MILTON S. 232-51, 255-53
SAGER, GEORGE V. 10-33, 14-34
SAKAMOTO, R. T. 460-67
SALO, JOHN V. 96-40
SAMPSON, F. 365-61
SCHAEFER, D. G. 573-73
SCHAEFER, VINCENT J. 239-51, 409-63
SCHAEFER, PETER A. 359-60, 518-70
SCHAMACH, SEYMOUR 434-65
SCHERMERHORN, VAIL 378-61, 479-68
SCHLEUSENER, RICHARD A. 368-61, 413-63
SCHMIDT, R. A. 507-69
SCHNEIDER, WILLIAM J. 367-61
SCOBIEY, F. C. 16-34
SEADERS, JOHN 450-66
SELLERS, DR. WILLIAM D. 361-60
SENSINTAFFER, R. M. 385-62
SERR, EUGENE, SR. 261-53
SHAFFER, NEIL F. 370-61
SHANNON, WILLIAM G. 427-65, 489-68, 526-70
SHEERAR, L. L. 204-48
SHERMAN, LEROY K. 117-40, 168-44
SHERROD, JOHN, JR. 280-55
SIMONS, WILBUR D. 263-53, 290-56, 312-57, 473-67
SHOWMAN, ARTHUR C. 139-41
SHUMWAY, CLYDE A. 528-71
SMITH, CHARLES PENNPACKER 266-54
SMITH, FREEMAN M. 469-67
SMITH, JAMES L. 454-66, 499-69
SNYDER, CHARLES G. 167-44
SOKOL, R. A. 566-73
SOMERS, W. P. 269-54
SOMMERFELD, R. A. 507-69
SORENSEN, JAMES F. 505-69
SPEERS, DOUGLAS D. 548-72
SPORNS, U. 512-70
SQUIRES, DR. PATRICK 440-65
STACKHOUSE, J. L. 292-56, 400-63
STAFFORD, HARLOWE M. 3-33, 164-44, 335-59
STANFORD, LEIGH L. 130-41
STANLEY, J. W. 193-46
STANTON, C. R. 446-66
STEEL, ROGER L. 413-63, 452-66

-50-

STEVENSON, DOUGLAS R.  537-71

 STEWART, D. N.  216-49

STINSON, J. ROBERT  471-67

STOCKWELL, HOMER J.  277-54, 340-59, 368-61, 436-65

STONE, ROBERT G.  57-38

STORR, DON  459-67

STRAUSS, FRED A.  227-50, 321-57, 564-73

STRILAEFF, P. W.  363-61

STUBBLEFIELD, GARFIELD  175-44

SUMMERSETT, JOHN  259-53

SWANSON, ROBERT H.  422-64, 475-68, 537-71

SWIFT, CHARLES III  538-71

- T -

TABLER, RONALD D.  535-71, 572-73

TALLMAN, A. V.  7-33


TAYLOR, EDWARD T.  403-63

TAYLOR, FRANK W.  201-48

TEMPLETON, G. W.  237-51

THEAKSTON, F. H.  466-67

- 51 -
<table>
<thead>
<tr>
<th>Name</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>THOM, H. C. S.</td>
<td>519-70</td>
</tr>
<tr>
<td>THOMAS, C. A.</td>
<td>457-67</td>
</tr>
<tr>
<td>THOMAS, PHILLIP W.</td>
<td>94-40</td>
</tr>
<tr>
<td>THOMPSON, C. W.</td>
<td>433-65</td>
</tr>
<tr>
<td>THOMS, M. E.</td>
<td>380-62</td>
</tr>
<tr>
<td>THORUD, DAVID B.</td>
<td>495-69, 551-72</td>
</tr>
<tr>
<td>TIPTON, ROYCE J.</td>
<td>42-37</td>
</tr>
<tr>
<td>TODD, C. J.</td>
<td>319-57</td>
</tr>
<tr>
<td>TROXELL, HAROLD C.</td>
<td>164-44, 270-54</td>
</tr>
<tr>
<td>TUCKER, E. M.</td>
<td>104-40</td>
</tr>
<tr>
<td>TYLER, RICHARD G.</td>
<td>16-34</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Vance, Howard M.</td>
<td>532-71</td>
</tr>
<tr>
<td>Van De Erve, Jerome</td>
<td>478-68</td>
</tr>
<tr>
<td>Van Horne, Otto R.</td>
<td>334-58</td>
</tr>
<tr>
<td>Van Ornum, Delbert G.</td>
<td>266-54</td>
</tr>
<tr>
<td>Veatch, F. M.</td>
<td>123-40, 282-55</td>
</tr>
<tr>
<td>Veihmeyer, Dr. F. J.</td>
<td>169-44</td>
</tr>
</tbody>
</table>
WAHLE, ROLLA H. 153-43

WALSER, JOHN T. 410-63

WALSH, KENNETH J. 308-57

WANSLEE, JESS C. 66-39

WARBURTON, J. A. 484-68

WARD, JOHN C. 567-73

WARNER, O. R. 455-66

WARNICK, DR. CALVIN C. 220-49, 234-51, 305-57, 352-60, 404-63

WARREN, VERNON 122-40

WASHICHEK, JACK N. 464-67

WATERHOUSE, R. D. 76-39, 93-40

WEAVER, DONALD K. 461-67

WEBB, C. E. 202-48

WEBER, FRED R. 400-63

WELLS, J. V. B. 284-55

WEST, A. J. 325-58, 344-59, 437-65

WHALEY, ROBERT L. 532-71

WILLEN, DONALD W. 454-66, 528-71

WILLIAMS, G. P. 293-56

WILLIAMS, MERLIN C. 470-67, 485-68, 560-72

WILLS, GEORGE 47-38
<table>
<thead>
<tr>
<th>Name</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>WILSON, JACK ALDEN</td>
<td>456-66, 477-68</td>
</tr>
<tr>
<td>WILSON, MILTON T.</td>
<td>310-57</td>
</tr>
<tr>
<td>WING, R. L.</td>
<td>164-44</td>
</tr>
<tr>
<td>WOLFE, C. G.</td>
<td>323-58, 333-58</td>
</tr>
<tr>
<td>WYCOFF, PETER</td>
<td>311-57</td>
</tr>
</tbody>
</table>

-X-  

-Y-  

YEVDJEVICH, VUJICA M. | 387-62 |
YOUNG, L. G.         | 484-68 |
YOUNGQUIST, R. C.   | 74-39  |

-Z-  

ZIMMERMAN, AARON L.  | 287-55, 550-72 |
ZOPF, DAVID O.      | 442-65 |

-54-
western snow conference bibliography

the biography of snow surveying

church, dr. j. e.*

proc. wiscc 1933 pgs. 9-12 reno, nevada, feb. 18, 1933
published univ. of nevada, agr. exp. sta. bull. 1934

A biography of previous attempts at snow surveying for the purpose of forecasting the snow-melt runoff in Europe, Eastern United States and the Western States is related. The need for knowledge of the yearly varying quantity of water in the snow-pack which furnishes varying volumes of stream flow to lakes and reservoirs for irrigation and power development is paramount to semi-arid agriculture in the Western States, is presented. The staunch support of the Nevada Agricultural Experiment Station in starting the initial phase of this work by the Meteorologic Observatory on Mt. Rose, Nevada at 10,800 feet elev., and including snow survey measurements of water content to correlate with stream flow and lake rise at Tahoe is described. The rapid growth and acceptance of forecast methods and the survey equipment developed at Mt. Rose from 1909 through 1933 is described. The formation of Water Forecast Committees in various River basins to coordinate snow survey forecasting and release of measurement data and advise local press releases of forecast volumes is described.

*meteorologist, Nevada Experiment Station, Reno, Nevada

western snow conference bibliography

introductory remarks - problems for discussion

clyde, George D.*

proc. wiscc 1933 pgs. 12-13 reno, nevada, feb. 18, 1933
published univ. of nevada, agr. exp. sta. 1934

Snow survey and water supply forecasting projects in Utah with the cooperation of the Utah Agricultural Experiment Station at Logan, Utah is described. The difficulties of finding reliable relations of rainfall and snow data to runoff data are discussed. The probable use of water supply forecasts by many operating agencies such as; Forestry; irrigation; power generation; navigation; and flood control are explained. The need for refinement of field equipment and procedures to assure accurate data and consistent results presents many problems. Cooperation between federal, state, municipal agencies and private companies should be encouraged and organized.

*irrigation engineer, Utah Agr. exp. Sta. Logan, Utah

western snow conference bibliography

progress and conduct of California Cooperative Snow Surveys

stafford, harlowe M.*

proc. wiscc 1933 pgs. 14-22 reno, nevada, feb. 18, 1933
published Univ. of Nevada, Agr. Exp. Sta. Bull. 1934
3 tables; 1 graph

A brief history of snow surveying in California and the legislative action creating the California Cooperative Snow Survey Program is presented. Details of financing the initial program is discussed along with cooperation arrangements of Federal, State, private irrigation and power companies, municipal water departments are discussed. Field procedures and equipment used together with instruction methods and procedures of stocking shelter cabins are discussed. A list of cooperators who are servicing some 134 snow survey courses is shown.

Water Supply Forecasting procedures are described using tentative normals of snow data for the percentage or index method are discussed. A tabulation of forecast accuracy is shown. Procedures for publication and disseminating current data are explained. A discussion of problem areas and river basins is included.


western snow conference bibliography

financing snow survey programs

boardman, dr. h. f.*

proc. wiscc 1933 pgs. 23-25 reno, nevada, feb. 18, 1933
published Univ. of Nevada, Agr. Exp. Sta. Bull. 1934

A round-table discussion relative to financing snow surveys was lead by the author who outlined the problems presenting themselves through limited funds from the Nevada Agricultural Experiment Sta­tion. George D. Clyde explained similar limited funds from the Utah Agricultural Experiment Station and the Parnell Fund and Agricultural County Extension Service and Water Commissioners of several Irrigation Districts were being used. However limited finances were hampering the expansion of the program, and other limitations were for qualified manpower. Nevada State Engineer, George W. Malone expressed the great importance of snow survey data to farmers on irrigation districts, and stated his difficulty in convincing the State Legislators of the financial obligation of the State in this program.

The entire group commented on the whole hearted cooperation and support of the U. S. Forest Service, the Park Service and the U. S. Weather Bureau in furnishing data.

*Head Civil Engineering Dept., Univ. of Nevada, Reno
The Utah Snow Sampler, which is an adaptation of the Mt. Rose Sampler, and its scale and accessories are described. In the new sampler the throat of the cutter has a diameter of 1.4872 inches instead of the 1.5 inches, so that 1 inch of water is made to weigh 1 oz., permitting easy conversion to inches of water when ordinary commercial scale readings are used and also facilitating the calibration of special scales. The Utah Sampler uses Al-alloy tubing which is rust resistant, has an extremely smooth bore, and equals structural steel in strength with only 1/3 of its weight. The snow scale developed for the sampler is tubular and much lighter and more compact than the Mt. Rose Scale but lacks a means for setting the index at zero. Scales of different capacity are required for snow covers of varying depths and high water content, scales of larger capacity being constructed with the spring under an initial tension. George D. Clyde described the Utah Snow Scales, Aluminum tubes. The Scales, Cradle, Sampler and Cutter are pictured.


WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SNOW SURVEY EQUIPMENT

MUNSON, SPENCER M.*

The cooperative procedures which were carried out by the State of California, with Federal, State, City and Private agencies and companies to create the California Cooperative Snow Surveys is outlined. It is stated that the U.S. Weather Bureau had been the first suggested to conduct the work, but it was decided that the project was more in the nature of one to be conducted by engineers; that the Bureau felt they would be more effective as a cooperator than an operator of such an undertaking. Mr. Alexander McQueen, Supervisor of the U.S.F.S. at Elko, Nevada commented on the effectiveness of the Snow Surveys in the Humboldt Basin, and that his Rangers were enthusiastic about the work. Mr. C. L. Foreleng, Director of the Intermountain Forest & Range Exp. Station at Ogden, Utah commented relative to their cooperation in the snow survey program in Utah. Several members of the Nevada State legislature commented on the hopeful cooperation of that body towards financial help through State funds to the University and the Experiment Station for agriculture at Reno, Nevada.

*BIBLIOGRAPHY

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SNOW SURVEY EQUIPMENT

MUNSON, SPENCER M.*

The Utah Snow Sampler, which is an adaptation of the Mt. Rose Sampler, and its scale and accessories are described. In the new sampler the throat of the cutter has a diameter of 1.4872 inches instead of the 1.5 inches, so that 1 inch of water is made to weigh 1 oz., permitting easy conversion to inches of water when ordinary commercial scale readings are used and also facilitating the calibration of special scales. The Utah Sampler uses Al-alloy tubing which is rust resistant, has an extremely smooth bore, and equals structural steel in strength with only 1/3 of its weight. The snow scale developed for the sampler is tubular and much lighter and more compact than the Mt. Rose Scale but lacks a means for setting the index at zero. Scales of different capacity are required for snow covers of varying depths and high water content, scales of larger capacity being constructed with the spring under an initial tension. George D. Clyde described the Utah Snow Scales, Aluminum tubes. The Scales, Cradle, Sampler and Cutter are pictured.


WESTERN SNOW CONFERENCE BIBLIOGRAPHY

COOPERATIVE (SNOW SURVEYS)

BOVIE, MAJOR E. H.*

The cooperative procedures which were carried out by the State of California, with Federal, State, City and Private agencies and companies to create the California Cooperative Snow Surveys is outlined. It is stated that the U.S. Weather Bureau had been the first suggested to conduct the work, but it was decided that the project was more in the nature of one to be conducted by engineers; that the Bureau felt they would be more effective as a cooperator than an operator of such an undertaking. Mr. Alexander McQueen, Supervisor of the U.S.F.S. at Elko, Nevada commented on the effectiveness of the Snow Surveys in the Humboldt Basin, and that his Rangers were enthusiastic about the work. Mr. C. L. Foreleng, Director of the Intermountain Forest & Range Exp. Station at Ogden, Utah commented relative to their cooperation in the snow survey program in Utah. Several members of the Nevada State legislature commented on the hopeful cooperation of that body towards financial help through State funds to the University and the Experiment Station for agriculture at Reno, Nevada.

*BIBLIOGRAPHY

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

LAKE TAHOE WATER LEVELS

BOARDMAN, DR. H. B.* and CHURCH, DR. J. E.**

A review of Lake Tahoe water levels from 1878 to date is presented with text discussion to answer the question: "How often will Lake Tahoe levels fall below the outlet in the next 50 years?" The use of snow survey data and precipitation data are combined in a "Percentage System" to compute a forecasting formula. Remarkable results were achieved and forecast accuracy is indicated in the text discussion. In discussion by Major E. H. Bowie, the snow-water ratio of newly fallen snow in the Sierra is explained. Mr. A. V. Tallman discussed the effect of precipitation during the run-off season on the Humboldt River as an aid to forecasting. Dr. J. E. Church described a new Snow Survey network of courses and a system for the Colorado River to aid in planning the operation of Boulder Reservoir created by Hoover Dam.

*Head, Civil Engineering Dept., Univ. of Nevada, Reno, Nevada
**Meteorologist, Nevada Agr. Expt. Station, Reno, Nevada

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

RELATION OF FORESTS TO SNOW

KITTREDGE, JOSEPH*

The effects of forest cover on the accumulation and melting of snow are discussed in relation to water conservation on the basis of surveys made in the U.S. at various periods dating back to 1911. Studies in various regions on snowfall interception by trees of varying crown density, the reduction of wind speed and snow accumulation in openings, and the reduction of solar radiation intensity and accompanying retardation of melt are summarized, and representative data are tabulated. Snow accumulation was found greatest in small openings without crown cover in forests (15.6% more than in the open) and least under a dense cover of trees (32.5% less than in the open). Melting was most rapid in burned areas, and slowest under virgin all-age red fir stand. There was a linear decrease of melting on clear days with increased crown density, amounting to 3 in./day with no crown cover and 2 in./day under 70% crown cover. Differences in kind, size, and density of forest or other vegetation are also reflected in the accumulation and melting of snow. The optimum forest with respect to water conservation appears to be one which is fairly open with interspersed glades.

*Professor of Forestry, Univ. of Calif., Berkeley, Calif.
Considerations in Measurement of Yield of Snow Packs in Percolation Water

Lowdermilk, W. C.*

Proc. WISCC 1933: Pgs. 35-37
Reno, Nevada, Feb. 18, 1933
Published Univ. of Nevada, Agr. Expt. Sta. Bull. 1934

Conclusions of a three year study of percolation of water through different soil depths toward the production of tree growth in the forests is presented. It is found that a large portion of the rainfall is evaporated from the bare soil, while there is greater possibility of increasing the deep percolation of melting snow water due to decrease evaporation and slow melting. There is greater percolation of rain water when storms are frequent, say at weekly intervals, than large storms that cause considerable surface run-off. Field instrumentation: rectangular tanks with sloping bottoms, 4" to 36" deep and filled with soil so arranged so that the percolated water could be measured, in conjunction with standard rain gauges etc. Provisions were made to measure the surficial runoff and evaporation losses. A table of resulting data is shown. Reference is made to similar studies by O. J. Adelka and Fueltse Hetf. Questions are listed relative to possible instruments for determining the evaporation losses from snow surfaces.


The Long-Term Trend of Rainfall in the Central Sierra Region

Sager, George V.*

Proc. WISCC 1933: Pgs. 39-52
Reno, Nevada, Feb. 18, 1933
Published Univ. of Nevada, Agr. Expt. Sta. Bull. 1934
1 Table; 11 Graphs; 6 References

Results of a study to ascertain if past rainfall records would indicate a probable trend or cyclic formation through a 60 year period (1897-1930) to indicate a probable termination of the long dry period, towards forecasting some relief even for a few years in advance. Data from precipitation stations at different altitudes extending from the Pacific Coast across the Sierra and Nevada to Salt Lake City were analyzed graphically by plotting departures from their normals against years. Graphs are shown. Lake levels at Tahoe, Pyramid and Winnemucca are also shown. Conclusions indicate there was little hope of finding a basis for seasonal or other long term forecasting from the data studied, including solar activity.

In discussion Mr. F. B. Headley presented a separate graphical procedure for studying in connection with streamflow probabilities for irrigation districts in Nevada. Here the comparisons are reduced to zones rather than the individual stations.

Author Index
I. Lowdermilk, Dr. W.

Field Equipment

Jones, James E.* et al

Proc. WISCC 1933: Pgs. 71-76
Reno, Nevada, June 28, 1933
6 Photographs

A round-table discussion is presented relative to the various pieces of equipment used in field snow surveying. George A. Lewis discussed the Mt. Rose Spring Balance, pointing out the excess friction and the lack of initial tension being insufficient for accurate results. He points out the convenience of having the 6 ft. lengths of tubing cut into 3 ft. lengths and another coupling added. This facilitates carrying the tubes rather than the 5 ft. sections used in California. The cutters would have to have a harder temper as the ones now in use were bent too easily.

Spencer Munson of California discussed the cutters used by that state as being hard enough. Also types of winter clothing was discussed including ski boots and equipment, and care of equipment during the off season.

Discussion was had relative to shellac versus wax for snow tubes, to keep the snow from sticking to the bare metal. George Clyde described the Utah aluminum tubes and scales. Fred and Walter Herz discussed ski travel procedures.

Author Index
I. Jones, J. E.
II. Lewis, G. A.
III. Munson, S. M.
IV. Clyde, G. D.
V. Herz, W.
VI. Herz, F.
Six problems dealing with streamflow forecasting from snow surveys and other factors involved in producing streamflow from snowmelt, are listed and discussed:

1. Can a series of streams be estimated according to a standard, or must each be a problem by itself?
2. Would a master station be more desirable for giving scientific data to all agencies concerned?
3. What is the best method of determining the long time effects of dry year on runoff, soil capacity, etc.
4. Has any method been devised for determining soil capacity for use in snow survey forecasting.
5. What is the effect of wind, temperature, rain, topography, porosity, and soil temperature on snowmelt runoff?
6. How much variation in time is permissible in consecutive years in making snow surveys to still get comparable results.

These 6 points were suggested for future papers and discussion at forthcoming meetings.

*Ed. Hydrography Dept., Dept. of Water, Los Angeles, CA
A study is made to ascertain to what extent the temperature at Reno, Nevada, Elev. 4521, could be taken as indicative of the departure at nearby mountain stations, thus giving a clue to the probable melting of snow in the mountains, runoff, and snow-wastage by evaporation. Mountain stations at Tahoe City -6230; Norden (Donner Summit) -7071; Marlette Lake -8000; all having 24 years of records 1910-33 were used for the study. Normals were computed and means of departures month by month were tabulated and graphed. A summary in the text indicates that other factors, difficult to measure are involved in a formula to forecast the snow-melt runoff.

Meteorologist, U. S. Weather Bureau, Reno, Nevada

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

EVAPORATION AT HIGH ALTITUDES AND LATITUDES

CHURCH, DR. J. E.*

Proc. TAGU 1934 15 326-351: WISSC at Berkeley, University of California, June 21, 1934
2 Location Maps; 24 Tables

A report of a study dealing with evaporation from snow-fields and tree accumulation beginning in 1910 on Mt. Rose, Nevada, (10,800) and in the Lake Tahoe Basin, 6225 altitude. A description of field equipment and procedures of measurement is presented. Tabulations of hourly and daily data are shown in the tables. Comparisons of data are discussed in the essay, together with discussion of troubles and solutions to improve the measurements. The author has included data collected while on the Hobbs Exposition to the Ice Cap of Greenland in 1926. Evaporation from snow surfaces were made at that time and data with discussion of resulting information is also included.

Meteorologist, Nevada Agr. Exp. Sta., Univ. of Nevada, Reno, NV

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

FLOW-CHEMISTRY OF GLACIER-FED AND SNOW-FED STREAMS

TYLER, RICHARD C.*

Proc. TAGU 1934 15 617-623: WISSC at Berkeley, University of California, June 21, 1934
2 Tables; 5 Graphs

Quantitative data of runoff for Washington streams are tabulated to determine their capacity and usefulness. The coefficient of variation is calculated for each stream to determine the variability or the dependability. Streams fed by glaciers and snow accumulation at the higher elevations are compared with other streams having the same total precipitation in the form of rain. Glacier and snow-fed streams have a more uniform flow through the year and a smaller coefficient of variation. A higher annual runoff per square mile resulting from the greater precipitation at the higher elevations, excessive flood-flows arising from a combination of rainfall and snow-melt, and diurnal flow variations produced by temperature fluctuations at higher elevation.

A discussion of the paper by F. C. Scobey is shown on page 624.

Dean, College of Engineering, Univ. of Washington, Seattle

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

RELATIONSHIP OF DEGREE-DAYS ABOVE FREEZING TO RUNOFF

COLLINS, E. H.*

Proc. TAGU 1934 15 624-629: WISSC at Berkeley, University of California, June 21, 1934
1 Location Map; 3 Tables; 5 Graphs

Methods of predicting the water supply available at the low-water period in Coeur d'Alene Lake, the storage reservoir for hydro-electric power development on the Spokane River, are assessed. Snow surveys were unsatisfactory because of the low elevation of the drainage area, and the storage rights limiting the retaining of flood waters. Temperature studies indicate that below freezing did not influence runoff, but that temp. above freezing effected snow-melt. The relation between degree days above 32°F and runoff were computed and plotted against runoff to create a graph for predicting runoff satisfactorily. By using a combination of the summation of degree-days and a summation runoff prior to the date of prediction better results are experienced.

Table 2 shows the resulting monthly forecasts for the years 1926 through 1931.

A discussion of the paper by Carl Elges and Dr. J. E. Church is presented on pg. 629.


WESTERN SNOW CONFERENCE BIBLIOGRAPHY

WATER POWER DEVELOPMENT ON THE SPOKANE RIVER

.providers, E. H.*

Proc. TAGU 1934 15 587-597: WISSC at Berkeley, University of California, June 21, 1934
2 Tables; 1 Graph

The author presents a study of the water and power development on the Spokane River in northeastern Washington State, which in addition to the hydropower, has hydroelectric development for irrigation. A study of the water is made by calculating the excess precipitation over the normal, the amount of snow in the mountains, the amount melted by the ordinary rules and also by such factors as temperature and degree of latitude. A detailed study of the water development in the area is given.

Author Index

COLLINS, E. H.


AUTHOR INDEX

COLLINS, E. H.
A description of the revised system of stream-flow forecasting for the Humboldt River in North Central Nevada is presented. The lack of existing records of the streamflow and snow survey data and other meteorological factors in the Humboldt Mountains has hampered accurate results of forecasting. The isolation of the river basin surrounded by wide expanses of dry desert lands poses a major problem to locate correlation data with streamflow. The gaging stations are far downstream and below many diversions for irrigation that are also not measured. A list of six (6) recommendations for new stations to measure the several factors necessary for better forecasting is included.

*Statistician, Nevada Agr. Expt. Sta., University of Nevada, Reno

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The Utah improvements on the Mt. Rose snow sampler by using dur-aluminum alloy tubing, and a cheaper cutting bit and a tubular scale are described. All improvements were made for lightness, cheapness and back-packing facility. The use of the lighter tubing in constructing the sampler allows for a shorter tubular scale without sacrificing accuracy. Snow survey shelter cabins located strategically near the snow course is recommended for safety of the field parties.

A discussion by S. P. Ferguson of Blue Hill Observatory relative to the original design of the Mt. Rose sampling equipment is included and his recommendations for the new design of sampling tubes and scales now that dur-aluminum alloy tubing has become available in the correct sizes, and of equal strength.

*Hydraulic Engineer, City of Los Angeles, Dept. of Water & Power, Los Angeles, California

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A description of a new automatic rain and snowfall record-gage is presented. (Shown in photograph). This instrument is designed to record a winter season catch of precipitation and print the resulting amounts on a graph. The receptacle has a capacity of 100 inches of precipitation either rain or snow. The receptacle is originally charged with a calcium chloride solution to prevent freezing and an oil film to prevent evaporation. The receptacle is balanced on a weighing frame and the weighing beam is kept in balance by a reversible motor that keeps the weighing 'Paul' constantly in balance. The weights are recorded on a weight driven 'Stevens Type 30' water-stage recorder. A wind motor provides current and charges batteries. The instrument is designed for isolated locations. The manufacturer; Leupold, Volpe! Company, Portland, Oregon. Later years Leupold - Stevens Instrument Company

*Hydraulic Engineer, Leupold-Stevens Instrument Company, Portland, Oregon
SNOW COVER MEASUREMENTS AND IRRIGATION WATER SUPPLY FORECASTING

MARR, JAMES C.*


Snow survey and water supply forecasting program recently organized under the U. S. Dept. of Agriculture, Soil Conservation Service, Bureau of Agriculture Engineers, Division of Irrigation Research, under an act of the 74th Congress effective July 1, 1935. The paper presents some of the early history of snow surveying in the Western States under the guidance of Dr. J. E. Church. A discussion of the various instruments for measuring snow and weighing the sample to obtain the inches of water in the snowpack is presented. Also the plans for Cooperative Program with other Federal and State and private agencies involved with irrigation and the management of water flowing in streams that are largely fed by melting snow.

NOTE: No other meeting was held in 1935

*U.S.D.A., Bureau Agricultural Engineers, Boise, Idaho
The growth to international importance of snow surveying for streamflow forecasting resulted in some progress but lacks in coordination and standardization of procedures. The Bureau of Agricultural Engineering investigated the possibility of correlating the existing snow surveys and the need for new networks, with emphasis on Calif., Nevada, Utah, Oregon, Wyoming, Colorado, and Idaho. Experience useful for a country-wide water supply occurs during a few weeks during May and June and usually in the form of rushing floods. This period is also when the melt water from this area furnishes the water supply for Lake City and the surrounding irrigated agricultural areas. The bulk of the water supply occurs during a few weeks during May and June and usually in the form of rushing floods. This period is also when maximum storms, warm weather, and melting of the winter snowpack occurs. Ground water supply does not play an important part. For sufficient year round supplies, reservoir storage is essential.

Rain gage measurements and snow survey measurements are used to compute the probable runoff for reservoir management. No data or procedures are presented.

A 25-year record is sufficient for reservoir management. No data or procedures are presented.
A narrative is presented describing possible procedures for estimating the streamflow normals, (Monthly, Seasonal), for gaging stations with short period of record. By virtue of the great variation of precipitation in the high altitudes and the valley stations and various orographic effects from basin to basin aspect, there seems to be a very little correlation in this procedure of extending runoff normals. There is apparently sound procedures to correlate stream gage stations where characteristics are similar. The soundest procedure is to establish precipitation stations and snow course surveys in the basin and create a reliable record of streamflow and be patient.

**An Example**

An example is given of extended snow cover normals by comparison with precipitation data for a small basin in Eastern Nevada. The expansion was accomplished by comparing the snow cover at an elevation of 7400 ft on March 1 with the Nov.-Feb. precipitation. In this case the expansion from precipitation data yielded better results than could be expected by comparison to the stream flow data of the Humboldt River. Tabulation of data and a graph illustrate the results with detailed text analysis.

**Western Snow Conference Bibliography**

**Elges, Carl**


**Parker, Glenn L.*

A snow sampler combining the capacity and strength of the Mt. Rose sampler and the lightness of the Utah sampler was ordered by the U. S. Bureau of Agricultural Engineers. Dur-aluminum and steel samplers are evaluated as construction materials for strength, core removal, and ease of sampling. Most of the fundamental features of the Mt. Rose sampler were adopted. Design deviations from both sampler types are listed. The Mt. Rose spring balance is considered superior to the tubular or Utah balance. Designs of a new springless balance and a weighting staff of dur-aluminum for use with the spring balance are described and shown in pictures. Tabulations of types of balance are shown.


WESTERN SNOW CONFERENCE BIBLIOGRAPHY

IMPROVEMENTS IN SNOW SURVEY APPARATUS

CHURCH, DR. J. E.*

Proc. TAGU 1936 Part II 550-557: WISSC at Pasadena, California, January 31, 1936

QUESTIONNAIRE AND ANSWERS ON SNOW SURVEY EQUIPMENT AND METHODS

JONES, JAMES E.*

Proc. TAGU 1936 Part II 557-562: WISSC at Pasadena, California, January 31, 1936

By virtue of the relatively new science of snow surveying and water supply forecasting, the Western Interstate Snow Survey Conference sent a questionnaire to some 231 offices, engineers, and scientists involved in the study of streamflow from snow melt and related problems. Answers to (6) six basic questions and comments were to be included.

I. Field equipment; your preference as to type, style, and material and why. 16 items were listed.

II. Snow survey courses; location, No./basin, No. points.

III. Water supply forecasting; method, procedures, justify.

IV. Collateral data; variables used, length records.

V. Streamflow data; normals, extension procedure, use.

VI. Cost of snow surveys; per survey, transportation, equipment, observers, annual budgets.

*Hydraulic Engineer, Dept. Water & Power, City of Los Angeles, General Chairman, Western Interstate Snow Survey Conference.
A narrative of 'The Cooperative Federal-State-Private Snow Survey Program' is presented. The details of organizing such a program throughout the eleven (11) western states was necessary, not only from a financial standpoint as from the physical impossibility of the small organization staff reaching the widely separated snow survey courses. The centralization of data collection and publication by states or river drainage areas, permitted all cooperators and others to profit from all the data collected, and the assessment of probable water supplies for irrigation and water management. Without the cooperation of the U. S. Forest Service, Park Service, Power and Irrigation districts or companies; the U. S. Geological Survey, Weather Bureau, Bureau of Reclamation and Corps of Army Engineers; the snow survey program and water supply forecasting would never had been possible.

*Irrigation Engineer, U.S. Bureau Agri. Engrs., Boise, Idaho

**Irrigation Engineer, Div. Water Resources, Sacramento, Calif.
more research will result in establishing courses of

Sierra Power paper and proposes methods of analysis and graphs for several snow
liable sampling points. H.
The variation in yearly water content of a particular sample point in
relation to the water content average of the snow course was obtained
for each of several years. Percentages of the mean of each sample
to the average or mean of the variation was plus or minus 10 percent of the average water content for the
A formula is given to estimate the adequacy of the sampling.

to 15 reliable sampling points. H. P. Boardman presents a discussion of the
and proposes methods of analysis and graphs for several snow
survey courses and detailed reasoning in the text.

ACCURACY OF INDIVIDUAL SAMPLES IN A SNOW COURSE
HUNTER, CLAUDE E.* and DEVORE, GEORGE W.**
Proc. TAGU 1937 Part II 646-652: WISSC at Denver, Colorado
June 25-26, 1937
1 Table; 5 Graphs
Variation in yearly water content of a particular sample point in
relation to the water content average of the snow course was obtained
for each of several years. Percentages of the mean of each sample
to the average or mean of the variation was plus or minus 10 percent of the average water content for the
A formula is given to estimate the adequacy of the sampling.
APPLICATION OF SNOW SURVEY DATA BY THE BUREAU OF RECLAMATION

REEDY, O. C.*


Snow survey data are used for forecasting water runoff on watersheds. The Bureau of Reclamation used the data from the Okanogan River Basin in Washington, the Malheur in Oregon, the Boise River Basin in Idaho, and the Jackson Lake and Snake River in Wyoming to forecast the water supply at Boulder Dam, Nevada.

*Hydrologic Engr., U.S. Bureau of Reclamation, Denver, Colo.

SNOW SURVEYS AND RUNOFF FORECASTING FROM PHOTOSHOPHS

POTTS, HARRY L.*


A series of photographs was taken from the same point of a high range near Hoosier Pass, Colorado, at intervals throughout the year. The percentage of the area covered by snow in each photograph was calculated by superimposing a transparent template on the picture and counting the squares in which snow appeared. The total runoff was calculated on Nov. 1 from the date on which each photograph was taken. Curves for 3 consecutive years were plotted as functions of snow cover and runoff on the same chart. Considerable variation in precipitation was obtained. It is shown that the distance between the 3 curves is approximately directly proportional to the differences in recorded precipitation. The total amount of water which will be available for use is determined by calculating the ratio between total runoff and total diversions at the city intake for an average year.

*Engineer, Denver Water Board, Denver, Colorado
7 Tables; 3 Maps; 1 Graph

Mountain snow surveys for the benefit of irrigation were suggested in 1909 and have been made annually since 1911 on an increasing number of watersheds. The influence of elevation on snowfall is discussed. Precipitation stations will be equipped with storage snow gages and their present number supplemented to give a well distributed network in which elevation, aspect and individual needs of the various basins will be considered. The development of the storage gage is presented. The advantage of the snow storage gage as basin snowfall samplers are enumerated. Streamflow forecasting from snow surveys is discussed. Recommendations are made to overcome the deficiencies of hydrologic research and include improvements of snowfall and snow depth measurements, determination of relations between factors causing snow to melt, and evaluation of surface conditions controlling the losses to runoff from melting snow.

#Chief, River and Flood Division, U. S. Weather Bureau, Washington, D. C.

**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

**THE EXPANDED PROGRAM OF THE UNITED STATES WEATHER BUREAU IN SNOW WORK**

**Catalogue No.**

**BERNARD, MERRIL***

**CRREL No. SIP U5233**

**DLC, QE500.A6 v 19**

**Proc. TAGU 1938 Part II 673-685: WISSC at Davis, Calif. Jan. 8, 1938**

1 Table; 3 Maps; 1 Graph

Western precipitation forecasting and runoff data with some degree of accuracy, without becoming involved with percent of normals.

**SUBJECT INDEX**

1. Precipitation
2. Network

**AUTHOR INDEX**

1. Bernard, M.

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**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

**DEVELOPMENT OF SNOW SURVEYING IN CALIFORNIA**

**Catalogue No.**

**PAGET, FRED H.***

**CRREL No. SIP U5234**

**DLC, QE500.A6 v 19**

**Proc. TAGU 1938 Part II 686-690: WISSC at Davis, Calif. Jan. 8, 1938**

1 Table; 1 Graph

The present use of water in California for irrigation, power and municipal purposes depends on reliable information on the amount of water which will be contributed by the mountain snow pack in the spring. The existing program of snow surveys was initiated in 1929. The extent of the California Cooperative Snow Surveys is presented, with 175 active snow courses covering 24 watersheds. Forecasting is based on results of snow surveys conducted in April and assumes that average conditions will prevail during the following months. Forecasts of April 1 are modified and corrections published on May 1 when abnormal precipitation during the early runoff period occurs. The 'Direct method curve' used to modify accurately the original estimate is illustrated using the Upper San Joaquin River watershed as an example. The Direct method of forecasting was made possible by the 10 years of existing records on snow courses and runoff, and provided sufficient data to establish a relationship between snow survey data and runoff data with some degree of accuracy, without becoming involved with percent of normals.

**SUBJECT INDEX**

1. Snow survey
2. Water supply forecasting
3. Statistical analysis

**AUTHOR INDEX**

1. Paget, F. H.

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**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

**ESTABLISHING FIRST YEAR-NORMALS ON THE BASIS OF ACCUMULATED SNOWFALL AND SOME FORECASTS FROM RUNOFF RATIO**

**Catalogue No.**

**FARROW, RICHARD C.***

**CRREL No. SIP U5235**

**DLC, QE500.A6 v 19**

**Proc. TAGU 1938 Part II 689-694: WISSC at Davis, Calif. Jan. 8, 1938**

6 Tables; 1 Graph

Three snow courses (one in each area) were laid out in 1937 at Glacier in the Selkirks, at Field in the Rockies, and at Fernie in the Southern Canadian Rockies. The locations are near various precipitation stations whose data can be related to runoff at higher elevations. Sampling data from the 3 courses, the method used in obtaining a tentative first year normal, the mechanics of forecasting used, and the application of the forecast to points further downstream by use of runoff ratio factors are discussed. The percentage method is compared with the density method in establishing first-year snow course normals. It is concluded that a relationship between snowfall data and runoff is evident and that precipitation during runoff does not affect runoff. A refutation by Carl Elges of the density method is contained in the discussion. (See also SIP U1695 and WSC 35-37).

**SUBJECT INDEX**

1. Water supply forecasting
2. Statistical analysis

**AUTHOR INDEX**

1. Farrow, R. C.
2. Elges, C.

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**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

**WINTER PRECIPITATION VERSUS SNOW SURVEY FOR FORECASTING ON SKAGIT RIVER, WASHINGTON**

**Catalogue No.**

**LEAVER, ROBERT**

**CRREL No. SIP U5236**

**DLC, QE500.A6 v 19**


7 Tables; 1 Graph

A discussion of a paper on the monthly flow forecast of the Skagit River at Diablo Dam is presented. The monthly precipitation on 1100 sq. mi. of drainage area and the monthly mean inflow into the reservoir over a 25 year period were compared. It is shown that 68.7 percent of the rainfall enters the reservoir in an average year. Also half of the rainfall occurs from October thru December; the runoff is less than 18% during the same period. The difference forms a surplus to be drawn upon during the remaining 9 months. Each year the percentage of normal precipitation for Oct.-March is near to the percentage of normal inflow from April-Sept. The flow of the river for each particular period can be predicted within a mean average of 5% from the 25 year record by summing up the maximum and minimum figures for each month. The value derived by using the snow survey seems questionable since the prediction of increase runoff from snow-reservoir conditions is affected by temperature. Discussion by H. H. Boardman.

**SUBJECT INDEX**

1. Water supply forecasting
2. Statistical analysis

**AUTHOR INDEX**

1. Leaver, R.
2. Boardman, H. F.

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**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

**SNOWFALL VERSUS SNOWFALL FOR FORECASTING ON SKAGIT RIVER, WASHINGTON**

**Catalogue No.**

**CRREL No. SIP U5235**

**DLC, QE500.A6 v 19**

**Proc. TAGU 1938 Part II 690-695: WISSC at Davis, Calif. Jan. 8, 1938**

1 Table; 1 Graph

A discussion of a paper on the monthly flow forecast of the Skagit River at Diablo Dam is presented. The monthly precipitation on 1100 sq. mi. of drainage area and the monthly mean inflow into the reservoir over a 25 year period were compared. It is shown that 68.7 percent of the rainfall enters the reservoir in an average year. Also half of the rainfall occurs from October thru December; the runoff is less than 18% during the same period. The difference forms a surplus to be drawn upon during the remaining 9 months. Each year the percentage of normal precipitation for Oct.-March is near to the percentage of normal inflow from April-Sept. The flow of the river for each particular period can be predicted within a mean average of 5% from the 25 year record by summing up the maximum and minimum figures for each month. The value derived by using the snow survey seems questionable since the prediction of increase runoff from snow-reservoir conditions is affected by temperature. Discussion by H. H. Boardman.

**SUBJECT INDEX**

1. Water supply forecasting
2. Statistical analysis

**AUTHOR INDEX**

1. Leaver, R.
2. Boardman, H. F.

<table>
<thead>
<tr>
<th>SUBJECT INDEX</th>
<th>AUTHOR INDEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Soil moisture</td>
<td>I. McLaughlin, W. W.</td>
</tr>
<tr>
<td>2. Soil temperature</td>
<td></td>
</tr>
</tbody>
</table>

*Frost in the Soil, a Suggested Factor Affecting Forecasts*

McLaughlin, W. W.*


The need for measuring the amount of frost in the soil mantle under the snowpack as well as the water content at key stations through the river basin is brought out as one of the many factors in streamflow forecasting. This problem is immediately associated with soil temperature and soil moisture at several depths below the soil surface. Measurement of these factors in connection with snow surveying and forecasting is being considered.

*Chief Engineer, Sierra Pacific Power Co., Reno, Nevada

Phillips, J. E.*


The benefits derived from snow surveys are often difficult to evaluate financially. The City of Los Angeles, Department of Water and Power, shows well planned operations by using snow survey data for reservoir regulation for municipal water supply from the Owens River Aqueduct; for requirements of possible pumping operations for supplementary water needs, also for water-spreading operations to build up ground water supplies through irrigation on city owned lands leased to farmers along the upper reaches of the Owens River. Plans for lease rentals and crops to be planted are based on knowledge gained from snow survey data.

*Engineer, Dept. Water & Power, Los Angeles, Calif.

Abstract

The needs for measuring the amount of frost in the soil mantle under the snowpack as well as the water content at key stations through the river basin is brought out as one of the many factors in streamflow forecasting. This problem is immediately associated with soil temperature and soil moisture at several depths below the soil surface. Measurement of these factors in connection with snow surveying and forecasting is being considered.


Abstract

The economic value of snow survey measurements used in water supply forecasting is well demonstrated in water development along the Truckee River, Nevada, by the Sierra Electric Power Co. Snow surveys are made monthly Jan. through May in order to monitor the progress of the snow build up in the drainage basin. Power plant operations are planned on this information. The regulation of Lake Tahoe water levels within the six ft. legal limit are also anticipated from the monthly snow survey data. Estimates of energy generation are made 12 months in advance and are of importance in computing probable operating costs and dividends that will be available to stockholders in the company.

*Chief Engineer, Sierra Pacific Power Co., Reno, Nevada

Devore, George G.*


The economic value of snow survey measurements used in water supply forecasting is well demonstrated in water development along the Truckee River, Nevada, by the Sierra Electric Power Co. Snow surveys are made monthly Jan. through May in order to monitor the progress of the snow build up in the drainage basin. Power plant operations are planned on this information. The regulation of Lake Tahoe water levels within the six ft. legal limit are also anticipated from the monthly snow survey data. Estimates of energy generation are made 12 months in advance and are of importance in computing probable operating costs and dividends that will be available to stockholders in the company.

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Engineer, Sierra Pacific Power Co., Reno, Nevada

WESTERN SNOW CONFERENCE BIBLIOGRAPHY
COST AND BENEFITS OF SNOW SURVEYING IN UTAH
CLYDE, GEORGE D.*
Utah's irrigation water supply is largely dependent upon the size of the winter snow pack stored on the high mountains of the central portion of the state. The type of farm crops are variable in their water requirements. With sufficient accurate foreknowledge of the probable water supply, crops can be selected for economical planting and use of water.

The drought year of 1934 was probably the most serious in western history. Advance information of this condition was indicated by snow survey measurements. A water conservation program was immediately organized with a crash program by Press and radio information. Strict adherence to regulations and the full cooperation of the farmers resulted in a saving of over $5,000,000 by economical use of water. Supplementary supplies were organized from well drilling in the Bear River Basin resulting in a crop saving of another $3,000,000 in that area alone.

Such savings warrant the cost of snow surveys for many years.


WESTERN SNOW CONFERENCE BIBLIOGRAPHY
IMPROVEMENT IN SKI, DURALUMINUM SAMPLER, AND WEIGHING APPARATUS
COWGILL, PHILLIP S.*
1 Sketch

Skins, waxed to the condition of the snow and equipped with some form of rigid bindings, are used almost entirely by snow surveyors. Experience with the new duraluminum sampler tubes points to the necessity of shellacking them to prevent the snow from adhering to the bare metal. The tubes work well in warm weather, but on very cold days the core froze to the inside of the tube. The duraluminum sampler tubes will be tried again after being shellacked. Experiments to determine the effect of different temperatures and atmospheric conditions are planned. The Mount Rose Type balance remains the most satisfactory where large variations in depth of snow are encountered.

*Mechanical Engineer, Univ. of Nevada, Reno, Nevada
Weston Snow Conference Bibliography


The Stevens Seasonal Snow-Rain Recorder

1. Snow survey markers

2. Precipitation gage

A discussion by Dr. J. E. Church questions the possible freezing of storage batteries, and solutions to the cold weather problem.

Some observations on snow conditions reported from New England are included. A dictionary list of acceptable snow surface conditions are listed and definitions are shown.

A classification of snow and crust conditions containing 14 items and definitions is presented. The descriptions are based on reports obtained from stations with more than 4 inches of snow. The snow depth is measured regularly at the same fixed point in a field unaffected by drifts. Soft, dry snow include fluffy, powdery, new, and heavy types.

Spring snow conditions are described as granular and frozen granular. Crust conditions are referred to as glazed, breakable, wind crust, common crust and icy crust. Some observations on snow conditions reported from New England are included. A dictionary list of acceptable snow surface conditions are listed and definitions are shown.

Weston Snow Conference Bibliography

The classification of snow for winter sports have definite bearing on the type of skiing available to winter sports areas. A reporting system is being developed with information being sent to metropolitan winter sports areas for release by press and radio. A nomenclature of types of snow surface: fluffy, powder, new, glazed, wet, sticky, or slushy; hard crust or breakable crust, granular or spring conditions. These types are listed on a form for sending and receiving for uniformity in editing for release. Some attempts are made to standardize the terms for use in the East and New England winter sports areas. In the Alps, scientists, government, and mountain clubs have consistently advocated and fostered the education of skiers and climbers in the matters of rational snow-craft as a means to protection of life and enjoyment of skiing at winter sports areas. In view of the rapid growth of winter sports in the west it is advisable that some standard nomenclature of terms be adopted.

A classification of snow for winter sports have definite bearing on the type of skiing available to winter sports areas. A reporting system is being developed with information being sent to metropolitan winter sports areas for release by press and radio. A nomenclature of types of snow surface: fluffy, powder, new, glazed, wet, sticky, or slushy; hard crust or breakable crust, granular or spring conditions. These types are listed on a form for sending and receiving for uniformity in editing for release. Some attempts are made to standardize the terms for use in the East and New England winter sports areas. In the Alps, scientists, government, and mountain clubs have consistently advocated and fostered the education of skiers and climbers in the matters of rational snow-craft as a means to protection of life and enjoyment of skiing at winter sports areas. In view of the rapid growth of winter sports in the west it is advisable that some standard nomenclature of terms be adopted.
Winter sports snow conditions terminology has become confused by colloquialisms, terms vary with the number of reports. An attempt is made by creating a symposium, bringing together reporters and knowledgeable ski instructors and experts to set up a set of terms to be used and definitions. Such a listing is exhibited. In the Western United States some 2,000,000 people are taking advantage of the winter sports radio broadcasts and newspaper releases. With the cooperation of the National Parks, U. S. Forest Service, State Parks, and many other companies and private ski tower operators, the reporting program to this ever-growing business is progressing.

A report on a reconnaissance of the possibilities of developing a winter sports ski area in the Sierra just west and south of Mt. Rose and sloping into the Lake Tahoe Basin above Crystal Bay on the north east corner of this lake. Observations were made by two skiers who spent the better part of one winter traveling over the area, cataloguing the snow conditions, depths, temperatures, wind and possible ski trails. Summer exploration indicated that although the area is somewhat isolated the possibility of easy access roads would open up the area to year round activities. The close proximity to Reno, Nevada; Truckee, California and the Lake Tahoe resort area would seem to make the area worth while considering.

*Soil Conservation Service, Berkeley, California

*Civil Engineer, Reno, Nevada
A progress report on a new Snow Survey and Water Supply Forecasting Procedure Manual, under preparation and to be published by the Department of Agriculture as one of their bulletins. The manual is described and the essential needs of water supply forecasts from snow surveys are enumerated. The care of snow sampling equipment and its use in the field are covered together with field office procedures, improvements and maintenance of snow courses. Procedures for preparing historical data for forecast analysis and winter travel, by skis or snowshoes, safeguards and suggestions as to stop-over cabins and stored supplies, all these items are covered and many more. Contributions have been included and edited from all available authorities in snow surveying.

Sketches of the manual are described for removing dents from samplers, shellacking, keeping threads cleared, sharpening and/or changing the cutter, and cleaning the tubes. Precise step-by-step instructions are given for making and recording a sampling including sources and detection of errors and after-care of samplers. It is suggested that winter travel is facilitated by using adequate foot gear, recommended clothing, dark glasses, and minor items for emergencies. Shelter cabins should be stocked each year before winter with an adequate supply of food and fuel. A sample grub list is given.

Improvements in the methods of forecasting streamflow from snow surveys are reviewed. Data for Lasuille Creek, Nevada in 1938 are used to compare three different systems of obtaining average water content of the snow cover. Boardman's Percent Normal System, and the direct curve method of computing the average water content are illustrated. The direct method retains all the desirable features of the percentage system yet eliminates computing normals and percentages. Discussions are presented by Fred H. Paget, J. E. Phillips, James C. Marr, and R. D. Goodridge.

With the completion of Boulder Dam and the filling of Lake Mead to maximum capacity, the problem of forecasting the inflow from the Colorado River became evident. Studies have been under way for several years gathering data and analysis work for developing a suitable formula to meet the complex problems involved in operating this huge multi-purpose project. Precipitation gage networks over the main and tributary basins had been intensified, snow survey courses established in the high elevations, evaporation and other pertinent meteorological data measuring stations been established in anticipation of the problem. Trial equations will have to be tested with actual practice to clear the deadwood and introduce new factors before a satisfactory solution is solved.
Anodyzing duraluminum equipment hardens and smooths the surfaces, prevents oxidation and discoloration of hands and clothing, and increases the durability of the equipment. Anodyzing is recommended for snow samplers. The smoother surfaces permit the snow cores to slip through the tube easier, and less wear is exerted on the threads of the couplings. It is suggested that the cost of anodyzing may outweigh the advantages.

The accuracy of the Mount Rose spring balance can be improved by providing a spring to hold the rack in close contact with the rotating pinion controlling the indicator, and by making the rack thick and of durable metal. A small swivel connecting the top of each spring to the head frame, would facilitate making necessary adjustments. The snowpack of 1937-38 was typical in that accumulation began late and piled up rapidly. Metamorphism converted the upper layers to a coarse grainy snow, but the lower layers remained fluffy ("Corky Snow"). The condition made sampling difficult. The problem was solved by allowing the tube to penetrate by gravity with minimum rotation. The method was called "Tickling the tube through" fluffy snow.

A bakelite, commercially known as Risch-Rasch, has been used as a running base on skis. Risch-Rasch has proven equally effective in preventing clogging when used on snow samplers. The bakelite, thinned with equal parts of acetone, can be applied by dipping or spraying. Three to four applications at 12 hour intervals are sufficient to last a snow sampler several years. No attempt has been made to remove the bakelite, but it is believed that the usual commercial solvent, Fortus might injure the duraluminum sampler. This material was tried on one sampler tube and no sticking of various types of snow or clogging was noticed.
The solution keeps the gage from freezing and evaporation is prevented by the solution of calcium chloride and water at 33.4% by weight. The solution keeps the gage from freezing and evaporation is prevented by the solution of calcium chloride and water at 33.4% by weight. The solution keeps the gage from freezing and evaporation is prevented by the solution of calcium chloride and water at 33.4% by weight.
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SKIING IN SOUTHERN CALIFORNIA: ESSENTIAL EQUIPMENT

TONGQUIST, R. C.*

Proc. TAGU 1939 Part I 83-84: WISSC at Los Angeles, Calif. December 16-17, 1938

Winter sports areas in Southern California in close proximity to Los Angeles are described. The area near San Gorgonio where elevations of 11,000 are accessible is particularly adapted to mountain ski trips with very good slopes and enchanting scenery. Types of equipment are described and explained. Snow conditions experienced in a trip through the area in the winter are described. Plans for future development of the areas and ski lifts are mentioned.

Discussion by George A. Lewis relates incidents in cross country travel on skis and recommends beeswax for dry snow and a resin wax for wet snow. Types and make or trade name are quite a controversial problem and likely to be of a personal decision. However, ski climbers are almost a necessity to save energy when a long up hill climb is involved along the trail.

Chief, River & Flood Div., U.S. Weather Bureau, Washington, D.C. @ Abstract

*Engineer, USDI, Park Service, Regional Office, San Francisco, California

OUTLINE OF WEATHER BUREAU NORTHEAST STATES WINTER SPORTS SERVICE

BERNARD, MERRILL*


1 Location Map; 9 Tables

An outline is presented for developing a winter sports reporting service by the Weather Bureau. Snow conditions are to be gathered from seven districts, assembled and reported by radio, telegraph, and news papers throughout the Northeast states. Outlets will also be from the District Weather Bureau offices as indicated on the location map. A check list reporting form is shown and a revised nomenclature of snow conditions with a coding procedure for economy in telegram and teletype messages. Samples of summary snow sports bulletins together with weather forecasts for the area involved are illustrated and shown.

Discussion by several authorities of the Western states is included.

*Engr., Dept. of Water & Power, City of Los Angeles, Calif.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

C. Catalogue No.

WSC No. 74-39

WASHINGTON, D. C. *

Proc. TAGU 1939 Part I 93-94: WISSC at Los Angeles, Calif. December 16-17, 1938

A report of the winter sports activities carried on under the supervision of the National Park Service, within the several National Parks of California and Oregon. These activities have been carried on for the past five years with amazing rapidity in the numbers of people taking part in skiing and ice skating. New areas are being opened with good success for the concessionaires. Snow conditions are reported by the Park Service to outside interests. Snow removal equipment is being used to open roads that otherwise would remain snow bound until spring crowds became evident.

Engineer, Missouri River Division, Corps Army Engineers, Kansas City, Missouri

*Abstract

A LIMIT OF PRACTICABLE USEFULNESS OF SNOW SURVEYS FOR FORECASTING RUNOFF AT FT. PECK, MONTANA

FREEMAN, D. B.*


2 Graphs

The prediction of the Missouri River flowing into Fort Peck Reservoir presents many problems where the reservoir is 225 miles east of the nearest snow survey course. The river traverses an entirely different environment from the headwater basins. Many unmeasured diversions are encountered as well as unmeasured tributary streams. Precipitation data appeared to show a better relation to percent normal than the snow survey data, probably due to the remote location of the reservoir and the large area in the rain fall altitudes. In order to produce a more reliable forecast from snow surveys a longer record of data is needed and considerable study will be necessary.

*Engineer, USDI, Park Service, Regional Office, San Francisco, California

*Abstract

ENGINER, MISSOURI RIVER DIVISION, CORPS ARMY ENGINEERS, KANSAS CITY, MISSOURI

@ Abstract

AUTHOR INDEX

I. Bernard, M.

INDEX

1. Winter sports -reporting service

SUBJECT INDEX

1. Winter sports -equipment

AUTHOR INDEX

I. Youngquist, R. C.

INDEX

1. Winter sports -reporting service

SUBJECT INDEX

1. Winter sports -nomenclature

AUTHOR INDEX

I. Waterhouse, R.D.

INDEX

1. Winter sports -areas

SUBJECT INDEX

1. Winter sports -forecasting

AUTHOR INDEX

I. Freeman, D. B.

INDEX

1. Winter supply -forecasting

SUBJECT INDEX

1. Water supply -precipitation data

AUTHOR INDEX

I. Freeman, D. B.
The values of snow surveys are shown to have a very high correlation to runoff when used relatively close to the source. This data is most useful in predicting forest fire hazards and how serious the fire potential will be during the late summer and fall months. The U. S. Forest Service is deeply involved in cooperation with other agencies in the field work of snow survey measurements. The data collected is being found very useful for other purposes than forecasting the probable streamflow.

*Senior Silviculturist, U.S. Forest Service, Missoula, Mont.

The relation between snow survey data and runoff from small watersheds is difficult to assess especially where part of the watershed is in the rainfall altitudes. Very frequent measurements of snow courses are necessary together with rain gage measurements and other meteorological and soil moisture data is required to fill in the desired information necessary when working with small watersheds. No information is given as to the size of the so called small watershed, or what altitudes are involved.

*Irrigation Engr., Montana Exp. Station, Bozeman, Mont.

The effect of fall precipitation as a soil priming factor in predicting irrigation water supply from April first snow survey data is presented. Graphical analysis are illustrated and discussed. Snow survey data at nine courses, and precipitation data for April, May, and October at Moran, Wyoming are tabulated and used in the analysis. Forecasts are determined from the graphs illustrated. Discussion by H. T. Gisborn, Lynn Crandle, O. W. Monson and J. E. Church are included.

*Irrigation Engineer, Bureau Agr. Engrs., Boise, Idaho
Analysis of snow cover and runoff in Upper Snake, Upper Yellowstone and Swift current watersheds

Monson, O. W.*

4 Tables; 10 Graphs

Snow survey water content measurements are used as a basis for forecasting irrigation water supply, together with other factors closely allied with snow melt. Four factors are listed, (1) rainfall during the snow fall period, (2) runoff during the fall months before snow fall, contributing to soil priming and ground water recharge, (3) deep percolation losses, (4) evaporation and transpiration losses and sublimation of the snow pack. Measurable factors are by correlation coefficient values. A regression equation is developed and the least squares line is drawn through the plotted points on the graphs as a means of visual inspection. A discussion of the results of the study is included in the text of the paper.

A table of data is exhibited and plotted graphs illustrate the runoff in percent of normal flow. Statistical procedures are used.

Discussion by R. E. Horton are included.

I. Monson, O. W.

**Western Snow Conference Bibliography**

Western Snow Conference Catalogue No.

**Relation of Fall Streamflow to Spring Runoff**

Eagle, H. C.*

Proc. TAGU 1939 Part I 117-121: WISSC at Spokane, Wash. Dec. 28, 1938 1 Table; 2 Graphs

Precipitation measurements and snow survey data together with fall runoff (mean October, as an index to soil priming and ground water conditions) are used in water supply forecasting procedures, for the Yellowstone River, Montana. Data exhibited in the table form the basis for a regression equation. Results of actual and forecasted values are shown on a graph. October runoff is weighted by cut-and-try procedure, which reduces the forecast error. Winter and spring precipitation are also adjusted. These adjustments are shown in tabulations and are also plotted on a histogram to show the effects of the adjustments.

I. Eagle, H. C.

Western Snow Conference Catalogue No.

**Construction of Snow Survey Shelter Cabins**

Work, R. A.* and Parshall, Ralph L.*

Proc. TAGU 1939 Part I 125-135: WISSC at Spokane, Wash. Dec. 28, 1938 1 Table; 4 Drawings; 10 Photos

The details of construction of a Snow Surveyors Shelter Cabin is presented. The need for such a structure is explained, featuring safety to men from storm or bitter cold weather fatigue. A food supply is stored in compartments to prevent freezing, sleeping bags and utensils are also available. Dimensions and roof structure are shown taking into consideration snow loads. A Santa Claus chimney is also constructed above the house to allow for access if the cabin is completely buried. This does away with much shoveling of snow at the end of a hard day's travel. Also a lower access is made available through the attic on the gable end. A log cabin is shown for use where no access road is available in the dry season, as well as a frame construction cabin. All miscellaneous parts are pre-cut and marked for assembly. Cost figures for 1927-39 are included and a list of materials. Discussion by Dr. J. E. Church is included.

I. Work, R. A.
II. Parshall, R. L.
III. Church, Dr. J.

Western Snow Conference Catalogue No.

**Chief Hydraulic Engineer, Water Rights Division, Dept. Lands, Victoria, British Columbia**

R. C.


Abstract

Western Snow Conference Catalogue No.

*Chief Hydraulic Engineer, Water Rights Division, Dept. Lands, Victoria, British Columbia*

Abstract

Western Snow Conference Catalogue No.

**Jr. Hydraulic Engineer, U.S.G.S., Helena, Montana**

U. S. Bureau of Agr. Engineers, Medford, Oregon

Abstract
A comparison was made of the relative accuracy of the Mt. Rose spring balance as improved by the Leupold, Vopel and Company of Portland, Oregon and the Chatillon type with iso-elastic springs. The improved balance was within the limits of observational error of ordinary field work. It is believed that the accuracy of the simple springs can be further improved. The graduations were not tested for accuracy of machining.

**Formation of Snow Crystals in the Mountains and in the Laboratory in Japan**

Nakaya, Ukitiro


A Movie Sound Track

Snowflake crystallization is studied and classified with respect to the climatology of the various zones of atmosphere through which they pass in reaching the earth's surface. The procedures used in handling these fragile crystals are described. Temperature, water vapor and atmospheric conditions create different crystal types. A duplication of nature's process is constructed in the laboratory in Northern Japan where natural and synthetic crystals are photographed. By a study of snow crystals the character of the upper air can be predicted. A time lapse picture showing in color, the process of snow crystal formation, was shown in beautiful color by microphotography.

**Comparison of Forecast and Actual Results, 1939**

Paget, Fred H.


A round table discussion of water supply forecasts made in 1939 is presented in 10 short papers. Forecast volumes are compared with actual streamflow figures as indicated in the several tables, for the following sections involved:

- Nevada - Eastern slope Sierra, H. F. Boardman & George Devor
- Central Nevada - Humboldt Basin, Carl Elges
- California - Western slope Sierra, Fred Paget
- Owens River, James E. Jones
- Huntington, Florence, Shaver Lake, W. Lang
- Utah - Cooperative snow survey, George D. Clyde
- Colorado - East slope Cont. Divide, Ralph L. Parshall
- Colorado River - Lake Mead, D. B. Freeman
- Columbia River - B. C. Canada, R. C. Farrow
- Powell & Fraser Rivers, Canada, B. C., R. C. Farrow

**Some Handy Kinks for Field Men**

Cowgill, Phillip S.*


Practical field experiences are related, especially for coating the duraluminum sampling tubes with orange shellac. Satisfactory results are obtained except where the coating is chipped off due to rough handling in cold weather. Procedures for coating the tubes inside and out are explained. Improvements made on the sampling tube carrying case, to include two straps, one for each shoulder to hold the case perpendicular in the center of the back, thus leaving both arms free for poling on skis, and maintaining better balance. Rubberized gloves are found to be a great aid when handling the sampling tubes, thus keeping the hands dry as well as the tubes, thus preventing the tube from becoming warm by handling with bare hands. This prevents water on the tube that freezes to the tubes and causes them to stick to the snow, inside and out. A question and answer session was included.

*Physicist, Hokkaido Imperial University, Sapporo, Japan

*Electrical Engineer, Sierra Pacific Power Co., Reno, Nevada

*Irrigation Engineer, Bureau Agr. Engrs., Ft. Collins, Colorado
Modern stations are equipped with batteries of 3-5 shielded storage precipitation gages. The gages, including shields and support stands, are of all metal construction and may be equipped with a clock mechanism capable of running 30 days without attendance and furnishing a record of precipitation, rain or snowfall. The gages are charged with a solution of calcium chloride with a film of oil to prevent freezing or evaporation. The gage stands may be as high as 20 ft. depending on the probable amount of snow depth at the location. A statistical analysis of the records of 47 stations over a 2 year period indicate that the batteries of gages may be reduced from 3 to 3 without loss of accuracy. A classification of hydrological stations is given and mountain snowfall stations are mapped. Detail construction of the metal stands and shields are shown in a sketch.

*Chief, Div. of Irrigation, SCS, Berkeley, California

**Hydrologic Supervisor, U.S.W.B., Salt Lake City, Utah

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

PROGRESS REPORT ON MOUNTAIN SNOWFALL PROGRAM OF THE WEATHER BUREAU

BERNARD, MERRILL* and COOD, ASHTON R.**


1 Location Map; 9 Photos; 4 Graphs

1. Shielded storage gages
2. Precipitation gages

AUTHOR INDEX
I. Bernard, IV. Codd, A. R.

1 Location Map; 9 Photos; 4 Graphs

The progress made by the Soil Conservation Service, Division of Irrigation in the field of snow surveys and irrigation water supply forecasting since its inception of the program authorized by Congress in 1935 is reviewed. With the cooperation of Dr. J. B. Church and Professor George D. Clyde the west-wide program in 1940 includes reports from 753 snow survey courses in the major river basins in the West. Although several areas are undeveloped, time will solve the many problems encountered. The cooperation of many Federal, State and private agencies have made possible a rapid expansion. Monthly snow survey bulletins and water forecast data are being duplicated and mailed to thousands of offices from January to May. This information is finding its way into the hands of engineers for better irrigation practices and water storage operations.

*Head, Div. of Irrigation, SCS, Berkeley, California

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

PROBLEMS OF THE DIVISION OF IRRIGATION IN FORECASTING WATER SUPPLIES

MCLAUGHLIN, WALTER W.*


The intensive cooperative program in snow activities of the National Park Service in Region IV of that agency is expanding rapidly. The several National Parks in California, Oregon and Washington are taking an active part in the field work of the West-Wide Snow Survey Program. Rangers are combining this work with their regular Park Patrol trips during the winter months. Aside from personnel the Park Service is furnishing shelter cabins and short-wave communications. With the ever increasing demands of winter sports information a program of disseminating snow conditions to newspapers and radio stations has developed into a complicated bit of business to the National Park Service, requiring training of personnel in the supervision of these activities for safety and economic operations.

*Engineer, Region IV National Park Serv., San Francisco, Calif.

**Engineer, Union Water Power Co., Lewiston, Maine

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

A QUANTITATIVE FORECAST SYSTEM FOR POWER-AND FLOOD-WARNING IN THE ANDROSCOGGIN RIVER BASIN, MAINE

BEAN, PAUL L.* and THOMAS, PHILLIP W.**


2 Location Maps; 1 Graph

Snow survey techniques in the Androscoggin Valley are described. Comparison of the depth of snow curves with the water content of snow curves gives a specific gravity of the snow cover at any given date. These data are used to estimate the ability of the snow cover to absorb rain. The characteristics of the snow cover from day to day as influenced by the temperature are indicated by a set of curves which are utilized in flood estimation. The forecasting of the 1936 flood through snow surveys is described.

In discussion, Mr. Phillip W. Thomas emphasizes the Quantitative Forecast System as applied to the power development by the Rumford Falls Power Co., as well as flood warnings. Illustrated by a key curve of elevation and precipitation data and tables of data on aspect of stations and elevation and snow survey measurements of water content. A location map with contours indicates the area involved.

*Engineer, Region IV National Park Serv., San Francisco, Calif.

**Engineer, Rumford Falls Power Co., Rumford Falls, Maine

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SNOW ACTIVITIES - NATIONAL PARK SERVICE

WATERHOUSE, R. D.*


1. Winter sports - areas reporting

AUTHOR INDEX
I. Waterhouse, R. D.
The three popular methods of forecasting streamflow by using snow survey data are discussed and evaluated. The percentage method, the area method, and the quantitative method. Although the quantitative method, which is largely empirical, produces satisfactory results for the Mokelumne River basin in California, when used for predicting streamflow for municipal supply for the East San Francisco Bay Municipal Water District. Area elevation data are used together with snow water content, precipitation data in the lower elevations. It is demonstrated that the quantitative method of forecasting runoff from snow surveys is practical, and future studies will point the way to improving the technique so that accurate results can be obtained over a wide range of climatological conditions. Formula, tables and graphical representations are shown, as well as forecast comparisons with actual flow.
A hydrologic history of the Humboldt River in Central Nevada is presented. The geophysical features that cause so many discrepancies in the climatic changes and resulting difficulties in forecasting streamflow from the area are discussed. Mention is made of the 1910 flood and an attempt at analysing the causes from fragmentary hearsay data is given. Progress is reported in establishing climatological stations and some 31 snow courses that will aid materially in the future to forecast the flow of the stream at the Paradise gaging station. Irrigation diversions are being measured.

*A Nevada Agr. Exp. Sta., Univ. of Nevada, Reno, Nevada

SUBJECT INDEX
1. Water supply forecasting

AUTHOR INDEX
I. Elges, C.
A one-sixth scale model of a deep-snow shelter cabin was prepared for snow load tests. An estimated 12.5 tons of snow was seen on an actual shelter cabin roof. The snow covered the cabin completely and is not known whether the full load was borne by the roof or whether part of the mass was supported by cohesive action of the lower snow strata. It was suggested that a removable roof be used for snow load tests.

The Tucker motor-sled was demonstrated on the slopes of Mt. Rose June 19-22, 1940. The motor-sled made 3 runs. It is driven by a helical thread wound on a revolving drum, and is powered by a 15 hp air-cooled gasoline engine. Total weight is 500 lbs. The sled showed a tendency to slip sideways on a 12% grade. The drum dug the snow away from itself when breaking through hard snow crust, or encountering soft snow. The machine is light, built sturdy, has a cruising speed of 5 mi/hr. and can carry 2 men up a 30-40% grade without great effort. More weight caused the motor-sled to break through the snow crust and stall. It is questioned that improved performance in soft snow.

The Tucker snow-sled is shown to have been a success in the field. The sled shows initial load of 3 lb. (47.1 inches water was applied. The index set to zero, and successive 1 lb. loads were added without unloading the springs. All readings showed less than 15% error in test No. 1. To begin test No. 2, a 2.31 lb. (36.3) inches water load was added initially and successive weights added. The largest error was 1.32%. The load was removed after each scale reading in test No. 3, and the index adjusted to zero before the next load was applied. The largest error was less than 1%. The sled should be re-designed and a Franklin air cooled motor of 80 hp is being installed at no addition in weight.

In discussion by the John Chatillon & Sons Co., of New York, three models of snow survey scales are pictured and a discussion in text form is shown with a calibration chart.
Cans of aqueous solution of CaCl₂ of various concentrations were placed in a low temperature room at temperatures varying from -6°F to -30°F. The results confirm data in The Chemical Engineers Handbook by John H. Perry (1934). An 8-in. gage charged to protect an expected 10 inches of precipitation to -20°F will require an initial charge of 26.9 lb. commercial CaCl₂ and 35.8 lb. water. The storage precipitation gage is not recommended if the gage must be unattended for a month or more at below 0°F temperatures. Freezing tests indicate that CaCl₂ solution is superior to NaCl solution in precipitation gages. The brine is used to melt the snow as it falls into the gage and to prevent damage to the gage by freezing water. A eutectic freezing point of -60°F results with a solution of about 30% CaCl₂ by weight. A 23% NaCl solution forms salt crystals at -57°F and becomes solid at -8°F. Precipitation gages in which CaCl₂ is used are usually charged with a 33.4% solution (1 qt. of salt to 1 qt. of water and 4 oz. SAE.10) after 2.5 in. of precipitation has been caught, another quart of salt is added to strengthen the solution. The film of oil prevents evaporation and overcomes the deliquescent effect of the salt. Tests were made of various percentages of strength solutions in a dry-ice chamber. NaCl solutions and a sample of water from the Great Salt Lake turned solid at -8°F. However, the 33.4% solution of CaCl₂ began to become slushy like frazil ice at a -55°F, and remained in this semi-liquid solution for two hours at a -65°F. Thus assuring no damage to the gages.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

PROBLEMS OF USING CALCIUM CHLORIDE IN PRECIPITATION GAGES
ELGES, CARL*
1 Graph; 2 Tables

Cans of aqueous solution of CaCl₂ of various concentrations were placed in a low temperature room at temperatures varying from -6°F to -30°F. The results confirm data in The Chemical Engineers Handbook by John H. Perry (1934). An 8-in. gage charged to protect an expected 10 inches of precipitation to -20°F will require an initial charge of 26.9 lb. commercial CaCl₂ and 35.8 lb. water. The storage precipitation gage is not recommended if the gage must be unattended for a month or more at below 0°F temperatures. Freezing tests indicate that CaCl₂ solution is superior to NaCl solution in precipitation gages. The brine is used to melt the snow as it falls into the gage and to prevent damage to the gage by freezing water. A eutectic freezing point of -60°F results with a solution of about 30% CaCl₂ by weight. A 23% NaCl solution forms salt crystals at -57°F and becomes solid at -8°F. Precipitation gages in which CaCl₂ is used are usually charged with a 33.4% solution (1 qt. of salt to 1 qt. of water and 4 oz. SAE.10) after 2.5 in. of precipitation has been caught, another quart of salt is added to strengthen the solution. The film of oil prevents evaporation and overcomes the deliquescent effect of the salt. Tests were made of various percentages of strength solutions in a dry-ice chamber. NaCl solutions and a sample of water from the Great Salt Lake turned solid at -8°F. However, the 33.4% solution of CaCl₂ began to become slushy like frazil ice at a -55°F, and remained in this semi-liquid solution for two hours at a -65°F. Thus assuring no damage to the gages.

*C. R. Perry, Nevada Agr. Expt. Sta., Reno, Nevada

WESTERN SNOW CONFERENCE BIBLIOGRAPHY
CALCIUM CHLORIDE SOLUTIONS IN THE OPERATION OF PRECIPITATION GAGES
Codd, Ashton R.*
2 Graphs

Freezing tests indicate that CaCl₂ solution is superior to NaCl solution in precipitation gages. The brine is used to melt the snow as it falls into the gage and to prevent damage to the gage by freezing water. A eutectic freezing point of -60°F results with a solution of about 30% CaCl₂ by weight. A 23% NaCl solution forms salt crystals at -57°F and becomes solid at -8°F. Precipitation gages in which CaCl₂ is used are usually charged with a 33.4% solution (1 qt. of salt to 1 qt. of water and 4 oz. SAE.10) after 2.5 in. of precipitation has been caught, another quart of salt is added to strengthen the solution. The film of oil prevents evaporation and overcomes the deliquescent effect of the salt. Tests were made of various percentages of strength solutions in a dry-ice chamber. NaCl solutions and a sample of water from the Great Salt Lake turned solid at -8°F. However, the 33.4% solution of CaCl₂ began to become slushy like frazil ice at a -55°F, and remained in this semi-liquid solution for two hours at a -65°F. Thus assuring no damage to the gages.

*Statistician, Nevada Agr. Expt. Sta., Reno, Nevada

WESTERN SNOW CONFERENCE BIBLIOGRAPHY
SNOW SAMPLING EQUIPMENT FOR GRANULAR AND CRUSTED SNOW IN NEW ENGLAND
Bean, Paul W.* and Bendsen, Frederick A.**
A system of 50 permanent snow stations was developed in 1937 in the Androscoggin Valley in New Hampshire and Maine for measuring snow cover to predict the rate and amount of spring runoff. Three or four samples of snow are obtained in a snow sampler with a 3-inch inside diameter and a cutter 2.65 inches diameter. The samples are weighed and the water content recorded. The size and shape of the snow crystals are determined with a microscope. The thickness of the ice on the ground and condition of ground are recorded. The snow temperature at 10 inches depth is measured. The 50 inch snow sampler used in these tests has been found superior to the Mount Rose Sampler for coarse New England snow. Discussion by Dr. J. E. Church and Kenneth L. Roberts is included.

*Engineers, Union Water Power Co., Lewiston, Maine
**Engineers, Union Water Power Co., Lewiston, Maine
The rapid growth of winter sports, especially skiing within National Parks and National Forest areas has demanded an increase of accessible roads during the winter season, are described. Due to the great number of beginners in these sports the rules of the road are spelled out in detail as well as the rules for skiing on the crowded slopes and ski towns. Largely simple ski etiquette is involved in ski safety.

Eight items are discussed and listed.

1) Use your own equipment, do not borrow on the hill.
2) The fast skier has the right of way, beginners should stay on the bunny slopes.
3) Fill in your 'Sits Marks', like replacing your divots.
4) When cross-country skiing always travel in pairs.
5) Avoid stepping on another's skis.
6) When skiing on trails stay on marked routes, no short cuts.
7) Respect the rules, regulations and property, building and equipment of the establishment operating the area.
8) Ski safely, ski under control, ski within your limits.

Eight trips were made to Snoqualmie Pass, 63 miles east of Seattle, between Dec. 27 and April 4, 1940. Profile cuts were made in the snow, temperatures were taken at various depths, and dye solutions were poured over the snow to test permeability. Snowfall was normal during the 1939-40 winter. Two cold spells occurred and these produced impervious crusts. No important crusts developed after January. A graph of the various crust layers and their movement during the winter and melt season is shown and described in the text.
A method of predicting floods originating in mountains with deep snow covers is described. Snow precipitation, rain, snow cover and snow-melt data are used to develop a synthetic hydrograph for each elevation of the snow line. The maximum flood hydrograph and the estimated location of the snow wedge are used for forecasting purposes. Flood data on several California, Oregon and Washington river basins are discussed.

The sources of maximum floods are placed near the snowline rather than in the upper reaches of the watershed where the area is smaller, temperature lower, and the body of snow deeper. The effects of the relative heaviness of the snow-cover on the windward and leeward sides of the mountains, the relation of temperature to snow-melt rates, the effect of rainfall on snow and snow density are factors producing floods. An analysis of temperature, snow on the ground, precipitation and flood peaks was made on four floods in the Tahoe-Truckee Basin during 1907, 1928, 1937 and 1940, and in the Sacramento and Humboldt Basins. Hydrographs of the various flood flows are shown, and included are the various factors involved. Snow data at various elevations in the basins is also tabulated. Several discussions are also included.
A recommendation of a procedure for reporting forecast accuracy of streamflow forecasts in terms of the mean flow as measured by the U.S.G.S. Surface Water Branch. A schedule of arithmetic values with corresponding word descriptions is advanced.

**Percent accuracy**

<table>
<thead>
<tr>
<th>Percent</th>
<th>Word Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>Unsatisfactory</td>
</tr>
<tr>
<td>5%</td>
<td>Poor</td>
</tr>
<tr>
<td>10 to 20%</td>
<td>Fair</td>
</tr>
<tr>
<td>20 to 30%</td>
<td>Good</td>
</tr>
<tr>
<td>More than 30%</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

General consensus of this schedule was discussed by members of various agencies.

Large quantities of frazil ice in shallow streams increase viscosity, decrease velocity, and increase the stage of the stream. High banks accommodate the increased stream stage by allowing the rising frazil ice to form a bridge under which normal flow continues. Overflow occurs where stream banks are too low to contain the river stage. Low spots are filled with ice; the banks are built up with deposited slush ice, and a new river is formed. The ice-gorging and overflow of the Madison River was studied to ascertain whether the operations of the Hebgen and Madison reservoirs were responsible for the overflow in the 1916-17 season. An analysis of weather conditions for that period indicated that the overflow was caused by a sustained cold spell and not by reservoir operations. Photographs illustrate the ice blocked Madison River, overflowing farm land. Ice forming factors are shown by graphs.
The various hydrological factors pertaining to the White River basin, one of the coastal streams in western Washington are analyzed for the purpose of planning the operation of Mud Mountain Dam, a flood control project. Access to the basin is limited to one road up the main valley and over Cayuse and Chinook Passes to the east. Access to tributary streams is by foot and difficult traveling. A network of meteorological stations was established. Snow survey courses were laid out to augment the data for possible flash flood conditions. Data and curves are exhibited and a plan of operation discussed.

A formal discussion with data and alternate plans are presented by J. C. Stevens and remarks by F. M. Veatch.
Snowmelt, rainfall and meteorological conditions are studied with relation to abnormally high stream flows. Previous floods caused by various combinations of these factors are reviewed and references to other studies involving snowmelt problems are quoted. The storage effect of a snowpack on rainfall in various quantities of snow, rain, infiltration rates, temperatures effecting flood producing potentials are cited. The thermodynamics of snowmelt are included in the development of formula and graphical solution, all shown and discussed in the paper.

*Assoc. Engineer, U.S.C.E., Los Angeles, Calif.

A discussion of the objections to the use of the ARITHMETICAL average or mean as a parameter to express the NORMAL climatological values; as Normal rainfall, Normal temperature or the Percent Normal. The NORMAL value should represent the most common value of a series with a probability of being equaled or exceeded approximately 50% of the time. The infallibility of this occurrence is illustrated in an array of tabulated data. It is suggested that another parameter be used to express the Normal values from a series; the median; the mode; the geometric mean; or the harmonic mean. It is further suggested that in speaking about the arithmetic average or mean that the term NORMAL not be used.

This matter became a Resolution to the Secretary of the Section of Hydrology of the American Geophysical Union for a nationwide acceptance.

*Hydraulic Engr. U.S.C.E., Portland, Oregon
A history of the Snow Survey Program in the State of California is presented. Details of the early cooperation with Dr. J. E. Church back in 1917 and progress of this work until a final beginning of a California State Cooperative Snow Survey Program in 1929, under the leadership of Harlowe M. Stafford. The establishment of snow survey courses in most of the major stream drainage basins was started and supplemented with precipitation stations in the lower altitudes, the collection of historical records was begun and analysis work for forecasting formulas was started. Fred H. Paget was assigned to this project in 1935. Mention is made of the West Wide Snow Survey and Water Forecast Program started by the Dept. of Agriculture in 1935.

Dr. J. E. Church in discussion lists the formation of Snow Survey Programs throughout the United States, chronologically beginning with Charles E. Mixer in 1900 through 1938.

A round table discussion of Water Supply Forecasts made in 1940 is presented in 9 short papers. Forecast volumes are compared with actual streamflow figures as indicated in the several tables, for the following sections involved:

California, Central Valley Streams
California, Owens River Basin
California, Huntington Lake, Big Creek
California, Klamath Basin
Nevada, Central Sierra, East slope
Nevada, Humboldt Basin
Idaho, Upper Columbia, U.S.A.
British Columbia, Kootenay, Okanagan
Oregon, Oregon Basins

Fred H. Paget
James E. Jones
W. A. Lang
L. Standish Hall
H. P. Boardman
George Devore
Leigh L. Stanford
Carl Elges
James C. Marr
S. H. Prane
R. A. Work
J. H. Ryan

*Engineer, Div. of Water Resources, Sacramento, Calif.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY
WHITHER SNOW SURVEYS?
CONKLING, HAROLD*
January 16-18, 1941

A history of the Snow Survey Program in the State of California is presented. Details of the early cooperation with Dr. J. E. Church back in 1917 and progress of this work until a final beginning of a California State Cooperative Snow Survey Program in 1929, under the leadership of Harlowe M. Stafford. The establishment of snow survey courses in most of the major stream drainage basins was started and supplemented with precipitation stations in the lower altitudes, the collection of historical records was begun and analysis work for forecasting formulas was started. Fred H. Paget was assigned to this project in 1935. Mention is made of the West Wide Snow Survey and Water Forecast Program started by the Dept. of Agriculture in 1935. Dr. J. E. Church in discussion lists the formation of Snow Survey Programs throughout the United States, chronologically beginning with Charles E. Mixer in 1900 through 1938.


WESTERN SNOW CONFERENCE BIBLIOGRAPHY
COMPARISON OF FORECASTS AND ACTUAL RESULTS, 1940
PAGET, FRED H. *
January 16-18, 1941

A round table discussion of Water Supply Forecasts made in 1940 is presented in 9 short papers. Forecast volumes are compared with actual streamflow figures as indicated in the several tables, for the following sections involved:

California, Central Valley Streams
California, Owens River Basin
California, Huntington Lake, Big Creek
California, Klamath Basin
Nevada, Central Sierra, East slope
Nevada, Humboldt Basin
Idaho, Upper Columbia, U.S.A.
British Columbia, Kootenay, Okanagan
Oregon, Oregon Basins

Fred H. Paget
James E. Jones
W. A. Lang
L. Standish Hall
H. P. Boardman
George Devore
Leigh L. Stanford
Carl Elges
James C. Marr
S. H. Prane
R. A. Work
J. H. Ryan

*Engineer, Div. of Water Resources, Sacramento, Calif.
An improved escapement for recording clocks is described and pictured. This piece of intricate equipment is designed for field replacement by the hydrographer when visiting stream or other measuring devices in remote places. The new escapement is mounted on a solid brass plate to insert in the standard clocks. On this plate is mounted the balance wheel with the Elinvar hair spring and its regulating lever, the double roller and shaft and escapement shaft. The base plate is keyed into position and held in place by counter sunk oil reservoirs; all built to precision requirements. The base plate is mounted the balance wheel with the Elinvar hair spring and its regulating lever, the double roller and shaft and escapement shaft. The base plate is keyed into position and held in place by counter sunk oil reservoirs; all built to precision requirements.

A carrying case to carry balance, tape, sampler tubes, cleaning hook, etc., has been designed in 2 units. The second section, can be detached and left if exceptionally long sampler will not be needed. Wide web shoulder straps make for easy carrying and a belt holds the pack in position, and keeps the case from flying over the head in a bad fall, a safety feature.

A Mount Rose type sampler with a cutter of inside diameter 1.485 inches was compared in field tests with a sampler having a cutter with inside diameter of 2.787 inches. The results of 32 samples with each set gave a coefficient of variation of 7.82% for the Mt. Rose sampler and 9.24% for the larger sampler. Additional 15 measurements using the gram scales gave lower values but similar variations. The Mt. Rose type of snow sampler proved more practical and as accurate as the larger sampler, under the conditions of the tests. Comparative data are exhibited in tables.
The relation between streamflow and water content of the snowpack is affected by many factors, such as topography, temperature, wind, and soil moisture conditions at freezing. Forecasts based on snow water content have varied as much as 24% from actual flow since 1935. It is assumed that various responsible components can be evaluated within limits and that corrections may be determined to permit an accurate forecast of the seasonal (April - July or Sept.) probable water supply. The photographic method of measuring snow (See WSC 41-37) and relating to streamflow to areas measured by a grid over photos has had promising results. The record is too limited at this time for final conclusions.

Operation curves for Lake Tahoe (Calif.) are given and discussed. Construction of the curves is based on recorded snowmelt runoff, while their use is based on snow survey predictions of runoff. The hypotetical operation of Lake Tahoe for flood control and conservation, using snowmelt runoff versus release curves, is illustrated. As the season progresses and forecasts are more reliable the plan of operation can always be changed, probably up through late April or on the May first surveys.
The problem of utilizing the natural storage of water by snow fields is compared to artificial storage by dams. The amount of water available must be determined and the rate of release or withdrawal must be evaluated. Observational facilities should be provided to determine the amount of water in the snow pack and to study the melting processes. Heat transfer by convection and radiation between the snow surface and the overlying atmosphere is considered an important factor. An organization chart for future research studies is exhibited.
FORECASTING THE DATE OF THE DECLINE OF THE CARSON RIVERS ON THE BASIS OF THE SEASONAL PERCENTAGE OF THE CONTRIBUTING SNOW COVER

KRUMMES, PETER*

1 Table; 1 Graph

Streamflow decline to 200 sec. ft. was predicted as an aid to farmers by comparison with records of previous years during which the April snow cover was approximately the same. The 1939 flow declined to 200 sec. ft., 5 days after the forecast date. The 1940 streamflow was 200 sec. ft., 10 days before the forecast date, probably due to abnormally high May temperatures. In discussion H. P. Boardman proposes a graphical solution to this problem by using the East Carson River as an example.

*Alpine Land and Reservoir Co., Gardnerville, Nevada
COMPARISON OF FORECASTS AND ACTUAL RESULTS, 1941

PAGET, FRED H.*

A round table discussion of water supply forecasts made in 1941 is presented in 5 short papers. Forecast volumes are compared with actual streamflow figures as indicated in the several tables, for the sections of the Western States involved:

California, 26 Central Valley Streams
California, Mokelumne River Watershed
California, Upper San Joaquin River
Nevada, Central Sierra, East Slope
Nevada, Humboldt River Basin
British Columbia, Canada; Columbia River
Kootenay River, Okanagan River

Paget, F. H.
Standish Hall
Lang, W. A.
Boardman, H. P.
Church, J. E.
Frame, S. H.

WINTER TRANSPORTATION IN THE HIGH SIERRAS BY “SNO-MOTOR”

DUCKER, P. H.*

The description and use of the Sno-Motor, for winter transportation to reservoirs in the High Sierra of Calif. are presented. The Sno-Motor has one 56-inch endless-type crawler tread assembly running completely around the vehicle. It operates similarly to a caterpillar tractor. The vehicle can negotiate a 50% slope and carry a 2.5 ton load. The engine, transmission-and drive mechanism, fuel tank and radiator are mounted on the bottom plate of the tractor to provide a low center of gravity and excellent stability for hillside travel. It exerts a weight of 170 lb/sq.ft. on the snow and has a speed ranging from 0.5 - 20 mph. Its 50 gallon gasoline tank provides enough fuel for 12 hours of operation. All the mechanism is housed within the oval shaped pontoon, operators cab is mounted over the rear.

Ducker, P. H.

DETACHABLE LASHINGS FOR SKI SAFETY

HERZ, WALTER J.*

A description of a Safety Ski Binding is presented. It is recommended that safety bindings be used for all cross country travel to prevent wrenched knee muscles and broken legs. The name of the manufacturer is included.

(See also TAGU 1942 Part II pg. 417-418 for picture and further description.)

Herz, W. J.

*Engineer, Sierra Pacific Power Co., Reno, Nevada

*Engineer, Sierra Pacific Power Co., Reno, Nevada

An exposed of the tremendous speed of war time construction of military cantonments and industrial expansion without adequate hydrologic planning is aired. Large sums of money were wasted hunting for water supplies where none existed within reasonable limits. No studies were made of surface supplies or groundwater supplies. Many cases of poor drainage systems with no lower ground to construct them, or the possibility of flood damage to buildings or life. Other cases of industrial expansion of plants and cities into well known flood plains along the large rivers. Little thought was given to previous records of flood damage or heights. Hydrologic planning is an essential part of all expansion and construction.

Hydrologic planning is proven to be an indispensable part of expanding industry and agricultural production demands even with drought conditions to keep pace with the World War II demands. Flood control works are hurriedly constructed and flood warning systems are increased with more attention given to the forecasts and warnings. Ground water supplies are mapped and potential uses for increased demands on municipal and agricultural demands. Hydrologists are consulted for air-field construction, snow removal and data necessary to support the military installations. The importance of consistent hydrologic records through war and peace is a means of being able to meet the demands of hydrologists nationwide when there is hydrologic planning to be done by the construction engineers and others.

On the Fraser Experimental Forest, Colorado, a detailed experiment is being conducted to find out the effects of cutting mature lodgepole pine on various factors affecting water yield. Of these factors, soil moisture deficiencies are particularly graphic is showing the relative consumption of water by uncut and cut-over stands. One year's data have been collected on soil moisture deficiencies; although the study will require several more years for completion, the methods and results are of sufficient utility to be worth current discussion. The experimental design and sampling procedures are discussed. Analysis of the first year records are shown along with text discussion of results and probable refinements to be made when further years of records are available.

Improving Streamflow Predictions by the Use of Past Records

Soil Moisture Under a Coniferous Forest

Head, River & Flood Division, U.S.W.B., Washington, D. C.
An exhaustive study of streamflow hydrographs plotted of data gathered at Cascade Locks on the Columbia River, covering the period 1886 through 1942. In the first phase of the work, the graphs are classified according to type, magnitude and timing of the first 6 months of flow of the water-year, peak flow is also tabulated, and used in the ensuing forecast procedure. The second phase consists of consulting the current records to fix the probable classification, and characteristic of the current year. The third phase consists of a search for a similar year that closely matches the present year up to the time of forecasting. Several examples of the pattern forecast are shown and discussed with forecast accuracy shown. Conclusions are drawn that the procedure works well on very large drainage basins where a great variety of weather conditions are involved. The scheme may not work as well on tributary basins with relatively small areas and also a short period of records.

*Engineer, Bonneville Power Administration, Portland, Ore.

**Western Snow Conference Bibliography**

Streamflow Forecasting by Pattern-Behavior

**Wahle, Rolla H.**

Proc. TAGU 1943 Part III 13-28: WSC at Corvallis, Oregon

June 16, 1943

10 Tables; 32 Graphs; 2 References

Two types of floods occur on the Sierra tributaries of the San Joaquin River: winter floods from heavy rains, and late spring floods from melting snow. Snow survey data as of April 1 have provided a reasonable accurate forecast of total April through July streamflow. Snow melt floods can be predicted at least a week in advance from snow pack daily temperature data. A hypothetical operation of the proposed Pine Flat Dam is outlined on a policy adopted for the control of rain floods and water conservation aimed to have a full reservoir at the end of the snow runoff period.

Tables and graphs illustrate the procedures.

**Author Index**

I. Wahle, R. H.

**Subject Index**

1. Water supply forecasting - runoff pattern analysis

"Irrigation Engr., Utah State Agr. Expt. Sta., Logan, Utah"

**Soil Conservation Service, Medford, Oregon**
Hydrologic Engineer, U.S. Weather Bureau, Washington, D.C.

A forecasting procedure is developed for estimating the forthcoming water supply from the 2,205,000 acre Klamath River Basin in Eastern Oregon. Two thirds of this basin lays in the rainfall altitudes while one third lies at high elevations with snow cover during the winter. The basin is divided into 6 smaller tributaries and handled separately. Where areas are covered with snow this source of supply is forecast with data from snow surveys while the rainfall portions of the basins are forecast with rainfall formulas. The data for these procedures are shown in computation tables, where the factors are weighted for areas and constants for either rain or snow. The weighting factors and the procedures are explained in the text.

Discussions are presented by Dr. J. E. Church, Bertram S. Barnes, and R. A. Work.

*and**Engineers for The California Oregon Power Company, Klamath Falls, Oregon

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

A SIMPLE PROCEDURE FOR THE DAY-TO-DAY FORECASTING OF RUNOFF FROM SNOW MELT

LINSLEY, RAY, K.*

June 16, 1943
4 Graphs; 9 References

Daily runoff from snow melt is based on degree days over a 24-hr. period. A degree day is one degree over 32°F for 24 hours. Mean temperature at one station is used and curves have been drawn relating melt in inches of water to the mean temperature at different altitudes. Another curve relates inches of melt to runoff during each part of the runoff season. The method is almost entirely empirical and neglects several factors. The procedure is applicable in regions developing semi-permanent snowpacks during the winter and in basins where extreme elevations restrict melting at any instant to a limited portion of the snow cover.

Discussion is included by R. A. Work.

*Hydrologic Engineer, U.S. Weather Bureau, Washington, D.C.
The efficiency of precipitation gages and snow surveying, the physics of snow, temperature in snow, and changes in snow texture were studied at Soda Springs, California, during 1942-43. Ten precipitation gages were used in the test. It was found that unshielded gages showed considerable catch deficiency. The use of oil in the cans has reduced the evaporation in shielded gages almost to zero. The weight beam of the Stevens Type-W recording gage was sensitive enough to respond to footsteps on the platform and the opening and closing of the door. A heavier oil was used in the damping cup to correct the condition. The movement of moisture in snow was determined by using dyes, of which Fuschine had all the requirements. Calorimetric measurements of snow were made and the results tabulated. Snow was found to crust at 35°F. The melting day lasted 6 hours in early spring at 7000 ft. altitude. Resistance thermometers were used to measure snow and soil temperatures. The layout of the experiment are shown in drawings and photographs, also instruments. Results of the data collected are discussed in the text.


**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

**SNOW STUDY PROGRAM AT SODA SPRINGS NEAR DONNER SUMMIT OF CENTRAL SIERRA NEVADA**

CHURCH, DR. J. E.*

Proc. TAGU 1943 Part III 77-90: WSC at Corvallis, Oregon
June 16, 1943
3 Tables; 1 Chart; 11 Photos; 2 Drawings

The efficiency of precipitation gages and snow surveying, the physics of snow, temperature in snow, and changes in snow texture were studied at Soda Springs, California, during 1942-43. Ten precipitation gages were used in the test. It was found that unshielded gages showed considerable catch deficiency. The use of oil in the cans has reduced the evaporation in shielded gages almost to zero. The weight beam of the Stevens Type-W recording gage was sensitive enough to respond to footsteps on the platform and the opening and closing of the door. A heavier oil was used in the damping cup to correct the condition. The movement of moisture in snow was determined by using dyes, of which Fuschine had all the requirements. Calorimetric measurements of snow were made and the results tabulated. Snow was found to crust at 35°F. The melting day lasted 6 hours in early spring at 7000 ft. altitude. Resistance thermometers were used to measure snow and soil temperatures. The layout of the experiment are shown in drawings and photographs, also instruments. Results of the data collected are discussed in the text.

A procedure is advanced for constructing a flood-hydrograph prior to occurrence by analysis of three specific elements or factors that produce the hydrograph. 1) The outflow from surface runoff (snow melt, rainfall), 2) the outflow from sub-surface storage, and 3) the outflow from ground-water storage. Portions of numerous hydrographs of past records are used to set up the cause and effects of the subdivisions of the hydrographs. Rainfall and snow melt enter the problem as snow storage. Graphs are exhibited and explained in the text together with the computed hydrograph and the actual hydrograph superimposed for comparison.

*District Office U. S. Engineers, Sacramento, Calif.

WESTERN SHOW CONFERENCE BIBLIOGRAPHY

BASIN STORAGE METHOD OF DEVELOPING FLOOD HYDROGRAPHS FROM PRECIPITATION RECORDS

PARSONS, WALTER J.*

2 Tables; 3 Graphs

WESTERN SHOW CONFERENCE BIBLIOGRAPHY

A METHOD FOR CALCULATING THE EFFECT OF SNOW ON RUNOFF DURING RAINSTORMS

PAULSON, JOSEPH B.*

4 Tables; 1 Graph; 3 References

The detail procedure for computing the several factors involved in producing the flood hydrograph caused from rain storms and snow melt discussed in WSC Paper No. 162-44 are presented. A formula for calculating the snowmelt runoff portion of the anticipated flood hydrograph is presented and explained. Tables are shown to explain the procedures used for the distribution of rainfall runoff and snow melt during 6 hourly increments of the storm duration. An example of the computation table used in securing the values used in plotting the anticipated flood hydrograph for the storm is included. Discussion of the problem is presented by Ray K. Linsley.

*District Office U. S. Engineers, Sacramento, Calif.

WESTERN SHOW CONFERENCE BIBLIOGRAPHY

DIFFERENCE IN BASIN CHARACTERISTICS AS REFLECTED BY PRECIPITATION RUNOFF RELATIONS IN SAN BERNARDINO AND EASTERN SAN GABRIEL MOUNTAIN DRAINAGES

STAFFORD, HARLOVE M.* and TROXELL, HAROLD C.**

3 Tables; 6 Graphs

A procedure is presented to show the relation of precipitation to runoff. When the relations are completed for one particular basin and characteristics of that basin are known, these relations cannot be used or applied to another basin. Each basin appears to be a law unto itself, although procedures can be duplicated. The relations and characteristics are found to be significantly different. In this study five basins in the San Bernardino and San Gabriel mountains of Southern California are analyzed. Data are shown and the various factors are described in the text. Graphical representations are included to show the relationships.

Discussions are included by R. L. Wing and C. B. Meyer.

*and**U.S. Geological Survey, Los Angeles, Calif.

WESTERN SHOW CONFERENCE BIBLIOGRAPHY

POST-WAR MANAGEMENT OF WESTERN FORESTED WATERSHED LANDS FOR WATER YIELD

CONNAUGHTON, C. A.* and WILM, H. G.**

Proc. TAGU 1944 Part I 36-40; WSC at Berkeley, Calif. Feb. 17-18, 1944

The need for additional water supplies in the semi-arid western states is indicated in post war demands for expansion of industrial and agricultural facilities. Announcements of large sums for reclamation projects and power production together with flood control and navigation problems. The U. S. Forest Service controlled lands in the mountainous states of the West where 80% of the water supplies originate must be managed through improvements of logging operations, through selective cutting to produce a maximum of timber products and water supply with a minimum of soil erosion, slt accumulation and also a prolonged snow melt season, to produce moderate runoff volumes. Proper management of forest lands will increase water yield and improve the forest lands for future production of forest products and water supplies.

In discussion Joseph Kittridge emphasizes that watershed management is essential to the economic growth of the western states, through careful conservation planning of the natural resources.

*and**U.S. Forest Serv. Expt. Sta., Fort Collins, Colo.

SUBJECT INDEX

1. Watershed mgnt.

AUTHOR INDEX

I. Connaughton, C. A.
II. Wilm, H. G.
III. Kittridge, J.
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

LAND USE AND VEGETATIVE COVER AS FACTORS INFLUENCING RUNOFF

KOHLER, KARL O.*

1 Table; 7 References

Watershed analysis is used to estimate the intensity of runoff and watershed yield by considering such factors as slope, topography, sub-surface rock, soil conditions, vegetative cover and land use as physical parameters. Hydrologic factors involved are precipitation intensity, and duration, temperatures, wind movements, snow accumulation. All factors are used towards determination of the most economical land use and watershed yield, towards improving an understanding of better watershed management. Large brush areas present a potential fire hazard and if laid bare cause much soil erosion where the root system is exposed. Citations of classic examples of watershed damage are included with figures to show economic losses.


*U.S.D.A., SCS, Portland, Oregon

SUBJECT INDEX
1. Watershed mgmt.
2. Basin analysis

AUTHOR INDEX
I. Kohler, K. O.
II. Madson, B. A.
III. Meadowcroft, N. F.

*Univ. Minnesota, Univ. Farm, St. Paul, Minnesota

# Abstract

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

INfiltration and the Physics of soil moisture

SHERMAN, L. K.*

6 Tables; 6 Graphs; 1 Reference

An analysis of moisture in the soil and the physical explanations of process of infiltration is presented. Examples of data are drawn from USDA Bulletin No. 729, and from well scattered sites over the State of Ohio. Infiltration enters the soil directly through capillary action in all directions and in some cases through gravity channels. This capillary action affects the root zone of plants and is of most interest to the agriculturists, while the gravity water, some of which may supply the capillary action, is of most interest to the hydrologist. From this source comes the ground water supplies, and largely soil moisture from precipitation. Infiltration rates are dependent on both. Graphs are exhibited to show effects of capillary absorption and the rate of absorption. Computed data are shown in tables. Discussion by several engineers and soil physicists are included with the references.

*53 Jackson Blvd., Chicago, Illinois

SUBJECT INDEX
1. Soil moisture
2. Infiltration capacity

AUTHOR INDEX
I. Sherman, L. K.
II. Hendrickson, A. H.
III. Barnes, B.
IV. Johnston, C. N.
V. Limley, R. K.

*Univ. of California at Davis, California

# Abstract

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SOIL MOISTURE RECORDS FROM BURNED AND UNBURNED PLOTS IN CERTAIN GRAZING AREAS OF CALIFORNIA

VEIHMEYER, F. J.* and JOHNSTON, C. N.**

3 Tables; 8 Photos; 8 Graphs; 18 References

A detailed study is presented, relative to soil moisture occurrences and disappearances in the root zone of the soil mantle, representing differing soil conditions and soil types and climate conditions. Attempts at revitalization of soil moisture for plant use are discussed. Plant-transpiration is studied under various conditions. Experimental plots are pictured and described. Data are plotted on graphs to show trends of soil moisture.

Discussion by P. B. Rowe and Henry W. Anderson relative to soil moisture studies performed by the U.S. Forest Service Expt. Sta., Berkeley. The 18 references listed indicate that considerable research work has been carried on relative to the problem of soil moisture.

*and**University of California at Davis, California

# Abstract
EFFECT OF HIGH WATER TABLE IN EXAGGERATING STREAMFLOW: 1942-44 HUMBOLDT RIVER NEVADA

CHURCH, J. E.* and BOARDMAN, H. P.**

3 Tables; 1 Location Map

An analysis of the 1942-43-44 seasonal streamflow forecasts in relation to obscure factors that upset the usual forecast accuracy. Considerable more streamflow occurred than forecast by about 120% above the normal flow, when snow survey measurements indicated only 70 to 90% snowpack. The percentage system of forecasting appears to have difficulty in aligning such factors as soil moisture and apparently high ground-water table. Ground-water levels measured in wells did not show a large percentage above normal. The preceding fall rainfall and the rainfall during the runoff season were quite high and probably account for the high flows.

Discussion is presented by W. G. Hoyt who forwards some analysis of the discrepancy. Reference is made to a previous analysis of the high and probably account for the high flows.

EFFECT OF HUMBOLDT RIVER NEVADA

Considerable more streamflow occurred than forecast about 120% above the normal flow, when snow survey measurements indicated only 70 to 90% snowpack. The percentage system of forecasting appears to have difficulty in aligning such factors as soil moisture and apparently high ground-water table. Ground-water levels measured in wells did not show a large percentage above normal. The preceding fall rainfall and the rainfall during the runoff season were quite high and probably account for the high flows.

Discussion is presented by W. G. Hoyt who forwards some analysis of the discrepancy. Reference is made to a previous analysis of the high and probably account for the high flows.

Errors in the application of glass stemmed mercury thermometers, electrical resistance thermometers (thermohms) thermocouples, and the Bouyoucos liquid resistance thermometers are presented. Heat absorbed and conducted to the temperature element by the electrical leads is a principal source of error, and was effectively eliminated by fastening the temperature elements to a strand of No. 9 galvanized iron wire suspended between 2 posts 8 ft. apart. Subsequently, temperature measurements were made in the snow pack above the soil surface and wires at 1-foot intervals for 12 feet in height. Measurements in the first 10 inches below the snow surface were affected by solar radiation and fluctuation in the ambient air temperature. The data indicated that the soil temperature and the temperature in the snowpack remained approximately 32°F even though air temperatures of below zero F. were observed. Photographs of the experimental area and the wires for holding elements are shown.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

WSC No. 170-44
Catalogue No.
CRREL No.

SUBJECT INDEX
1. Forecast accuracy

AUTHOR INDEX
I. Church, Dr. J. E.
II. Boardman, H. P.
III. Hoyt, W. G.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

WSC No. 172-44
Catalogue No.
CRREL No.

SUBJECT INDEX
1. Snow temperature
2. Snow cover -thermal effects

AUTHOR INDEX
I. Gerdel, R. W.
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

A STEEL PIPE CLIMBER

WORK, R. A.* and CHILDRETH, R. W.**

1 Drawing; 3 Photos

The painting of steel pipe snow survey course marker posts presents a problem when the pipes are set in concrete and 20 feet tall. An ingenious device is described and shown in detail drawing and photograph. The climber is used by slipping the feet into stirrups, grasping the pipe above the head, pull both feet up. When down pressure is exerted in the stirrups. legs are pressed against the pipe and another step up can be made. Climb to the top of the pipe, replace the sign marker and start painting down.

Discussion by Fred Paget recommends a light weight extension ladder for this purpose. Photographs of this procedure are pictured. Ashton Codd suggests to forget the stripes, and use a brush attached to a long extension aluminum rod, and paint the pipe one solid color: like danger orange.

*and**U.S.D.A., Soil Conservation Service, Medford, Oregon

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

ADJUSTING FORECAST CURVES FOR ABNORMAL SPRING AND SUMMER TEMPERATURES

WORK, R. A.*

10 Tables; 9 Graphs; 12 References

Factors affecting the snow and runoff relationship are listed, and a method presented for adjusting snow survey results of April 1 in constructing the forecast curve so as to compensate for temperature deviation from normal during the runoff season. The method is based on results of studies on two small drainage basins in Oregon. The selection of 2-month period of temperature departures as well as the correction coefficient to be applied are selected on the basis of the amount of water stored in the snow on April 1 as measured by snow survey. Results of the corrections as applied to both basins are tabulated and graphed for several years.

Discussions are presented by Fred H. Paget, Harry Olsen, Ray K. Linsley, and Garfield Stubblefield.

*U.S.D.A., Soil Conservation Service, Medford, Oregon

A PRACTICAL SNOW SURVEY METHOD OF FORECASTING RUNOFF

POTT, HARRY L.*

2 Graphs; 3 Photos

Photographs were taken of the snow cover on a section of the Continental Divide near Hoosier Pass at the headwaters of the Middle Fork of the Platte River, beginning in the spring of 1934. The same section of each photograph was covered with a transparent template of cross section paper to calculate the percent of the area covered with snow. The data of a 10-year period indicate that predictions of total streamflow can be made from a photograph taken on May 1.

*Board of Water Commissioners, Denver, Colorado

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

MIDWINTER FORECASTING OF THE SNOW WATER RUNOFF ON YEARS OF EXTREMELY LIGHT OR HEAVY FEBRUARY 1, MOUNTAIN SNOW COVER

CREDLE, WAYNE D.* and MARR, JAMES E.**

7 Tables; 5 Graphs

A need is shown to develop a forecasting procedure of seasonal runoff as early as February 1st. A scheme is developed from snow survey data and streamflow for the Snake River and tributaries and also for stations along the Columbia River below the Canadian border. Records from 39 snow survey courses were analyzed in relation to streamflow records over a series of years where parallel records are available. Although the scheme is feasible, the variability of the occurrence of storms was too uncertain to place much reliability in the procedure. The need for longer periods of records is much in demand for such forecasts. A month to month or day to day procedure could be more efficient.

*and**U.S.D.A., Soil Conservation Service, Boise, Idaho

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

A PHOTOGRAPHIC SNOW SURVEY METHOD OF FORECASTING RUNOFF

POTT, HARRY L.*

2 Graphs; 3 Photos

Photographs were taken of the snow cover on a section of the Continental Divide near Hoosier Pass at the headwaters of the Middle Fork of the Platte River, beginning in the spring of 1934. The same section of each photograph was covered with a transparent template of cross section paper to calculate the percent of the area covered with snow. The data of a 10-year period indicate that predictions of total streamflow can be made from a photograph taken on May 1.

*and**U.S.D.A., Soil Conservation Service, Boise, Idaho
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

THE EFFECT OF TIMBER CUTTING IN A LODGEPOLE PINE FOREST ON THE STORAGE AND MELTING OF SNOW

Wilm, H. G.*

Proc. TAGU 1944 Part I 153-155:WSC at Berkeley, Calif. Feb. 19, 1944 1 Table; 3 References

Experiments conducted in mature forest of lodgepole pine at Rocky Mt. Forest & Range Experiment Station in Colorado, show that planned cutting will increase the snow cover during the accumulation period. A total of 17.5 inches of water passed through the forest canopy on heavily cut-over plots, as compared with 13.33 inches in the uncut forest. The accelerated melting rates of the cut-over plots were compensated by the excess snow stored initially. All experimental plots became bare at approximately the same time. Cutting is not advised in areas where floods and erosion are problems. (See also SIP U1839)


WESTERN SNOW CONFERENCE BIBLIOGRAPHY

THE USE OF SNOW SURVEYS AS AN AID IN FLOOD CONTROL OPERATION OF RESERVOIRS

Christian, Francis G.


The hypothetical operation of the proposed Pine Flat Dam on the Kings River, California as outlined by Paget is discussed. Several improvements in the technique of recognizing the start of the decline of runoff are suggested. Some of the methods permit recognition of the start of the decline within 5 days after the peak flow has occurred. (See also SIP 1908 – WSC 154-43) Discussion by L. Standish Hall presents a similar problem on the Meikulem River in operating the Salt Springs and Pardue Dams. Operational graphs are presented and discussed. Further discussion is presented by R. K. Linsley, suggesting further methods of defining the snow melt hydrograph.

*U.S. Engineers Office, Sacramento, Calif.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

THE UTAH SNOW-MOBILE

Clyde, George D.*


The two basic principles making the Utah snow-mobile successful for transportation over deep snowpack are the split track and the guide runner. The excessive weight of an ordinary tractor was overcome in the Utah Snow-mobile by mounting wide, light metal tracks on the rubber tires of an ordinary automobile. The tracks were wide to reduce the unit load on the snow surface. Snow packing between the tracks and the wheels was overcome by designing a split track with the wheels operating between the two segments of the track. This arrangement provided a self-cleaning device, preventing accumulation of snow between the tracks. Conventional steering tends to overturn the vehicle when one track was stopped. A movable runner, projected in front of the vehicle, operated on a fixed swivel at the end of the frame which was rigidly fastened to the chassis. This runner was operated through a cable-chain mechanism fastened to the steering column of the vehicle. Photographs show the mechanical design and features of construction, also transportation over highways. Specifications and performance records are listed.

*Utah Agr. Expt. Station, Logan, Utah

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

WINTER TRANSPORTATION ON THE HIGH SIERRA BY SNOW-MOTOR

Lang, William A.


The "Snow-Motor" owned by the Southern California Edison Company has been driven 956 miles during 245 hours running time. The cost of operation includes gasoline, oil, and repairs, amounts to $1.26 per mile during two years time. The "Snow-Motor" was used to transport 35,000 lbs of 12 gage steel sheets 48" x 96" in size over deep snow 31 miles from Big Creek to Florence Lake Dam over a 9300 ft. elevation summit between April 30 and May 13. A lighter and smaller Snow-Motor has been developed. Its outstanding advantage is that the machine can be operated without a sled when necessary. Photographs show the machine in operation with the heavy load pulled on a trailer sled. Specifications and performance records are included in the text.

NOTES ON THE OPERATION OF POWER DRIVEN CONVEYANCE FOR SNOW: MOTOR TOBOGGAN

MARR, JAMES C.*


A "Motor-Tooboggan" purchased by the Division of Irrigation, Soil Conservation Service, and the Boise River Board of Control in 1942 has been used for snow surveys during 3 winters. The toboggan operated satisfactorily on reasonable firm cold snow with side grades not exceeding 15%. The engine heated excessively in low gear on sticky and on over-ripe snow. The upkeep has been high. The runners were replaced 3 times in 250 miles of travel. Many repairs and adjustments were necessary. The motor-tooboggan is not recommended for use in snow surveying.

*U.S.D.A., Soil Conservation Service, Boise, Idaho

THE IMPORTANCE OF RUNOFF FORECASTING TO THE OPERATION OF THE PACIFIC SOUTHWEST POWER INTERCHANGE COMMITTEE

HINSON, H. B.*


The importance of accurate water supply forecasts for use by the Power Interchange Committee towards the production of power on the Pacific Coast is presented. The coordination efforts of the Committee to conserve fuel oil and gas reserves for steam generation in relation to hydropower is one of the aspects of 'War Time' economics. The snow hydrologists preparing streamflow forecasts are providing an active service to the wartime economy through power development for industrial use and planning for the routing of power to areas where shortage of power occurs at peak demand periods.

*Chm., Southwest Power Interchange Comm., Sacramento, Calif.
This paper presents a new method of analysis of rainfall and runoff data which permits surface runoff and ground water flow to be segregated and infiltration capacity determined during stream rise. The method is equally applicable to areas with and without snowcover. The determination of infiltration capacity during the snow melt period is, however, the most difficult problem and the method is here applied to this case, using data for areas in the Allegheny Experimental Forest, with varying degrees of forest cover density. For these areas the rate of snow melt per degree-day of temperature excess above 32°F decreased as the cover density increased. During snow melt infiltration took place at rates governed by the rate of supply of rain and melt water, averaging for the entire snow melting period one-third to one-quarter of the infiltration capacity of the soil. The infiltration capacity under snow cover with unfrozen soils was found to be about 0.05 in. per hour or 0.20 in. per day.

*Horton Hydrologic Laboratory, Voorheesville, New York

**Simplified Plotting of Statistical Observations**

GUMBEL, E. L.*

3 Tables; 7 Graphs; 11 References

A procedure is presented to show that the MEAN number depends, in general, upon the nature of the variable. In order to analyze this postulate consideration was given to the largest observation in a sample of size and ask: What is the mean number of observations such that this value or larger one, happens once again? This question is important for statistical variates as earthquake magnitudes, precipitation, floods, temperatures, and pressures, where the largest value involves specific dangers. Similar problems arise in quality control and in gunnery. However, for a wide class of statistical distributions, it converges toward the sample size. The general solution given in the first section will be applied, in the second section, to some interesting distributions, in the last section it will be used to simplify the plotting procedure advocated in a previous article. (See No. 6 of references)

**The Dynamics of Liquid Water in Deep Snowpacks**

GERDEL, DR. R. W.*

3 Tables; 2 Graphs; 5 References

Any solution of the snow melt problem which will improve the forecasting of floods as well as forecasting of agricultural and industrial water supplies is dependent upon a knowledge of the hydrodynamics and the dynamic potentials which influence the retention and discharge of water by the snowmantle. As a result of studies made of the dynamics of free water in the snowpack at the Central Sierra Snow Laboratory, conclusions are drawn of the melting process of the snowpack. Thermodynamic phenomena associated with the melting or metamorphosis of the snowpack are also discussed, together with techniques of measuring the factors associated with these phenomena. Data are tabulated and graphical representation show relations of factors involved.
A NEW FORECASTING CURVE FOR THE KAWEAH RIVER IN CALIFORNIA

PAGET, FRED H.*

4 Tables; 4 Graphs; 8 References

The April through July runoff volume of the Kaweah River at Three Rivers as a function of water equivalent of snow on the ground April 1, spring precipitation, and soil moisture deficiency in the fall is presented. The empirical relation obtained from 15 years of record has a maximum error of less than ten percent. The novel feature of the soil moisture deficiency factor is that it is determined by fall precipitation prior to the accumulation of continuous snow cover at a particular station.

Discussion by W. B. Langbein indicates that the application of statistical methods produces a procedure of measuring the effect of the independent variables and permits a more efficient choice and use of the most effective values. Methods are illustrated and discussed.

MECHANIZED TRANSPORTATION FOR SNOW SURVEYING

WORK, R. A.*

2 Photographs

A series of field tests of a 4-passenger snow vehicle are described. The machine is supported in the rear by 2 pontoons equipped with endless open-link tracks. Support in front is provided by 2 connected hickory skis. Small pneumatic tires lift the skis from bare ground when required. The front skis are attached to a steering yoke that will rotate over about 30° from the horizontal so that the skis maintain a flat position on the snow. The skis have a 1" keel down the center to prevent side slip and aid in steering. A 6-cylinder automobile engine with transmission operates the vehicle at top speed of 2 miles per hour. Twelve characteristics to be noted in the performance of over-snow vehicles are listed. This vehicle mentioned met the requirements for performance. (Tucker SnoCat)

In discussion R. W. Childreth describes a trial run of an over-snow vehicle developed by the Iron Fireman Manufacturing Company of Portland, Oregon. The trials were made on Mt. Hood, in snow conditions difficult for ski travel. Operation details are given.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

RESEARCH COMMITTEE ON SNOW, WESTERN SNOW CONFERENCE 1945

CHURCH, DR. J. E.*

2 Graphs; 18 Tables; 1 Photo; 9 References

Reports of several member authors are presented. The teeth on snow sampler cutters have been reduced in number and lengthened to avoid packing and freezing of ice in the cutter. Sampler tubes, particularly those of aluminum tend to stick in frozen snow. This difficulty has been largely overcome by shellacking, swabbing with kerosene, and the application of ski wax. Iron pipes of 3 in. diameter set in concrete are excellent snow course markers. Storage gages and recording gages with CaC12 and protected with wind shields and a film of light oil, have been satisfactory during the 1944 - 1945 snow season. Snow melt day lasts only 6 to 8 hours during April and May at Donner Summit, Calif. Examples of snow surveys, streamflow forecasts and actual runoff are given as a check on forecast accuracy.
and U.S.B.R., number of stations for multiple correlation, of methods for esti­mass curve adjustments of precipitation records, of the optimum system for forecasting precipitation runoff relationship. One of the conclusions of the study is the need for a long period of record in estimating a reliable system of forecasts to be made on various dates for various periods of the surveys and precipitation data are presented. There is discussion of the seasonal volume of runoff by means of snow survey data made early in the year. Reference is made to Water supply forecasting procedures used by the U.S. Bureau of Reclamation office at Boulder City, Nevada, for estimating the in­flow to Lake Mead are outlined. Some of the results and examples of multiple correlation of runoff from the Upper Colorado with snow surveys and precipitation data are presented. These are discussion of forecasts to be made on various dates for various periods of the mass curve adjustments of precipitation records, of the optimum number of stations for multiple correlation, of methods for esti­mating missing records, and of other factors influencing the precip­i­tation runoff relationship. One of the conclusions of the study is the need for a long period of record in estimating a reliable system for forecasting.

* Nevada Cooperative Snow Surveys, Reno, Nevada

Author Abstract

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

VALUE OF MIDWINTER SNOW SURVEYS

CRIDDLE, WAYNE D.*


7 Tables; 4 Charts; 1 Reference

The use of midwinter snow surveys is exemplified from records of a few western streams, and the results are compared with forecasts based on April snow surveys. The results indicate that a forecast based on the maximum value of the snowpack, whenever it occurs, may be superior to a forecast based on the value observed on the same time each year. Reference is made to WSC Paper No. 176-44.

*USDA, Soil Conservation Service, Boise, Idaho

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SEASONAL STORAGE PRECIPITATION GAGES

CODD, ASHTON R.


A non-recording winter storage precipitation gage used success­fully in a region of heavy snowfall is described. The gage is con­tical in shape with a standard 8-inch diameter orifice and is charged with a CaCl₂ solution of 34% by weight, and covered with a film of light oil. The gage is mounted in a steel tower constructed of 5 ft. sections to exceed the deepest snow depth by at least 5 feet. The gage has a capacity of 300 inches of precipitation. The bottom 100 inches is taken up with the CaCl₂ antifreeze solution leaving 200 inches for snowfall and rainfall in the form of added water. The gages are calibrated for stick measurement and also fitted with the necessary valves and safety plugs for draining the solution for weighting at the end of the precipitation season. The antifreeze solution is weighed into the gage and measured by stick depth and then the diluted solution is stick measured and weighed out of the gage. The difference in total weights is compared with the difference of stick measurements by calibration.

*U.S. Weather Bureau, Sacramento, Calif.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

WATER SUPPLY FORECASTING PROCEDURES

BOARDMAN, H. P.*


10 Tables; 8 Graphs

The relative accuracy of snow survey and winter precipitation data as applied to forecasting the spring and summer runoff of a typical Sierra Nevada western-slope river was investigated. Fifteen years of snow survey data were available, and the same period of precipitation records were used in the comparison. It was obvious on examination of the graphs that several years (4 in the case of snow survey and 3 in the case of precipitation) were much out of harmony with all other years. Justification for these discrepancies was found; they were usually caused by abnormal fall or spring precip­i­tation. These years with abnormal precipitation were omitted in determining the position of the line on the graph showing the re­lationship of winter precipitation or the water equivalent of snow to stream flow. The conclusion is in favor of snow survey data.

*U.S. Bureau of Reclamation, Denver, Colorado

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

Precipitation gages are calibrated for stick measurement and also fitted with the

SUBJECT INDEX

1. Water supply forecasting

- snow surveys

I. Stanley, J. W.
II. Kennedy, R. E.

*U.S.B.R., Boulder City, Nevada

Author Abstract

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

FORECASTING COLORADO RIVER FLOW

STANLEY, J. W.* and KENNEDY, R. E.**


2 Location Maps; 6 Tables; 6 Graphs

The use of midwinter snow surveys is exemplified from records of a few western streams, and the results are compared with forecasts based on April snow surveys. The results indicate that a forecast based on the maximum value of the snowpack, whenever it occurs, may be superior to a forecast based on the value observed on the same time each year. Reference is made to WSC Paper No. 176-44.

*U.S.B.R., Boulder City, Nevada

SUBJECT INDEX

1. Water supply forecasting

- snow surveys

I. Boardman, H. P.

*and**U.S.B.R., Boulder City, Nevada

Author Abstract
A different design of a storage precipitation gage is described and pictured. The gage is designed primarily for low altitude where freezing is not a problem. However, an initial charge of antifreeze solution could be used during winter months to insure against freezing and loss of the catch. Where rain gages cannot be attended in isolated locations this design appears to be adequate.

Discussion of the gage design is presented by Ashton R. Codd.

*U.S.F.S., Oak Grove Station, Pasadena, Calif.
The basic principles of the idealized hydrologic cycle are reviewed with emphasis on storage and movement of water in the soil. A distinction is made between ground water runoff and overland runoff in terms of storage and lag, expressed as accumulated deviations from uniform flow over a period of several years. These functions are presented for the period 1920 through 1945 for three rivers in central Oregon: John Day, Deschutes and Metolius, which exemplify minimum, moderate, and maximum effects of storage lag. The Metolius River is shown to have extremely small fluctuations in discharge from year to year, ascribed to a great portion of its flow being derived from ground water runoff; and its response to fluctuations in annual precipitation lags behind that of the John Day River by about five years. Specific techniques and measures for improving seasonal water supply forecasts are suggested.

In discussion Mr. E. N. Peterson emphasizes the importance of more accurate and dependable water supply forecasting to the power development agencies and companies in the future.

*U.S. Geological Survey, Portland, Oregon

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SNOW LAYER DENSITY CHANGES

WORK, R. A.*

1 Location Map; 10 Tables; 8 Graphs; 9 Photographs; 9 References

A 25-ft. square area of snowpack near Crater Lake, Oregon was studied systematically during the 1940-41 season. By successive excavation and refilling of portions of the study site, and by means of identifying ribbons, the metamorphosis of each layer of the snowpack was observed at regular intervals during the accumulation and melting season. Observations and conclusions are given regarding changes in density, mass or water equivalent, water storage, water transmission characteristics, and melting rates of the snow. Many results confirm existing knowledge and belief of a quantitative basis, others add to or modify well established opinions. An example is the lack of relationship between the density of snow layers and the weight of the overlying snow.

Discussion is presented by Forest L. Rhodes of the Corps of Army Engineers, San Francisco, California.

*U.S.D.A., Soil Conservation Service, Medford, Oregon

SUBJECT INDEX
1. Snow research
2. Snowpack density

AUTHOR INDEX
I. Work, R. A.
II. Rhodes, F. L.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

THE INFLUENCE OF FOREST COVER ON SNOW MELT

WILM, H. G.*

1 Chart; 3 Graphs; 2 Tables; 16 References

There is presented a survey of important literature on the effect of forest cover on snow-melt, with recent results of investigations in the Fraser Experimental Forest near Fraser, Colorado. It is shown that forest management, by selective cutting, influences greatly the accumulation and retention of snow on the ground. The evidence supports Dr. J. E. Church's Fir forest, possessing a maximum number of glades, as the most desirable type of snow conservation.

Discussion by Walter U. Garstka points out the fact that forest management and watershed management must walk hand-in-hand to secure the optimum of water supplies, timing of runoff and timber products supplies, wood, lumber, paper, livestock grazing, power, flood control and irrigation.

*U.S.F.S. Experiment Station, Fort Collins, Colo.

SUBJECT INDEX
1. Snowmelt -research
2. Watershed mgmt.

AUTHOR INDEX
I. Wilm, H. G.
II. Garstka, W. U.

*U.S.D.A., Soil Conservation Service, Medford, Oregon

Author Abstract
ITS OBJECTIVES

Engineer, Hydrology Div., U.S.B.R., Denver, Colorado

A degree-day factor was computed from the slopes. The degree-day beginning and ending with the same temperature were selected, and the factor was applied to a sequence of assumed temperatures to calculate the design snow-flood. The procedure is considered preliminary.

The Cooperative Snow Investigation Program was initiated in 1945 by the Weather Bureau and the Civil Works Division of the Corps of Engineers. The main objectives include the determination of methods of evaluating maximum streamflow resulting from precipitation, and methods of forecasting seasonal and short-term streamflow, including floods. The expansion of basic knowledge of the hydrodynamic and thermodynamic properties of snow, and of meteorological, climatological, and hydrological phenomena is an essential element of the program. The organization includes the program director, the processing and analysis unit, the Upper Columbia Snow Laboratory, the Central Sierra Snow Laboratory, the Willamette Basin Snow Laboratory, and the technical director. The program is outlined in 5 major sections: seasonal totals of elements, time distribution of processes, areal distribution of precipitation, generalisation and transfer of conclusions and methods.

The Cooperative Snow Investigation Program was initiated in 1945 by the Weather Bureau and the Civil Works Division of the Corps of Engineers. The main objectives include the determination of methods of evaluating maximum streamflow resulting from precipitation, and methods of forecasting seasonal and short-term streamflow, including floods. The expansion of basic knowledge of the hydrodynamic and thermodynamic properties of snow, and of meteorological, climatological, and hydrological phenomena is an essential element of the program. The organization includes the program director, the processing and analysis unit, the Upper Columbia Snow Laboratory, the Central Sierra Snow Laboratory, the Willamette Basin Snow Laboratory, and the technical director. The program is outlined in 5 major sections: seasonal totals of elements, time distribution of processes, areal distribution of precipitation, generalisation and transfer of conclusions and methods.

- Program Director, Corps of Engineers, San Francisco, Calif.
- Author Index
  1. Rhodes, F. L.
- Subject Index
  1. Hydrology
  2. Meteorology
  3. Cooperative snow investigations

THE PROBLEM OF SNOW IN DETERMINING THE SPILLWAY DESIGN FLOOD

Barnes, Bertram S.*

Proc. WSC 1948: Pgs. 23-29 Reno, Nevada, April 15-17
2 Graphs

Hydrographs from rain and from snow are combined to produce the design-flood hydrograph which is essential in determining the required capacity of the spillway of a dam. The rain flood is derived from a hypothetical storm in the basin. The snow hydrograph was derived by plotting the cumulative values of degree-days against cfs days in the form of a double mass curve. A lag of 3 days between temperature and runoff produced the smoothest curve. Runoff periods beginning and ending with the same temperature were selected, and the average slope of the mass curve for each period was determined. A degree-day factor was computed from the slopes. The degree-day factor was applied to a sequence of assumed temperatures to calculate the design snow-flood. The procedure is considered preliminary.

- Author Index
  1. Barnes, B. S.
- Subject Index
  1. Snow melt and runoff
  2. Statistical analysis
  3. Floods

*Engineer, Hydrology Div., U.S.B.R., Denver, Colorado

THE PROBLEM OF AN EXPANDING ICE SHEET

Monfore, G. E.* and Taylor, Frank W.**

Proc. WSC 1948: Pgs. 30-45 Reno, Nevada, April 15-17
7 Graphs; 5 Photographs; 8 Equations; 8 References

The coefficient of expansion of ice is about $30 \times 10^{-6}$ per F$^\circ$, or nearly 5 times that of steel. The Bureau of Reclamation made a study of the pressure exerted by an ice sheet during a time in temperature. Two types of pressure gages were developed. The indentor gage consists of 2 circular sheets of steel held 0.025 in. apart by a steel ring. A hardened steel ball attached to the inside of one plate presses against a polished steel target on the other. Maximum pressure is measured by the amount of indentation. The resistance gage of similar shape can measure continuous pressure by change of resistance of a constantan wire on which a stretching force is applied during pressure. Laboratory experiments have yielded graphs for pressure exerted at various rates of increasing temperature. Two differential equations describing the thermal behavior of ice sheets were solved and the results plotted in a series of curves. Rate of change by mean temperature of an ice sheet can be obtained by multiplication of values read from these graphs. Field measurements have been started but definite results have not yet been reported.

- Author Index
  1. Monfore, G. E.
  2. Taylor, F. W.
- Subject Index
  1. Ice pressure measurement

INVESTIGATION OF GLACIERS IN BRITISH COLUMBIA

Webb, C. E.

Proc. WSC 1948: Pgs. 46-54 Reno, Nevada April 15-17
1 Map; 5 Tables; Article Canadian Alpine J. 31:207-217 6/48

Glacial surveys were made to determine the rate of recession or advance of the glaciers for streamflow investigations. Methods consist of setting up fixed reference marks near the toe of a glacier tongue. Annual measurements of the distance from the nearest point of the foot to a reference point, taken annual photographs, and trigonometric measurements of markers set out on the ice. Survey results are indicated for glaciers of Garibaldi Park, Franklin Glacier and glaciers of the Selkirk Mountain Range. It is concluded that the rate of recession is not governed entirely by weather. Valley conditions and the steepness of the slope have a marked effect. The glaciers were in a stable condition until 1890, when a general recession began.

- Author Index
  1. Webb, C. E.
Wisconsin River. The complexities of frozen ground, and variations in soil temperature, soil moisture and river gaging stations between ground water levels and natural streamflow is being developed. Precipitation pattern are problems to be solved. A relationship between precipitation gages, snow survey courses, ground water observation wells, and various diurnal fluctuations. It was estimated that 19.7 in. of 38.5 in. of precipitation ran off in the streams. The remaining in. of precipitation is lost by evaporation, ground water storage, and sampling error. Reflection of albedo under ground seepage, and sampling error. Reflection of albedo increased from one-third of the western states. The results are suggestive rather than conclusive.

Discussion by Ashton R. Codd with references and quotations from Dr. J. E. Church.

*Physicist, U.S.W.B., Sacramento, Calif.

Sheerar, L. L.

A brief history of a privately owned company developing a storage and river regulation system is presented. Reservoir storage was increased from 98,000 AF to 390,000 AF in 30 years time. A network of precipitation gages, snow survey courses, ground water observation wells, soil moisture, and river gaging stations was established. Hourly, daily and semi-daily data are collected. River flow forecast procedures are in use for regulation of 21 reservoirs supplying water to paper mills, utilities along the Wisconsin River. The complexities of frozen ground, and variations in precipitation pattern are problems to be solved. A relationship between ground water levels and natural streamflow is being developed.

*Asst. Mgr., Wisconsin Valley Improvement Co., Wausau, Wis.

*Director, Bureau of Land Management, Dept. of Interior
A simple formula for predicting daily runoff from snow has been developed. The basis of the formula is that streamflow from melting snow is largely a function of antecedent streamflow, heat supply, and time of year. These factors are obtained statistically from meteorological data. The formula gave results accurate within 9% when used in predicting daily flow from snow at the Central Sierra Snow Laboratory for the Castle Creek drainage basin during April and May, 1945. The time of year factor was omitted in this calculation.

Discussion by Walter U. Garstka.
Extensive measurements of fall deficits in soil moisture were conducted in the Fraser Experimental Forest. Soil samples were taken in an area of virgin lodgepole pine in late September, and again in the spring to determine the field-capacity of the soil. The difference between the average (field-moisture capacity and the average fall-moisture content was the soil-moisture deficit. Soil moisture deficit averaged about 16% to 25% of the snow cover over a four year period. Variations in deficits from year to year amounted to 16% of the gross snow cover. Studies in Spruce and Fir forest cover showed about 14% deficits. The difference between the average field-moisture capacity and the snow line. The Sno-Cat traveled 331 miles between Feb. 12 and Feb. 29, 1948 over light sandy snow up to elevations of 9000 ft. The Sno-Cat averaged 5.1 Mi/gal. gasoline and the repair costs were $10.70. The Dodge Power Wagon averaged 8 Mi/gal. gasoline over roads considerably snow-blocked. Snow-Catting was difficult where snow lacked cohesion. Wider and longer front skis are recommended to increase the bearing surface. Discussion by Fred Paget.

Author Abstract

Western Snow Conference Bibliography

MECHANIZED SNOW SURVEYS IN MONTANA

John Doe, A. R.*

Proc. WSC 1948: Pgs. 152-156 Reno, Nevada, April 15-17

1 Photo

A Tucker Sno-Cat, a power-driven over-snow vehicle, and two man crew of trained snow surveyors were used to measure 24 snow courses extending a distance of 300 miles. The 1948 models Sno-Cat, 4-door sedan, was powered by a 95 H.P. Plymouth engine, and had a 3 speed transmission. The unit was equipped with sleeping bags, tent, stove, and emergency supplies for 2 men. A Dodge Power Wagon with a special bed on the chassis was used to transport the Sno-Cat in the valleys below the snow line. The Sno-Cat traveled 331 miles between Feb. 12 and Feb. 29, 1948 over light sandy snow up to elevations of 9000 ft. The Sno-Cat averaged 5.1 Mi/gal. gasoline and the repair costs were $10.70. The Dodge Power Wagon averaged 8 Mi/gal. gasoline over roads considerably snow-blocked. Snow-Catting was difficult where snow lacked cohesion. Wider and longer front skis are recommended to increase the bearing surface. Discussion by Fred Paget.

Author Abstract

Western Snow Conference Bibliography

FORECAST OF RUNOFF BASED ON THE WATER CONTENT OF THE WATERSHED SNOW COVER CORRECTED BY A FACTOR INVOLVING FALL FLOW OF THE STREAM

Parshall, R. L.*

Proc. WSC 1948: Pgs. 157-161 Reno, Nevada, April 15-17

4 Tables; 3 Graphs

The fall flow of a stream is an indication of the soil moisture content over the entire watershed. A correction based on October, November and December flow in acre feet has been applied to the April 1 water content of the snow. This procedure is applied to many streams in Wyoming, Colorado and New Mexico to improve the accuracy of runoff forecasts. A graph is used to illustrate that the introduction of the fall-flow factor tends to produce a smoother curve than with snow survey data only plotted against runoff. Discussion by G. B. Jacobson.

Author Abstract

Western Snow Conference Bibliography

SOME OBSERVATIONS ON FALL SOIL MOISTURE DEFICITS UNDER FOREST COVER AND THEIR RELATION TO THE WINTER SNOWPACK

Goodell, B. C.*

Proc. WSC 1948: Pgs. 152-156 Reno, Nevada, April 15-17

Discussion by Rocky Mtn. Forest & Range Exp't Sta., Fort Collins, Colo.

Extensive measurements of fall deficits in soil moisture were conducted in the Fraser Experimental Forest. Soil samples were taken in an area of virgin lodgepole pine in late September, and again in the spring to determine the field-capacity of the soil. The difference between the average (field-moisture capacity and the average fall-moisture content was the soil-moisture deficit. Soil moisture deficit averaged about 16% to 25% of the snow cover over a four year period. Variations in deficits from year to year amounted to 16% of the gross snow cover. Studies in Spruce and Fir forest cover showed about 14% deficits. The difference between the average field-moisture capacity and the snow line. The Sno-Cat traveled 331 miles between Feb. 12 and Feb. 29, 1948 over light sandy snow up to elevations of 9000 ft. The Sno-Cat averaged 5.1 Mi/gal. gasoline and the repair costs were $10.70. The Dodge Power Wagon averaged 8 Mi/gal. gasoline over roads considerably snow-blocked. Snow-Catting was difficult where snow lacked cohesion. Wider and longer front skis are recommended to increase the bearing surface. Discussion by Fred Paget.

Author Abstract

Western Snow Conference Bibliography

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BIBLIOGRAPHY

SOME OBSERVATIONS ON FALL SOIL MOISTURE DEFICITS UNDER FOREST COVER AND THEIR RELATION TO THE WINTER SNOWPACK

Goodell, B. C.*

Proc. WSC 1948: Pgs. 152-156 Reno, Nevada, April 15-17

Discussion by Rocky Mtn. Forest & Range Exp't Sta., Fort Collins, Colo.

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Author Abstract

Western Snow Conference Bibliography
The economic aspects of snow

Chief

Irrigation in many areas depends largely on water stored in the form of snow. The average precipitation during May to August at Montrose, Colorado is 37.2 inches. The delay of nearly 33% of the streamflow is attributed to snow accumulation. The result of experimental timber cutting at the Rocky Mountain Forest & Range Experiment Station at Fort Collins indicate that moisture stored can be increased approximately 25% by planned cutting on dense, high altitude forest lands. The Forest Service anticipates that timber cutting experiments may change the early snow melt and increase the streamflow through fall. Snow is an important economic consideration in the generation of power by streams.

Author index

1. Stewart, D. N.

Subject index

1. Snow - economics
2. Snowmelt & runoff

Author index

1. Burdick, R. T.

I. Annual snowfall averages range from 15.4 in. to 389.4 inches. The result of experimental timber cutting at the Rocky Mountain Forest & Range Experiment Station at Fort Collins indicate that moisture stored can be increased approximately 25% by planned cutting on dense, high altitude forest lands. The Forest Service anticipates that timber cutting experiments may change the early snow melt and increase the streamflow through fall. Snow is an important economic consideration in the generation of power by streams.

Subject index

1. Snowmelt & runoff
2. Precipitation gage - shielded
3. Snow evaporation

Author index

I. Peasley, P.
II. Garstka, W. U.
III. Goodell, B. C.

*Civil Engineer, Corps of Engineers, Oakland, Calif.

**Hydrologist, U.S. Weather Bureau, Oakland, Calif.
Frazil and Anchor Ice

Farrow, R. C.*

Proc. WSC 1949: Pgs. 31-36

2 References

Denver, Colorado, April 26

Frazil ice is formed in turbulent streams when temperatures are below freezing. Needles of ice form on the surface and are submerged by the turbulent water forming a turbid mass of ice and water. Slush ice is caused by heavy snowfall on open water that is near or below freezing point. Slush ice chokes intakes, penstocks and turbines, necessitating the closing of power facilities to clear the pipes. Experiments with steam to combat ice at intakes have proven expensive and inefficient. Compressed air forced through the water at the intakes has been effective. Anchor ice forms most rapidly on dark colored streambeds of turbulent streams on cold clear nights. Anchor ice never forms under the cover of sheet ice. Anchor ice will thaw loose and float away during days of bright sunshine and form again on very cold clear nights.

Discussion by Ralph L. Parshall.

Studied on Shielded Snow Gages

Warnich, Dr. C. C.*

Proc. WSC 1949: Pgs. 37-44

4 Photos; 1 Plate

Cooperative research was conducted by the Univ. of Idaho, the Bureau of Reclamation, and other agencies to improve high altitude precipitation gages and their windshields. A smokewind tunnel was built at the Univ. of Idaho to study the action of wind around gages. A ventilating fan produced wind velocities of 20 Mi/hr. and smoke was generated by forcing dry air through a bottle of TICl4 and combining the vapor with moist air. One-quarter scale models of Sacramento-type and Standpipe-type gages with and without shields were placed before the approach section to study the path of the airstream. Field studies were started Sept. 1948 near Mullen Pass on the Idaho-Montana border. Two standpipe gages, two Sacramento storage gages and one Stevens-type Q13 recording winter-precipitation gage, equipped with various shields are being used. Results are as yet inconclusive.

Discussion by J. C. Stevens.

Science and Adventure

Church, Dr. James E.*

Proc. WSC 1949: Pgs. Appendix i-xiii

An autobiography relating to Dr. J. E. Church's scientific and humanitarian accomplishments in the field of ice and snow from 1895 through 1949. His foundation of the Mt. Rose Observatory in 1906 and early concepts of a relation to conservation of snowmelt and runoff to forest type and methods of timber cutting. The first authentic water supply forecasts of the rise in Lake Tahoe in 1910-1911, and listing of six elementary steps as an outline for forecasting procedures. Glacier ice melt does not add materially to the annual streamflow, only the snow melt on top of the glacier. Snow fall, ice and temperature measurements on the Greenland ice cap; snow survey conferences in Russia; snow surveys in India's Himalaya Mountains; snow surveys and water forecasting in the Andes of Argentina and Chile are discussed. International friendship in science overpowers political intrigue. Snow surveys and water supply forecast schemes for the Rhine and Rhone rivers with headwaters in Switzerland are of interest to Holland.

Discussion by I. Church, Dr. J. E.
Three radioactive snow gages were installed in the experimental area at the Central Sierra Snow Laboratory, during December 1949. A gage tube was held by a 20-ft. truss arm attached to a 50-ft. pole. A lead shielded collimator embedded in concrete beneath the truss arm held 2 units of radioactive Cobalt 60. Impulses of the gage tube were amplified and transmitted over a 150-ft. cable to the recorder in the main laboratory. Largest sources of error was in variation of background impulses caused by cosmic rays. Four of 7 -- 5 min. counting periods each day gave accuracy within 2 to 3%. Water films of less than 0.01 in. to 55 in. can be measured by means of beta emissions from Strontium 90, and gamma rays from Cobalt 60.

A system of avalanche hazard forecasting was established in 1938 at Alta, Utah by the U. S. Forest Service, based on the snow research of the service. The objective was to provide snow rangers with a simple and logical method of forecasting critical avalanche hazard conditions and to develop protective measures. Hazard forecasting is a continuous process of observation of 10 avalanche factors, old snow depth and surface, new snow depth, type and density, rate of snowfall, wind force and direction, temperature developments and snow settlement. These factors are variables which operate singly and in combination, and may even have a simultaneous plus and minus effect. It is possible that some of the Alta techniques can be used by Snow Surveyors.
A review of regulations for operating Hoover Dam to meet legal requirements is presented. Economical operation of the dam in conjunction with power and irrigation requirements and maintaining discharge releases to inhibit flooding below the dam are described. Maximum flow downstream from the dam is limited to 40,000 cfs which adds another restriction in releasing large volumes of flood control water. Storage space above the dam also has its control height to guard against use of spillswys, thus a loss of power. Inflow volumes to the reservoir are forecast for each month January through July. The forecast scheme is designed for temperature and evaporation factors. Various months use different weighting of factors to meet the conditions. Accuracy is high in the first few months but improves considerably in the later months. Tables and graphs illustrate the procedure explained in the text.

Discussion by Gerald B. Levin.

*River Control Office, U.S.B.R., Boulder City, Nevada

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

A REVISION OF FORECASTING METHODS AS PRACTICED BY THE CALIFORNIA COOPERATIVE SNOW SURVEYS

STRUSS, FRED A.*

Proc. WSC 1950: Fgs. 49-59 Boulder City, Nevada, April 17-18
5 Tables; 10 Graphs; 2 References

A revised procedure for forecasting runoff, basically a modification of the direct method of the California Cooperative Snow Surveys, is presented. The snow-water content, as measured by snow survey procedures, of the basin, adjusted to April 1 conditions is calculated as a percent of normal cover on that date. Corrections in this index figure are made for precipitation during the runoff period, for basin streamflow, for April temperatures at different snow courses and for soil priming. Streamflow forecasts, accurate within 10%, can be made from the corrected snowpack index.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

A DAY'S CONTRIBUTION TO THE SNOWMELT HYDROGRAPH

BERTLE, F. A.* and DUNFORD, E. G.**

Proc. WSC 1950: Fgs. 60-64 Boulder City, Nevada, April 17-18
1 Table; 2 Graphs; 1 Map

Recent work performed on the analysis of 1 day's contribution to the snowmelt hydrograph is summarized. The data are part of the Cooperative Snow Investigation of the USBR-USFS at Frasier Exp. Forest, and cover separately the St. Louis Creek and the Pool Creek drainage basins. The total runoff from each day's melt is defined and all measurements are correlated to the total volume of runoff from the one day's melt using the combined data from 1948 and 1949. The relationship of the first day's volume to the total volume is plotted. A definite break is apparent with the double mass curve of accumulated first day volumes vs. accumulated total daily runoff at the point representing the maximum runoff for the year. It is suggested that the 2 parts of the melt season, before and after the peak, be considered separately in establishing correlations.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

METEOROLOGICAL INVESTIGATIONS OF THE EFFECTS OF SEEDING CLOUDS FOR INCREASING PRECIPITATION

GRANT, LEWIS O.*

Proc. WSC 1950: Fgs. 65-70 Boulder City, Nevada, April 17-18
1 Table; 2 Graphs; 1 Map

Techniques for segregating the effects on precipitation of cloud seeding with dry ice and silver iodide are investigated. Weather records of Phoenix, Arizona for 1937-1947 were studied with respect to temperatures at different levels, stability of the atmosphere, winds, pressures at different levels, tropopause heights, and surface dewpoints. The weather records were compared with the results of seeding clouds during July 1948. Rain was observed after several of the seeding operations. Ground generators of silver iodide have given more consistent positive results than seeding by aeroplane.

*American Institute of Aerological Research, Pasadena, Calif.
The Precipitation Control Company of Phoenix, Arizona was formed to develop and perfect the mechanics and techniques of increasing precipitation. Silver iodide from airplane generators is used to seed super-cooled clouds. Calcium chloride is used to cause clouds to thicken and precipitate in non-super-cooled clouds. Ground generators have not proved successful. A technique called "Advanced Air Mass Seeding" is used on days which appear to be favorable for cloud formation. Small clouds are seeded early in the day, preparing them for precipitation as soon as the clouds cool to the critical temperature. Two or 3 times as much rain is produced due to generation caused by reflected heat from the ground and rising air currents. Over-seeding in cloud structures is often brought about by smokes and vapors with subsequent loss of normal precipitation. The installation of precipitating and cleaning equipment in smoke stacks is recommended to increase the efficiency of seeding by silver iodide.

-President, Precip. Control Co., Phoenix, Arizona
A practical method for making predictions of volumetric yield and flood discharges from snow is presented. Available data on the water stored in snow in the spring and during subsequent precipitation are obtained from 43 selected snow courses. The predictions are accompanied by estimates of error and probable limits within which the real yield or flood discharge is likely to fall, by statistical means. Two-thirds of the total error in predicting peak discharges is in the error associated with the relation of flow volume to snow water. Later season forecasts become progressively more precise. The effects of early season temperatures on peak discharge were indirectly evaluated by subtracting April volume from the estimated April-June volume, and relating flood discharges only to the remaining amount expected to flow during the last part of the 3-month period.

Discussion by Clarence Pederson.

*Supervisor of Snow Surveys, SCS, Medford, Oregon
**U.S. Forest Service, Portland, Oregon
***Soil Conservation Service, Boise, Idaho

Procedures for refining total seasonal runoff forecasts as the snowmelt season progresses are presented on the basis of temperature and runoff data. Methods described were developed for operation in the Seminole Reservoir in the North Platte River Basin, Wyo. The principle of snowmelt runoff variations with changes in temperature is used to develop mass curves of accumulated values of degree-days of melting temperatures against accumulated daily inflow to the reservoir. The mass curves have a striking similarity in shape. The possibility of comparing accumulated runoff expressed in percent of total seasonal runoff with accumulative degree-days of melting temperature are investigated. Cumulative snowmelt runoff distribution graphs are developed. A definite relationship is found to exist between the percent of seasonal snow melt and cumulative temperature.

Discussion by Walter U. Garstka and Milton S. Sachs.

#U.S. Bureau of Reclamation, Denver, Colorado
A discussion of 13 basic characteristics, necessary for a universal proposed mechanized over-snow vehicle for use in snow surveys, is presented. A suggested relative numerical rating for each characteristic is included. These characteristics, in the order of importance, are: (1) mechanical dependability, (2) ability to travel on soft or sticky snow, (3) ability to traverse steep side slopes, (4) ability to operate on ground bare of snow, (5) ability to ascend steep grades, (6) maneuverability, (7) ability to quickly surmount obstacles such as fallen trees, (8) economy of operation, (9) speed, (10) ability to ford open flowing streams, (11) safety, (12) portability, and (13) comfort for 2 men.

Discussion by George J. Klein.

Klein, George J.*

The objective of the Canadian Snow Cover Survey was to obtain data on the physical features of the snow cover at a number of observation stations, and to provide a basis for future studies of the fundamental properties of snow. The method followed at each station consisted of digging a test pit in the snow cover once each week and measuring temperature, specific gravity, free-water content, hardness and average size and shape of snow grains. Air temperature, snow cover depth and the location of the snow layers were also determined. Standard snow classifications were used. Some of the results obtained show that air temperature and wind had a decided influence on the condition of the snow cover, while the effects of sunshine were small. The specific gravity of settled snow was usually between .25 to .35 and for wet settled snow the specific gravity rose as high as .45, at temperatures below freezing.

Discussion by Dr. J. E. Church, Jr.

Klein, George J.**

Several examples are used to show the benefits derived from the work being conducted by the Soil Conservation Service in the Federal-State-Private Cooperative snow surveys and irrigation water forecasting. Nearly 200 different organizations participate in the program through the contributed funds, labor or data. The method used by the Soil Conservation Service to measure the water in the snow storage reservoir for establishing a relation between snow cover and runoff is explained. Typical benefits derived from the use of snow surveys and streamflow forecasts are cited, such as reservoirs operated for irrigation, hydroelectric power, flood control, recreation and other beneficial conservation uses are shown.

Discussion by W. A. Lang, J. R. Riter, F. B. Blanchard and G. W. Templeton.

Church, Dr. J. E.*
LOCALIZED EFFECTS INDUCED BY SEEDING SUPERCOOLED CLOUDS WITH DRY ICE AND SILVER IODIDE  
SCHAEFER, VINCENT J.*  
20 References  
Condensation nuclei as condensation centers for the formation of cloud droplets. An automatic recording, condensation nuclei is used to detect the extreme variability in concentration of such nuclei. The seeding of clear air, supersaturated with respect to ice, with suitable nuclei causes the formation of ice crystals large enough to have a falling velocity within less than 1 min. after seeding. Various techniques of seeding stratus or cumulus clouds, using dry ice or silver iodide are described. Accounts of actual aerological seeding experiments made, and results obtained are indicated.

*General Electric Research Laboratory, Schenectady, New York
Correlations of temperatures with snowmelt runoff from a watershed during the spring floods are presented. The establishment of correlations are discussed by which temperatures for April, May, June, might be forecast from data available on April 1, with sufficient accuracy to estimate the form and sequence of snowmelt runoff. The methods forming the basis for such forecasting are presented. A forecast for the flow of the Boise River in the spring of 1951 from 28-year temperature data of Idaho City is made using average 5-day values of daily maximum temperatures. A satisfactory correspondence between the forecasted and the actual hydrograph is evident.

Earlier analyses of techniques for water forecasting in the Columbia River Basin found both water yields and flood discharges to be highly correlated with the water content of snow as determined by snow surveys, and with spring precipitation. The present study demonstrates that the addition of preceding fall precipitation expression the degree of soil priming and the extent to which autumn affect in soil moisture are replenished by precipitation before the snowpack accumulates each winter. The inclusion of the soil-priming variable, as compared to previous analyses, made a 40% improvement in the standard error of the forecast made on April 1 of each year. Similar improvements in precision were observed for later forecasts made on May 1 and May 15.
Eight test plots, 10x10 ft., covered with 10 in. of snow, were evenly spread with soot varying from 0-10 lb. per plot. Snow depth and water content were measured with a sampler at the center of each plot before applying the soot and again 4 hrs. later. The temperature ranged from 22° to 6°F during the experimental period. The greatest decrease in snow depth occurred in the plot covered with 1 lb. of soot. The rate of decrease in snow was almost twice as great on the sooted spots than on clear plots. No significant difference in the decrease of water content was found. Lampblack was applied experimentally on the Kaiser Pass road on March 30, 1951, at the rate of 10 lbs. per 100 sq. ft. as a method of snow clearance in spring. The danger of spreading the soot too thickly and preventing melting is pointed out in the discussion.

In discussion Dr. Robert W. Gerdel points out some interesting references on the subject of "Unconventional Methods of Snow Removal".

*Lahlum, Lt. Col. A. H.*

*Hydrographer, Southern Calif. Edison Co., Los Angeles, Calif.*

*SIPRE, Willmette, Illinois*

*U.S. Weather Bureau, San Bruno, Calif.*
METHODS OF EVALUATION IN CLOUD SEEDING
ELLIOTT, ROBERT D.*
Proc. WSC 1952: Pgs. 73-79 Sacramento, Calif., April 21-22
2 Maps; 14 Graphs; 4 References

Cloud-seeding experiments are hard to evaluate because of difficulty in segregating artificially created effects of seeding from natural processes. Control areas in the immediate vicinity which, from previously established records, are not liable to produce abnormal precipitation, should be chosen. It becomes increasingly difficult to find a control area which is not influenced by another cloud-seeding operation conducted nearby.

*North American Weather Consultants, Pasadena, Calif.
A historical and progress report on snow survey activities in the Northeastern States is presented. The measurement of snow and snow-water equivalent was done in upper New York State as early as 1834 by John B. Jervis, for the purpose of estimating possible water supplies for reservoirs that regulated water for the Chenango Barge Canal. He also established the first two streamgaging stations in the United States in 1835 on Eaton Brook and Madison Brook, however records are not continuous. Charles A. Mixer made some snow-water equivalent measurements in 1900, but were not continued. Continuous records were started in 1926 following the procedures outlined by Dr. J. E. Church, Jr. The growth of snow surveys in the Northeast States has been consistent over the passing years and the application of the data has increased steadily, similar to those in the Western States. No irrigation uses are reported, however, forecasting from snow surveys is common for power production, flood control and reservoir regulation.


A NEW PROGRAM OF COORDINATED FEDERAL-STATE WATER SUPPLY FORECASTS

WORK, R. A. * and POLOS, ANTHONY J. **

Proc. WSC 1953: Pgs. 4-5 Boise, Idaho, April 20-22

An attempt is made to coordinate the water supply forecasts of the Soil Conservation Service, the U. S. Weather Bureau, and the British Columbia Dept. Lands and Forest, Div. of Water Resources, and the California Department of Water Resources. The plan being to compare forecasts of all agencies, before issuance, where data is prepared for the same gaging station and runoff period. The coordinated forecasts would then be released to operating and regulating water users in general. Thus eliminating confusing statements and varying figures. Plans are also made for mutual cooperation on research to produce better and more reliable forecasts through joint membership of the Water Forecast Committees for the major river basins in the Western United States.

* Head, Water Supply Forecast Unit, SCS, Portland, Oregon
** Head, River Forecast Center, USWB, Portland, Oregon

Photographic observational techniques for snow surveying the Columbia Basin under study by the Weather Bureau are described briefly. Twelve stations for obtaining photographs by cooperative observers were in operation in 1952 and 1953. No conclusive results are given, but comparison of photographs obtained in 1952 with the daily streamflow suggest favorable results.

*U.S. Weather Bureau, Portland, Oregon
A report is presented showing the usefulness of snow survey forecasts in pre-planning or industrial operations in the mid-reaches of the Columbia River. Mention is made of the dangers of population crowding into the seldom used flood plain of the large rivers and the difficulties of saving life and property when occupants cannot see the potential dangers. Conditions existing before and after the 1948 flood are depicted. Examples of flood warnings are shown in the text and documented for date and time.

*Water Resources Development Corp., Denver, Colorado

**EVIDENCE OF MAN-MADE CLIMATIC CHANGE**

KRICK, DR. IRVING P.*

Proc. WSC 1953: Pgs. 11-18 Boise, Idaho, April 20-22

5 Charts; 1 Reference

Cloud seeding to produce additional snow water content in the snowpack of the Upper South Platte and Arkansas River Basins in Colorado is explained. Detailed meteorological and physics of cloud characteristics for cloud seeding are described. Evaluation is based on statistical methods, using a 10 year period of snow survey water content data prior to seeding and comparing the 3 years of seeding data of snow surveys conducted during this period. Claims are made that seeding increased the snowpack by 200% over the basic 10 years, while other basins to the south along the Rocky Mountains did not show this increase during the seeded last 3 years. Charts illustrate the 3 years of seeding operations and location of river basin target areas.

In discussion Milton S. Sachs points out that good results are shown in increasing the snowpack by cloud seeding in the Northwest along the Cascades and Rockies. He states that large scale operations are more effective and not so difficult to evaluate.

*General Electric Corp., Richland, Washington

**AN APPROACH TO STREAMFLOW FORECASTING**

FULCHER, MARTIN K.*

Proc. WSC 1953: Pgs. 18-23 Boise, Idaho, April 20-22

4 Tables; 1 Graph; 2 References

A water supply forecast scheme is presented for the Colorado River above Grand Canyon. A statistical study of 9 tributary streams resulted in a decision to treat each tributary by itself and then route them by correlation procedures for a collective forecast at Grand Canyon. The Green River above Linwood is used as the pilot study. Data from 10 precipitation stations were weighed by the Thiessen method. These data were used as soil priming factor from the preceding fall months. Snow survey data from 9 courses was used for April 1 forecasts. Fall and winter temperatures through March were used as a temperature factor. Multiple regression formula are solved with the 4 variables, resulting in a multiple correlation coefficient of 0.918.

*U.S.B.R., Office River Control, Boulder City, Nevada
The use of precipitation measurements and snow survey data singly and combinations for forecasting is discussed and applied to the North Fork Clearwater River in Idaho. An average error of 8.7% was obtained using precipitation data alone, and 4.6% when combined with snow survey data. Forecasts issued by the Weather Bureau in January, February and March will use only precipitation data but April and May forecasts will also utilize snow survey data where applicable.

In discussion Mr. Clarence Pederson indicates his approval of the combination of variables in the formula. However, he warns against using a precipitation period that extends beyond the date of the forecast. Using estimated or average figures invariably leads to trouble. Also reliable accuracy checks cannot be made by inserting the values of the variables used in developing the formula. If every 3rd or 5th data is omitted, and then a reliability check is made using these omitted, the check will be much more significant.

A largely empirical method for rapidly reproducing floods is described. The basic factors considered are: areal extent and depth of snow cover, maximum daily air temperature, precipitation, losses and the unit hydrograph. A natural and a computed hydrograph are compared with good agreement.

In discussion Dr. J. E. Church submits a series of letters soalitative observations made during July 1951 from elevations of 9000 - 14,000 ft. as well as instrumental measurements made on the crest of Mt. Whitney are discussed. Snow in an air-exposed pan melted about 1.7 in. in a 24 hr. period and in situ about 1.0 in. per day, and never exceed 10% of the total ablation. Results of observations indicate that considerable water evaporates from melting snow, but that the vapor loss is predominantly from moist soil and water surfaces, rather than from the snow surface.

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An abstract of this paper is available from the U.S. Weather Bureau, River Forecast Center, Portland, Ore.

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*U.S. Weather Bureau, River Forecast Center, Portland, Ore.

USE OF BASE FLOW IN FORECASTING RUNOFF DURING THE NON-FLOOD SEASON

McDONALD, C. C.

1 Table; 4 Graphs

A study is presented of streamflow for the period July through September for the Salmon River at Whitebird, Idaho as related to 'Base Flow' on July first. 'Base Flow' is considered to be the flow of a river after the snowmelt flood has drained from the soil and ground water aquifers and the recession graph has started to flatten off. Base flow on July 1 and precipitation during the period account for 97% of the variance in runoff. It is possible to forecast the total runoff from July through September within limits of error normally acceptable in water supply forecasting by means of base flow alone. The approach to each river would, of course, be different, but the theory holds. Relationships are shown graphically with probability and frequency curves being exhibited together with tabulated data and formula development.

# Staff Engineer, U.S. Geological Survey, Tacoma, Washington

CONCEPT AND CHARACTERISTICS OF BASE FLOW IN THE COLUMBIA RIVER BASIN

SIMONS, WILBUR D.*

Proc. WSC 1953: Pgs. 57-61      Boise, Idaho, April 20-22
5 Graphs

Potentialities of using the base flow depletion curves as a parameter in streamflow forecasting are presented, especially for predicting fall and winter flows. Five factors are listed that are related to fluctuations in streamflow. Procedures for separating the hydrograph into its component parts are shown, particularly the recession limb. Procedures for constructing the base flow depletion curve are illustrated.


BASE FLOW AS A PARAMETER IN FORECASTING APRIL-JUNE RUNOFF

NELSON, M. W.*; McDONALD, C. C.** and BARTON, MANES***

9 Tables

A preliminary analysis using base flow of the preceding fall as a parameter in forecasting snowmelt runoff during April - June period for major tributaries to the Columbia River is presented. Three separate forecasting formulas were developed for each stream; first, using water content with April-June flow; second, using April 1 water content and Nov. 1 base flow with April-June flow; and third, adding April precipitation. Statistical parameters for the 12 equations are tabulated and discussed. Base flow was found to be highly significant. April precipitation is not significant especially when it must be estimated for the April first forecast. In basins of low elevation headwater precipitation carried more weight. Base flow proved to be an integrating factor of difficult to measure variables, evapotranspiration, soil moisture and ground-water storage.

# Soil Conservation Service, Boise, Idaho
**U.S. Geological Survey, Tacoma, Washington
***Oregon State Agr. Expt. Station, Corvallis, Oregon
The duties and aims of the newly appointed advisory committee on Weather Control are explained in some detail. Reference is made to PROJECT CIRRUS, dealing with weather modification and the present state laws regulating weather modification in 7 western states and New York State. Reports of the committee will be unbiased and built on true facts of gathering and research project findings. In discussion Mr. Robert D. Elliott points out occurrences of possible bias in weather modification reports and expresses willingness to furnish information from western operators.

The paper is discussed by Mr. Perry M. Ford.

During the past 50 or 60 years, the U. S. Geological Survey, Surface Water Branch, has operated 12,500 stream gaging stations, about half of these are active today. Those discontinued were found to be either excess or correlations with other stations could supplement the data without serious damage to the records. Consideration is being given towards this procedure at many stations. The benefit-cost ratios are being studied, where the operation and maintenance costs have gone up. The cost-benefit ratio is an important factor in how long a station should be operated. Primary stations on main rivers will, of course, be maintained. Examples of statistical methods employed are described and illustrated graphically. Optimum benefits occur in the first 5 years with maximum benefits occurring in about 15 years.

The paper is discussed by Mr. Perry M. Ford.
A description and illustration of correlation techniques is presented, that the U. S. Geological Survey is using in making studies of streamflow relationships. The procedures are illustrated by a study of two basins about 68 miles apart, but both having similar hydrologic characteristics, and located in northeastern Utah. Data is tabulated and analyzed on a monthly basis by statistical methods using the usual parameters as a means of comparison. In discussion Mr. R. D. Goodrich presents a solution of streamflow correlation from a different section of the country, but obtained comparable results.

Low winter streamflow as an index to short-term and long-term carry-over effects in water supply forecasting.

A study is presented of minor indices effecting annual streamflow volume forecasting in the Intermountain West. Time trend of precipitation measurements with streamflow also time trends becoming evident by gradual increases of water-use and evaporation losses. The carry-over effect of groundwater storage was found to be related to size of figures representing the low-flow period or winter stream flow, i.e., February. This low-flow value is shown to be an integrator of minor indices, expressing ground water and soil moisture conditions. Mr. C. C. McDonald in discussion intimates that the date of base flow must be selected so that the actual measured flow data is available to the forecaster when needed, and that an estimated value plus or minus average will greatly affect the degree of correlation, also that the trend of streamflow is related to base flow.
An analysis is presented of observations in mid-July over a continuously melting snow patch in a dense forest during five days of clear, calm weather. Each heat component is evaluated from measurements (including supplementary estimates), of long-wave and short-wave radiation, of free air temperature and humidity at a meteorological station, and on rather crude measurement of condensation and of air temperature gradients close to the snow. The snowmelt equivalent of heat supply is compared with measured ablation. Approximately 50% of melt at the snow surface was due to long-wave radiation, 20% to convective heat, 15% to latent heat of condensation and 15% to short-wave radiation. Thus, 85% of the melt was accounted for by air temperature and humidity, ordinarily available at a meteorological station, and 15% by short-wave radiation which can be estimated from records of insolation elsewhere. The results of the study are formulated in a melt equation involving only linear functions of air temperature, humidity and short-wave radiation.

Discussion by Walter U. Garstka.

#U.S. Corps of Engineers, Portland, Oregon

WATER YIELD FROM SNOW AS AFFECTED BY CONSUMPTIVE WATER LOSSES

CRADEDD, GEORGE W.*

Proc. WSC 1954: Pgs. 70-73 Salt Lake City, Utah, April 19-21 1 Table; 7 References

Watershed management procedures are shown to be effective in conserving snowmelt water, producing forage crops, reducing sediment in streams, and controlling herbaceous plants on high watersheds of the inter-mountain western region. Deforestation was found to produce only temporary relief to gain a greater snowpack that produced more water with greater transpiration and increased the siltation of streams, especially during heavy summer rain storms. A grass mixture of smooth brome, timothy, Kentucky bluegrass, dandelion and sweet clover proved the most effective soil cover and forage producing vegetation. Advantages are cited on range land in the intermountain watershed studies.

BOYER, PETER B.*

Proc. WSC 1954: Pgs. 54-70 Salt Lake City, Utah, April 19-21 2 Tables; 4 Photos; 6 Graphs; Formula development; 12 References

The results of the study are formulated in a melt equation involving only linear functions of air temperature, humidity and short-wave radiation. The April-Sept. precipitation as an independent variable is difficult to evaluate when the forecast is made on April first, where the forecaster must use a normal or average figure, or attempt to estimate a plus or minus normal figure. This variable alone carries a large weighting factor and a misestimate could spell disaster in forecasting the inflow to Hungry Horse Reservoir.
USE OF MELT-SEASON SNOW SURVEYS
KOELZER, VICTOR A.*
Proc. WSC 1954: Pgs. 86-89 Salt Lake City, Utah, April 19-21
1 Graph; 2 Tables; 2 References
A method of interpreting results of snow surveys after the start of snow melt is given, and use of the procedure is illustrated for a section of the North Platte River basin. This involves relating the amount of snowmelt to the amount of snow measured at given dates after the melting season commences. Regular melt season surveys are recommended for areas with present and planned substantial control structures.
In discussion Mr. Homer J. Stockwell points out the need for snow survey data during the melt season. He also points out the possibility of including soil moisture data during the late season forecasts, particularly on streams where substantial control structures are planned.

EFFECT UPON SEASONAL RUNOFF FORECASTS OF MEASUREMENT ERRORS IN BASIC DATA
DEAN, W. W.; FROST, W. T.** and KUEHL, D. W.***
Proc. WSC 1954: Pgs. 90-94 Salt Lake City, Utah, April 19-21
2 Tables; 4 References
A study was made of random sampling errors inherent to hydrologic data used for statistical development of multiple-linear regression formula to forecast the probable season water supply. Random errors were induced into basic data of both the dependent and independent variables and multiple linear equations were developed. The usual statistical parameters of correlation coefficient and standard error were compared with those formula developed where the obvious random errors were NOT induced. These tests indicated that the introduction of errors in the magnitude chosen did not cause any large effects in the regression equation. It is suggested that every effort be made to gather and use data without errors in measurement and keep hydrologic data up to standard.

*Hydrologist, U.S.B.R., Washington, D. C.
**Snow Survey Leader, SCS, Portland, Oregon
***Meteorologist, U.S.W.B., Portland, Oregon
ABSTRACT: "WATERSHED MANAGEMENT OPPORTUNITIES IN THE WEST"

COLMAN, E. A.*

Illustration used in talk not available in paper printed.

A discussion is presented relative to the conservation of water producing areas of the State of California, to meet the anticipated needs of expanding population, agriculture and industrial development. The water producing areas of the state are divided into 4 zones: (1) the brushland belt occupying 17.5% of the state's area and producing 12.0% of the water supply, (2) the timber belt below the snow line 3,500 to 5,000 ft. elevation comprising 12.5% of the state area and supplying 33% of the state's water supply, (3) the timber belt zone in the snowpack area with 9.0% of the state's area and producing 38.0% of the water supply, (4) the alpine zone covering 3.0% of the state's area producing 14% of the water supply. Conservation practices are outlined for water and snowpack management in these zoned areas for planning more economical use of the products of water supply.


BIBLIOGRAPHY

WSC No. 279-55
Catalogue No.
CRREL No.

SUBJECT INDEX
I. Watershed mgmt.

AUTHOR INDEX
I. Colman, E. A.

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A REVIEW OF THE FIRST 10,000 ABSTRACTS PREPARED BY THE SIPRE BIBLIOGRAPHY PROJECT

SHERROD, JOHN JR.*

Proc. WSC 1955: Pgs. 2-3 Portland, Oregon, April 13-15

The Snow and Permafrost Research Establishment (SIPRE), Corps of Engineers, U. S. Army, through its support of the SIPRE Bibliography project at the Library of Congress, is preparing and publishing abstracts of all technical literature on snow, ice and frozen ground. The details of this extensive project is explained, as well as the type of material abstracted and catalogued for reference. Translations of papers published in foreign languages are also included in the project. A table of time and language distribution of papers is shown. The abstracts and reference material is published in book form, 8x10 paper cover and staple bound, with 1,000 to 1,500 abstracts per volume.

Bibliographer's Note: These abstracts are also duplicated on 3x5 library reference cards. The above volumes are released in January and July of each year and as of 1965 there are 25 volumes. An cumulative index CRREL report No. 12 was released in June of 1964, however, each volume has its own index. At this time there are approximately 40,000 abstracts prepared and published on a variety of more than 4000 subjects.


WSC No. 279-35
Catalogue No.
CRREL No.

SUBJECT INDEX
I. Snow and ice

AUTHOR INDEX
I. Sherrod, J. Jr.

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OBSERVATIONS ON THE NISQUALLY GLACIER, WASHINGTON AND GRINNELL, JACKSON AND SPERRY GLACIER, MONTANA

GILES, GORDON C.* and COLBERT, JESSE L.**

Proc. WSC 1955: Pgs. 3-6 Portland, Oregon, April 13-15

Data collected during various periods back to 1857 on the terminal recession, changes in surface elevation, and surface movement of these glaciers are discussed. Nisqually Glacier receded about 4900 feet since 1857 at an average rate of 50 feet per year. The surface elevation has risen 83 feet between 1945-51. Other detailed data is included since more interest has been shown in glacier activity. Little change has been observed in Sperry and Grinnell although Grinnell has retreated 30 to 40 feet per year since 1949. Sperry is considerably less active.

*and**Hydraulic Engrs., U. S. G. S., Tacoma, Wash.

WSC No. 281-55
Catalogue No.
CRREL No.

SUBJECT INDEX
1. Glacier

AUTHOR INDEX
I. Giles, G. C.
II. Colbert, J. L.

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ESTABLISHING SNOW SURVEY NETWORKS AND SNOW COURSES FOR WATER SUPPLY FORECASTING

CODD, ASHTON R.* and WORK, R. A.**

Proc. WSC 1955: Pgs. 6-13 Portland, Oregon, April 13-15
1 Graph; 3 Photographs

The purpose of snow surveys and the planning of survey networks are discussed. Factors determining the type of snow course network, the number of snow courses, and measurement schedules are outlined. Criteria for the selection of the snow course location are examined, including: elevation, water production of the area, relation to other snow courses, accessibility, and the physical characteristics of the site. Conditions influencing the accuracy of runoff forecasts, such as the variability of water equivalent of snow, the number of snow samples taken, the relation between the snow course and its environment, and the marking of sampling points are considered.

Discussion by J. H. Doughty-Davies and F. M. Veatch.

*Snow Survey Supervisor, SCS, Bozeman, Montana
**Head, Water Supply Forecast Section, SCS, Portland, Oregon

WSC No. 282-55
Catalogue No.
CRREL No.

SUBJECT INDEX
1. Snow survey

AUTHOR INDEX
I. Codd, A. R.
II. Work, R. A.
III. Doughty-Davies, J.
IV. Veatch, F. M.
An illustration is cited of the economic value of snow survey water supply forecasting, for an irrigation project dependent upon reservoir storage from snow melt or pumping from the Flathead River with a fixed maximum load rate. The lower the maximum load, the lower the yearly power rate. Water supply forecasting is accomplished using snow survey courses in the Mission Range in western Montana, and other hydrologic variables, temperature and fall precipitation. A series of multiple regression formulas were developed for forecasts to be made on March, April, May, and June. In the spring of 1950 cold weather delayed the runoff well beyond the usual May and June dates. Low snow had disappeared into the soil and the prospects for sufficient snow water looked bad, even in the face of snow survey data for April showing an above normal water content. Starting the pumps would throw the power rate for the year into the highest bracket. Faith in the forecasts prevailed, and on July 2 warm temperatures arrived, canals and reservoirs were full and all reservoirs were filled in one week. Actual money savings of $35,000 in power bills was made.

*Chief, Surface Water Branch, U.S.G.S., Washington, D.C.

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**USE OF ELECTRICAL SOIL-MOISTURE UNITS IN MOUNTAIN SOILS**

Horton, J. S.*

Catalogue No.

CRREL No.

Proc. WSC 1955: Pgs. 20-26 Portland, Oregon, April 13-15

1 Table; 3 Graphs; 23 References

A procedure for measuring soil moisture at several depths in a mountain soil mantle using fiberglass, monel metal units (Colman Units) is presented. These units have a thermometer (temperature element) enclosed in the monel metal case. Three wire leads are brought to the surface through a pipe to prevent rodent damage. The meter is an alternating current design circuit to measure impendence in mill-amps, thus avertting a direct resistance reading that would be contaminated by soil salts or acids. The mill-amps readings are converted to Ohms by a calibration chart furnished with each meter. The process of calibrating the units to soil moisture by field and laboratory procedures, is discussed. Calibration curves are exhibited. A discussion of results is included in the text of the paper.

*U.S. Forest Service, Missoula, Mont.

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**AN INSTRUMENT FOR MEASUREMENT OF THE DENSITY OF PLANT COVER OVER SNOW COURSE POINTS**

Ingebo, P. A.*

Catalogue No.

CRREL No.


1 Photograph; 1 Graph; 2 References

An instrument and method of measuring the percent of vegetative cover, (forest canopy cover, overstore cover) are described and illustrated. The instrument consists of an inverted aluminum frustum of a cone with diameters of 12 and 6 inches. A silver ball is centered near the bottom and an eye piece is mounted on one side to observe the reflection of the hemisphere on the silver ball. A dot-grid is mounted on the top 1/2" diameter, the grid is quartered and circles at 15°, 30°, and 45° from the vertical are drawn on the grid. By looking through the eye piece the dots that are covered by trees or leaves are counted by quadrants and segments and tabulated. The instrument is leveled and oriented (N). A graph illustrates the percent canopy cover to percent of snow accumulation in the open and under the trees of differing percent cover as a result of some 750 observations.

In discussion Dr. Paul E. Lemmon describes a similar hand held instrument.

*U.S. Forest Service, Vicksburg, Miss.

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**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

**FORECASTING NATURAL RUNOFF IN RELATION TO PUMPING FOR IRRIGATION**

Peak, G. W.*

Catalogue No.

CRREL No.


An illustration is cited of the economic value of snow survey water supply forecasting, for an irrigation project dependent upon reservoir storage from snow melt or pumping from the Flathead River with a fixed maximum load rate. The lower the maximum load, the lower the yearly power rate. Water supply forecasting is accomplished using snow survey courses in the Mission Range in western Montana, and other hydrologic variables, temperature and fall precipitation. A series of multiple regression formulas were developed for forecasts to be made on March, April, May, and June. In the spring of 1950 cold weather delayed the runoff well beyond the usual May and June dates. Low snow had disappeared into the soil and the prospects for sufficient snow water looked bad, even in the face of snow survey data for April showing an above normal water content. Starting the pumps would throw the power rate for the year into the highest bracket. Faith in the forecasts prevailed, and on July 2 warm temperatures arrived, canals and reservoirs were full and all reservoirs were filled in one week. Actual money savings of $35,000 in power bills was made.

*Snow Survey Leader, SGS, Casper, Wyoming
A recently developed method of forecasting runoff of streams where snowmelt is the predominant factor in the flood hydrograph is described. This procedure was developed on the basis of data for the years 1943-45 and 1950-52, which included both large and small seasonal volumes and high and low peak flows. Radiosonde temperatures provided the basis for most of the temperature parameter, and daily increments of total computed runoff from snowmelt and rain were divided into 2 components: surface runoff and ground water runoff. The method permits computation of an entire seasonal hydrograph without reference to the observed hydrograph, once the snowmelt season has begun. Other day-to-day factors are involved. The procedure was tested on the Payette River, Idaho with satisfactory results.

*Hydrologist, U.S.W.B., Portland, Oregon

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A water supply forecasting scheme to define and illustrate the general principles governing the economics of operation for hydro-power plants, reservoirs, and certain other water works are shown. The many alternate selections of operating schedules are explained and shown by examples of actual data. Water supply forecasts are an important factor in these estimates to produce the maximum of returns to the operators. Antecedent precipitation and precipitation frequency charts are illustrated together with percentile positions to enter a nomogram to arrive at the moneys to be anticipated from an assumed schedule of operation. Several trial runs must be made and judged by the results as to which schedule is the most feasible to follow. A general outline for the procedure is shown in a list of 8 steps to be followed.

*Manager, Water Resources and Planning Division, East Bay Municipal Utility Dist., Oakland, Calif.
Snow Survey the average error for the April forecast 5.5%; May forecast 3.9%; the same 7 stations was averaged. For the three comparative years.

For the Columbia River at Birchbank, B. C. The formulas are checked equation.

developing seasonal (April-Sept.) water supply forecasting formulas

W. Nelson, M. W.* and Simons, W. D.**

The method for forecasting runoff in this British Columbia watered (500 sq. mi.; to 7000 ft. elevation) is described. The source of data forecasting were snow surveys, precipitation records at the townsites.
The results of investigations and tests of a method for determining the free water content of snow by measuring compacted density are reported. Best results were obtained by inserting snow loosely in one-inch layers in a 250 cc. container and tamping each layer 4 times by dropping a 1 kg. weight 10 cm. A good relation was found between free water content and compacted density, especially for settled and coarse spring snow as well as water content above 5%; below 5% there was more variation in the relationship. The rate at which compacted density increases with water content above 5% was compared for different types of snow. Fine-grained snow tended to compress to a higher density than coarser snow. The advantage of the method is that it gives information on the physical structure of wet snow during the tests.

The thermodynamic relationships involved in forest transpiration in snow-covered areas during non-advective weather are analyzed using data from the 1949 melt season (May 9-13) in the Willamette Basin Snow Laboratory and assuming that net advection, net basin energy change, and net moisture content change of the air and soil are nil. The energy used for transpiration is computed as the difference between the net all-wave energy change with space and the energy required for melting snow. The transpiration loss is found to consume about 50% of the net input energy to the basin, amounting to an average of 0.14 in./day (about 10% of melt) for the period investigated. Condensation water undergoes a repeated cycle of evaporation and condensation, aiding the transpiration process by supplying water to vegetation and aiding melt by returning some of the total transpiration energy to the snow. Data on the magnitude of the processes involved in the transpiration loss, including melt components are tabulated.

The method described and a sample forecast for the Feather River, California is presented. The forecast formula or graphs are based on data for the April-July spring runoff period, during which most of water occurs. The general parameters used include: the measured water content of the snowpack at high elevations, the carries from previous years in the form of ground water, and late season precipitation. A "percentage of normal" index (the normal based on a 30-yr. period) is used to convert raw data into a form readily adaptable for use in the multiple graphical relationship, permitting rapid calculation for an approximate forecast. Data on the normal precipitation and snowpack expectancy are graphed, and a forecast diagram and forecast computation form for the Feather River are included.

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The results of past studies on the relation between snow and forests are reviewed and tabulated, and problems of future research are discussed. The forest is located about 6000 ft. elevation and has an average annual precipitation of 30-40 inches, 60-80% of which is in the form of snow (which accounts for 80-90% of the annual streamflow). The first studies conducted were concerned with the relation between snow accumulation and the size of openings in various types of forests, and the effects of deforestation with snow evaporation; the question whether evaporation from intercepted snow is actually sufficiently faster than from the pack surface to account for the apparent gain in snow when trees are cut; the blowing of snow from tree crowns, and its possible sublimation during transit.

Other projects will include: convection and condensation during snowmelt, the effects of tree trunks and small trees on snowmelt, the hydrologic effect of any forest management practice, and the water yield from alpine snowfields.

*Forester, U.S.F.S., Fort Collins, Colo.

**SNOW HYDROLOGY SUMMARY REPORT**

JOHNSON, OLIVER*

Proc. WSC 1956: Pgs. 42-43 Penticton, B. C., April 17-19

The Corps of Army Engineers, North Pacific Division, at Portland, Oregon, in cooperation with the U. S. Weather Bureau have produced a report of field studies completed by the Cooperative Snow Investigation program. These studies were conducted by the two agencies at three snow laboratories in differing climatic conditions in the Sierra Nevada, Cascade and Rocky Mountain areas. This report deals with the many problems involved in snow hydrology. The summary report consists of 12 chapters. Detailed text of the report includes tabulated data collected, graphs and formula development for solving complicated theories. An outline of the 12 chapters is included. Copies of this report are available from the Division Engineer, Corps of Army Engineers, Portland, Oregon.

*Hydraulic Engr., Corps of Army Engineers, Portland, Oregon
A discussion of problems involved in operating the facilities of the California State Water Plan is presented. Reservoir storages are operated to obtain the maximum flood protection as the prime function together with meeting the other demands of the multiple use project of controlling streamflow for navigation, irrigation, hydroelectric power production, salinity control, municipal water supplies, fisheries management and recreation needs. In California most of the water in the many streams has been allocated for a given set of soil conditions, geologic conditions, vegetative characteristics and climate. Vegetation densities are studied for better quality and quantity of water from rainfall and snowmelt. Studies that result in greater contribution of water from an area for a given set of soil conditions, geologic conditions, vegetative characteristics and climate. Vegetation densities are studied for balancing water yield from medium altitude zones of brush land where 25 years of records are available. Plot studies proved inadequate and as a result pairs of small watersheds were substituted that proved to produce more responsive data. A tabulation is included showing values and types of vegetative cover, soils and treatment applied. Data are also shown in graphical diagrams.

Water conservation practices are described that produce more and better quality and quantity of water from rainfall and snowmelt. The use of underground storage of water as an important part in the over-all plan of operation. Graphs illustrate the advantage of conjunctive planning.
An analysis of snow cover distribution, depth and water content, indexed according to storms or dates, terrain characteristics and forest types and percent cover is presented. Data collected by the Cooperative Snow Investigations (see WSC Paper No. 199-48). The data collected from 32 snow survey courses was cataloged into categories as listed. Statistical methods were applied and the values of various statistical parameters are tabulated and shown on graphs to express the results of the analysis.

An electronic computer for automatic data processing (ADP) of climatological data as applied to Weather Bureau records and other applications is discussed in length and detail. The card punching programs of the Weather Bureau in cooperation with National Defense agencies is described together with the gigantic project of assembling such data at the New Orleans unit. After World War II two programs were continued. These are listed below.

The need and demands for card deck copying and distribution is growing by leaps and bounds by requests from many private companies, agencies and private operators. Such demands have necessitated the transfer of much of the data to TAPE operated machines for greater speed of computation.

How the wind blows during periods of snowfall is important in understanding the manner in which snow accumulates among trees and in open areas, and on slopes of varying inclination and orientation. Winds are predominantly southerly when snow falls at the Central Sierra Snow Laboratory near Donner Pass. The valley of Castle Cr. in which the laboratory is situated has a typical mountain-valley wind regime, northwest down the valley in night and morning and southeast up the valley during afternoon and evening. Data for wind travel and direction were analyzed during the period of 1947-48 and winter of 1957 finding a marked similarity of wind direction and precipitation values. Greater portions of precipitation fell during the southwest wind directions by two thirds greater. Less than 2% of precipitation fell during calm periods. Data are tabulated and graphed on wind rose diagrams.
A new approach to streamflow forecasting is described clearly and applied to the 1956 field data. The resulting forecast for that year was only in error by 9% of the observed runoff.

In discussion Mr. George R. Hamburg and Mr. H. Boyd Phillips pointed out the advantage of this seldom used forecast procedure for working with inflow to reservoirs.
Snow surveys of a more complex procedure than usual are used in conducting research on glaciers to determine: (1) an understanding of the hydrology of glacier covered regions and (2), the use of glaciers as a quantitative indicator of climate. Research project information gathered by the Geological Survey indicate the possibility of a backward look at climatic factors of past years. Data trends shown graphically for snow accumulation or ablation of the glacial ice.

Then use machine core drills for deep examination of the strata of glaciers. But more often dig pits into the snow covering the glacier to ice, and 13 of the variables listed for an April-September runoff period forecast. The snowpack data is added.

Snow surveys on the glaciers at times use standard tubes but more often dig pits into the snow covering the glacier to ice, then use machine core drills for deep examination of the strata of the glacial ice.

A report of the advantages of helicopter travel as a means of reaching remote snow courses by snow surveyors of the Dept. of Water Resources, California is presented. With the advancement of helicopter design and construction this mode of over-snow vehicle is being used extensively and sufficient data has been accumulated to attack the problem from an economic standpoint, as compared to foot travel and over-snow surface vehicles. The savings of time such as measuring 10 snow survey courses in one day as compared with 10 back breaking days by foot travel. Of course advantage must be taken of weather for flying. There seems to be no way to evaluate safety as both means of travel have their own safety hazards, and manpower fatigue falls into this same category. Large savings are made in eliminating overnight cabins, construction and maintenance. The speed with which data can be transmitted to the forecasting office has some consideration.
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

HELICOPTERS - FROM THE FIELDMAN'S VIEW

DEAN, WILLARD W.*

Proc. WSC 1957: Pgs. 71-72 Santa Barbara, Calif., April 17-19

The U. S. Geological Survey presents an economic study of using helicopters for over-snow transportation into remote locations of streamgaging stations and snow survey courses. Data is presented on helicopter use, contracts with operators and details of the working plans for the seasons snow survey and stream gaging schedules. A tabulation of operation statistics is shown.

*Hydraulic Engr., U.S.G.S., Sacramento, Calif.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

THE SANTA BARBARA RANDOMIZED CLOUD SEEDING PROGRAM

ELLIOTT, ROBERT D.*

Proc. WSC 1957: Pgs. 73-76 Santa Barbara, Calif., April 17-19
1 Location Map; 1 Photo; 1 Table; 1 Reference

The seeding program began in January 1957 and is scheduled to continue for 3 years. The organization, history, operations thus far conducted, and the manner in which the seeding is carried out under the randomizing plan are discussed. No complete statistical analysis of results can be accomplished prior to completion of the project. However, thus far (Jan. 10 - Apr. 12, 1957), 4 storms have occurred yielding over an inch of precipitation in the mountains. Of these, two were seeded completely and one partially. The ground based silver iodide smoke generator layout and the recording rain gage network are shown on the location map.

*President, North American Weather Consultants, Santa Barbara, Ca.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SOME POSSIBLE EFFECTS OF SEEDING CONVECTIVE CLOUDS

DENNIS, ARNETT S.*

Proc. WSC 1957: Pgs. 77-78 Santa Barbara, Calif., April 17-19

In order to determine possible effects of cloud seeding, the life history of a typical shower must be considered. This paper discusses the formation of convective clouds and the formation of solid and liquid precipitation within them. It is pointed out that if the cloud forms are seeded with silver iodide, the precipitation process starts earlier, and that the seeding of convective clouds with silver iodide reduces the intensity of hail storms and can often eliminate hail entirely. It is still uncertain whether or not continuous seeding by ground generators can increase the rainfall at the ground. Selective cloud seeding requires high flying aircraft and a high degree of skill in judging the condition in the cumulus clouds. However, there is some evidence that seeding convective storms reduces their electrical activity.

*Weather Modification Company, San Jose, Calif.
SNOW REMOVAL PROBLEMS IN THE PROVINCE OF BRITISH COLUMBIA

Dembiske, F. E.*


The problems of removing snow from roads and highways in British Columbia are outlined and the organization and equipment of the snow removal program are discussed. The most notable of the problems are due to the different types of snow that fall during a winter, an insufficient supply of skilled laborers, protecting the public on the roads during the winter, snow slides, winter communications and service between the districts and the snow removal headquarters, to say nothing of pressure groups. A discussion is presented on the planning of snow removal operations, organization of field crews in July together with budget data and clearances through the Provincial Departments. The most success is gained from well trained operators and selection of congenial personnel on crews together with a large portion of 'Spirit de corps'.

*Senior Maintenance Engr., Dept. of Highways, Victoria, B. C.

LYSIMETER STUDIES OF SNOWMELT

Hildebrand, Carver E.*

Proc. WSC 1957: Pgs. 94-105 Santa Barbara, Calif., April 17-19

An outline that summarizes the observations of the snowmelt quantities and meteorological parameters by which the several processes of heat transfer were evaluated, are presented. The results of the study are expressed in the form of melt coefficients which were verified by a comparison of actual snowmelt with that computed by these coefficients. Independent statistical analysis were also made. The data tabulations list the snowmelt and heat transfer parameters for each day of the period study. The snowmelt quantities were measured by a lysimeter shown in two photos. Construction drawings are shown and tabulation of data collected are also included.

*Hydraulic Engineer, U.S.C.E., Portland, Oregon
Snow outlining the areas under study. Instrumentation of study areas are pictured and described.

To improve snowmelt timing, equalize streamflow, reduce erosion and

The hypotheses that 5 measurements should be enough to characterize the water content of the snow course and that the MEDIAN of 5 measurements should provide almost as good an index to the snowwater equivalent as would their mean. Tests were made and verified by analysis in detail the individual measurements on a typical 19-point Sierra Nevada snow course for the last 15 years of record. The history and reliability of such snow course measurements are discussed.

The history and reliability of such snow course measurements are discussed. In discussion Mr. C. G. Wolfe and Mr. J. F. Hannaford defend the views of the field man's point of view that snow survey courses of water equivalent as would their mean. Tests were made and verified safety point of view.

Also the office forecaster would much rather have 5 samples taken at 500 or 1000 feet intervals up a basin, rather than 15 or 20 taken at one altitude.

The farmer water-users are taking an active part in the soil conservation service districts. A large number depend on snowmelt water for irrigation, reservoir storage, and water management. They are taking a keen interest in water supply forecast committee meetings and forecast bulletins issued primarily for localized use. These local bulletins and committee meetings show a marked economic impact on the farm crop planning, particularly when there is a short supply of water. Savings in farm operation can amount to as much as $378,850 in one year in one Conservation District by, (1) saving on land preparation, (2) selection of crops that use small amounts of water, and (3) good water management. Although this case may be an ideal situation, other districts can show a great savings by proper farm management and water conservation through the use of the localized forecast bulletin data.

The hypotheses that 5 measurements should be enough to characterize the water content of the snow course and that the MEDIAN of 5 measurements should provide almost as good an index to the snowwater equivalent as would their mean. Tests were made and verified safety point of view.

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Also the office forecaster would much rather have 5 samples taken at 500 or 1000 feet intervals up a basin, rather than 15 or 20 taken at one altitude.
An approach to the problem of forecasting spring runoff is described with particular reference to the conditions in the Gouin Reservoir in Quebec where a large capacity of 6.3 million acre-feet is required to regulate the flow for the 7 hydro-electric plants on the St. Maurice River with a total installation exceeding 2.0 million H.P. The preliminary work that led to the selection of the variables is described, and the frequency functions are discussed. The main advantages of the described method are that (1) the assumption regarding the total length of the flood period becomes unnecessary, and (2) a better understanding of the nature of the variables that influence the volume of the spring runoff is achieved.

The preliminary work that led to the selection of the variables is described with particular reference to the conditions in the Gouin Reservoir in Quebec and regulates the flow for 7 hydro-electric plants. A description of the use of electronic computer for routing procedures of water supply of the Lewis River in southwest Washington is presented, in connection with the Geophysical Year Program 1957-58. In discussion Mr. David Rockwood describes electronic computer procedures carried on by the Corps of Army Engineers in the North Pacific Division Office at Portland, Oregon. He mentions the many advantages of automatic data processing machines where large amounts of the data must be handled in a short time.

*Dept. Northern Affairs, Water Res. Branch, Montreal, Quebec

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

THE OPTIMUM USE OF WATER FOR POWER CALCULATED BY DATATRON ELECTRONIC COMPUTER

A description of the use of electronic computer for routing procedures of water supply of the Lewis River in southwest Washington is presented, in connection with the Geophysical Year Program 1957-58. The computer complex is described and read-out sheets are shown to present the data available to the operator of reservoirs and to meet the power demands.

An analysis is presented of runoff forecast methods and their accuracy, and the distribution of errors by algebraic sign. The results stress the importance of basing river flow forecasts on data obtained as close to the water source as possible. Data of the most simple and direct character are more efficient. The basic data, as gathered by snow surveys from the heart of the water producing areas generally result in the most accurate forecasts because it is a more precise method of sampling the greatest factor in streamflow production in mountainous western areas.

NOTE: A table showing the discrepancies between two basic principles of water supply forecasting was misplaced at the time of printing, but is shown in the 1959 Proceedings of the Western Snow Conference on page 34.
A discussion of the economic value of water supply forecasting is presented dealing with monetary values. It is pointed out that if "Economics is the science concerning the production, management, and distribution of wealth", then truly water to the farmer, in irrigated areas, is true wealth. This depending entirely on the possibility of furnishing reliable information as to data relating to; too much water or too little, together with time of delivery. It is pointed out that floods can be a liability without the foreknowledge of occurrence, and a credit if proper facilities are available for water management and planning through accurate information. An actual shortage season is described on one irrigation district where a savings of $378,850 was saved by adhering to the water supply forecasts and applying good water management to produce good crops despite the water shortage and the season was not a total loss.

# Evaluating the Economic Value of Water Supply Forecasting

**Author**: C. Blount

**Title**: The Economics of Water Supply Forecasting

**Conference**: Western Snow Conference

**Year**: 1958

**Abstract**

The paper discusses the forecast schemes used by the California Cooperative Snow Survey to forecast runoff during the April-July snow melt season, the problems encountered in the use of such schemes, and the basic considerations in the evaluation of a snowpack. The basin selected for study (Yuba Basin) and the methods of evaluating the snowpack are described, snow survey data from the basin are compared graphically, and a revised forecast scheme is presented. The results indicate that the evaluation of the snowpack on the basis of only a few selected courses may lead to unrealistic results. Graphs and explanations are shown to adjust the original forecast to include 5 independent variables. (1) Snowpack index adjusted for area-elevation, (2) varying precipitation and soil moisture, (3) runoff occurring prior date of forecast, (4) antecedent conditions, (5) forecast period precipitation estimate.

# Evaluation of Cloud Seeding Efforts in the Southern Oregon Cascades, 1952-1957

**Authors**: H. Barton, M. Manes

**Conference**: Western Snow Conference

**Year**: 1958

**Abstract**

Cloud seeding operations for the California Oregon Power Co. have been conducted by North American Weather Consultants for the past 7 years in the Southern Oregon Cascades. The purpose was to increase the mountain snowfall and, consequently, the summer streamflow for the production of hydroelectric power. The seeding methods and the climate of the area are discussed. Based on regression and percentile analyses of the data for the first 6 years of seeding, the following conclusions were reached. (1) the average April snow water content for 1952-1957 showed a 22% increase over the expected amount. (2) The average Nov.-March precipitation for the 6 seeding years showed a 22% increase over the expected amount, a nonsignificant increase. (3) The average April-July streamflow for 1952-57 was 4% higher than expected, a nonsignificant increase. (4) For 4 of the 6 seeding years, the highest percent of normal precipitation in the State has occurred in the Fremont-Peilis area, lending strong support to the thesis that a downwind effect exists beyond the target area.

# Water Supply Forecasting for the Missouri River Basin

**Authors**: O. Van Horn, C. Wolfe

**Conference**: Western Snow Conference

**Year**: 1958

**Abstract**

A streamflow forecast procedure for the Missouri River Basin, to meet the needs of the Corps of Engineers Division office at Omaha, Nebraska is described in detail. Snow survey and precipitation data were analyzed by automatic data processing system (ADPS). Problems encountered during the electronic computer developing the multiple regression equations are discussed, primarily the coding and decoding and negative values of multiple correlation coefficients. Tests were made for minimizing the effect of "Local Anomaly" and negative values are described. A system of dividing the Missouri Basin into snowmelt basins from predominantly rainfall basins proved satisfactory values for coefficients. The resulting scheme provided results well within the 20% limits.
A historical resume of snow surveying starting in 1914 in the Eastern States of the United States is presented, with references to snow observations recorded as early as 1899. A description of instrument development, tools and field procedures is presented. Water supply forecasting from snow survey measurements is described as handled in the early days of the science. Procedures are presented for distributing the data on a cooperative basis by several agencies and companies using the water supply forecasts. Although the data is not as widespread in the East, it is equally as important to the municipal water supply agencies and for use in supplying water to canals in the East.

A chronological history of snow surveying as originated by Dr. James R. Church Jr. at the Univ. of Nevada is outlined. This work began in 1906 with the measurement of high mountain temperatures and other climatological factors on Mt. Rose, Nevada, with the Nevada Agricultural Experiment Station cooperation. The development of new instruments for measuring the snow water equivalent (water content) of the snowpack in 1909 is described. A description of the application of snow water content to water supply forecasting is presented. A resume of the importance of water supply forecasting to irrigation in the West and hydroelectric power development, reservoir regulation, flood control and water management is presented.

A discussion by William A. Lang points out interesting historical details of organization and instrument development. Additional historical notations are mentioned by Walter Hopkins.
I. Stockwell, R. J.

1. Soil moisture forecasting

AUTHOR INDEX

I. Kohler, M. A.

1. Water supply forecasting

SUBJECT INDEX

Proc. WSC 1959: Pgs. 26-33 Reno, Nevada, April 21-23
4 Graphs; 1 Table; 6 References

A discussion and comparison of two basic theories of water supply forecasting, one based primarily on rainfall measurements and the other based primarily on snow survey water content measurements. The 1947-57 period of years is used for comparison. A close similarity of forecast accuracy of both methods is illustrated by graphs. The conclusion states that a combination of the two independent variables would produce a more accurate forecast. Reference is made to a similar paper presented in the 1958 snow conference, WSC Paper No. 328-58.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

PRELIMINARY REPORT ON EVALUATING THE UTILITY OF WATER SUPPLY FORECASTING

Kohler, Max A.*

Proc. WSC 1959: Pgs. 26-33 Reno, Nevada, April 21-23
4 Graphs; 1 Table; 6 References

Snow of soil are illustrated. The existing network of soil moisture ohms resistance to percent soil moisture in the several horizons stations in Colorado and New Mexico river basins are mentioned in as to location of measurement site and placement of units at regular intervals in the soil as a stack of units. A conversion chart of ohms resistance to percent soil moisture in the several horizons of soil are illustrated. The existing network of soil moisture stations in Colorado and New Mexico river basins are mentioned in connection with their use in water supply forecasting.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

USE OF SOIL MOISTURE RESISTANCE UNITS IN WATER SUPPLY FORECASTING

Stockwell, Homer J.*

1 Place; 1 Graph; 7 References

Soil moisture measuring units are used to sample the soil moisture condition under the snowpack. The data derived is used as a correction factor in preparing water supply forecasts when using water content snow survey data. Field installation procedures are discussed as to location of measurement site and placement of units at regular intervals in the soil as a stack of units. A conversion chart of ohms resistance to percent soil moisture in the several horizons of soil are illustrated. The existing network of soil moisture stations in Colorado and New Mexico river basins are mentioned in connection with their use in water supply forecasting.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

ECONOMICS OF EARLY SEASON SNOW SURVEYS

Hannaford, Jack F.

4 Graphs

Snow surveys made prior to the optimum date of April first are shown to be economical in value to water users, depending upon the use made of the early season forecast. Although snow surveys are expensive to make in some cases, the accuracy of the forecasts prepared from these data as compared to alternative forecasts based on other data is outstanding and well worth the expenditure. Purely graphical methods are used and illustrated by using the flows of the Kings River inflow to Pine Flat Reservoir, Calif.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

AERIAL RECONNAISSANCE OF MOUNTAIN SNOW FIELDS FOR MAINTAINING UP-TO-DATE FORECASTS OF SNOW MELT RUNOFF DURING THE MELT PERIOD

Parsons, Walter J.* and Castle, Glenn H.**

Proc. WSC 1959: Pgs. 49-56 Reno, Nevada, April 21-23
7 Graphs; 1 Table

A simple graphical method of determining the runoff volume to be expected after any date in the melt season by means of aerial surveys of the snow line is described and evaluated on the basis of a 6-year study of the Kings and Kern River basins in California. Snow line areas are sketched while in flight by using a transparent overlay on an aeronautical chart. Registration marks are placed on the overlay for use with subsequent flights. The areas are measured and the volumes computed. Water content of snow surveys are used to compute the volume of water remaining in the snowpack. This data is applied graphically to charts to determine the volume of water to be expected during the ensuing months of the runoff period. The resultant current forecasts had average errors of less than 10 percent during the critical period from 75-30 days before the end of the melt season.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SURVEY METHODS FOR MAINTAINING A RUNNING WATER SUPPLY FORECAST

Parsons, W. J.* and Castle, C. H.

I. Hannaford, J. F.

@ Abstract

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The results of studies in Calif. on the effects of various types of logging on the water yield from snow are reported. The studies were made on an 18.7 acre block cutting 300 ft. wide and 2500 ft. long, on a 1.71 acre block cutting 800 ft. wide and 1800 ft. long, and on a commercial diameter limit cutting. The controls were natural openings and forest stands. All three methods of logging increased maximum snow accumulation and decreased annual water losses. At maximum depth the strip cutting showed 10 inches more water than the un-cut forest, block cutting and the commercial cutting showed 5 and 7 inches more. The rate of snow melting was greater in the commercial cutting area than in the un-cut forest. Small amounts of snow remained longer in the un-cut forest. Summer soil moisture losses in soils 48 in. deep, were decreased by logging while the annual water yield from precipitation was increased.
need for reliable forecasts and the close cooperation of all agencies involved.

A discussion of meteorological occurrences of flood and drought over the Rio Grande River basin is presented. It is pointed out that for the lack of sufficient data to prove any long time or even short cyclic occurrences of weather pattern, the prediction lacks a solid mathematical basis. Historical data from archaeological findings are quoted. The beneficial use of short term (15 year) averages of snow survey, temperature, wind movement, and soil moisture data produce a good forecast of streamflow during the melt season. The economical value of advance information for regulating irrigation reservoirs is pointed out as a distinct value to both power and irrigation interests.

The Federal law under which the Corps of Army Engineers is authorized to enter into the construction, operation and regulation of flood control structures such as dams, levees, and river channel improvements of future streamflow management, is outlined. The three operational divisions of the Rio Grande River above El Paso, Texas are delineated on a map and the plan of regulation is described. The absolute need for accurate water supply forecasts from snow survey data, precipitation and soil moisture data is shown. Case histories and operational techniques are described showing further improvements of future streamflow management, is outlined. The

*U.S. Corps of Army Engineers, Albuquerque, New Mexico

*Chief Engineer, Middle Rio Grande Conservancy, Albuquerque, N.M.

A description of the processes used on the electronic computer for deriving multiple regression formulas using the many independent variables required in snow water supply forecasting is presented. The advantage of obtaining statistical relations between as many as 33 variables and streamflow figures within 15 minutes is shown. The detail results and procedures for developing a multiple regression formula for the Madison River at West Yellowstone, Mont. with explanation of results, are given. Reasons for the 4 different forecast periods, together with peak flow and number of days to exceed critical flows are described. Four tables are included to show the results of the statistical criteria and formulas used.

*Associate Hydraulic Engr., Calif. Snow Surveys, Sacramento, CA

# Abstract

# Abstract


# Abstract
A discussion pertaining to the use of electronic computer for developing multiple regression formula to be used in water supply forecasting. The economics of using the electronic computers, to save manhours, increase accuracy and have available a better selection of independent variables for use in the formula is brought out. Cost figures of manually operated calculators and the electronic computer handling the same problem, are shown.

Discussion by Robert T. Davis indicates a confirmation of the economic value of using electronic computers for developing forecasting formula. A step-by-step program for the computer is described and its benefits shown.

**AUTHOR INDEX**

I. Maxwell, L. M.
II. Warnick, C. C.
III. Beattie, L. A.
IV. Hespelt, G. G.

**SUBJECT INDEX**

1. Electronic computer
2. Water supply forecasting
3. Statistics
   - snow cover

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**CRREL Abstract**

The purpose of a hydrologic telemetering system is to provide data on snow melt runoff parameters from remote mountain locations at frequent intervals and at sites where such information is pertinent to operating reservoirs for flood control, irrigation, and power releases. The system is devised by the Engineering Experiment Station, University of Idaho at Moscow. The parameters selected for measurement are: total accumulation of precipitation, soil moisture, air temperature, snow quality (wetness), snow water equivalent, and snow depth. A description and photos of the systems are shown, also schematic diagrams of the electronic telemetering systems at the sending and receiving end of the system.

**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

APPLICATION OF THE ELECTRONIC COMPUTER TO SEASONAL STREAMFLOW FORECASTING

CODD, ASHTON R.* and FARNES, PHILLIP E.**

Proc. WSC 1960: Pgs. 21-23 Santa Fe, New Mexico, April 12-14

A detailed technical discussion of reservoir evaporation is presented with several criteria for reducing evaporation. A description of how monomolecular layers of several different materials reduce evaporation is presented, including the action of cetyl alcohol or hexadecanol. A description of the experimental work in this field is also presented, including the details experiment, and safeguards set up by the steering committee, that included, State and Federal Health Departments, Geological Survey and Bureau of Reclamation representatives. Work on other reservoirs was also indicated where the toxic effect of the monomolecular layer material might affect fish, water fowl, or other plant or animal life. The durability of the layer on reservoirs was studied. A substantial list of references of reports and other experimental programs is included with the paper.

**AUTHOR INDEX**

I. Codd, A. R.
II. Farnes, P. E.
III. Davis, R. T.

**SUBJECT INDEX**

1. Reservoir evaporation
2. Evaporation reduction

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The use of electronic computer for developing multiple regression formula to be used in water supply forecasting for developing, the formula is brought out. Cost figures of manually operated calculators and the electronic computer handling the same problem, are shown.

**AUTHOR INDEX**

I. Maxwell, L. M.
II. Warnick, C. C.
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**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

AUTOMATIC MEASUREMENT OF HYDROLOGIC PARAMETERS AT REMOTE LOCATIONS

MAXWELL, L. M.*; WARNICK, C. C.*; BEATTIE, L. A.**; HESPelt, G. G.***

Proc. WSC 1960: Pgs. 25-31 Santa Fe, New Mexico, April 12-14

The purpose of a hydrologic telemetering system is to provide data on snow melt runoff parameters from remote mountain locations at frequent intervals and at sites where such information is pertinent to operating reservoirs for flood control, irrigation, and power releases. The system is devised by the Engineering Experiment Station, University of Idaho at Moscow. The parameters selected for measurement are: total accumulation of precipitation, soil moisture, air temperature, snow quality (wetness), snow water equivalent, and the snow depth. A description and photos of the several procedures for measuring these parameters are shown, also schematic diagrams of the electronic telemetering systems at the sending and receiving end of the system.

**WESTERN SNOW CONFERENCE BIBLIOGRAPHY**

RESERVOIR EVAPORATION AND ITS REDUCTION

GARSTKA, WALTER U.*

Proc. WSC 1960: Pgs. 39-43 Santa Fe, New Mexico, April 12-14

20 References

A detailed technical discussion of reservoir evaporation is presented with several criteria for reducing evaporation. A description of how monomolecular layers of several different materials reduce evaporation is presented, including the action of cetyl alcohol or hexadecanol. A description of the experimental work in this field is also presented, including the details experiment, and safeguards set up by the steering committee, that included, State and Federal Health Departments, Geological Survey and Bureau of Reclamation representatives. Work on other reservoirs was also indicated where the toxic effect of the monomolecular layer material might affect fish, water fowl, or other plant or animal life. The durability of the layer on reservoirs was studied. A substantial list of references of reports and other experimental programs is included with the paper.

**AUTHOR INDEX**

I. Garstka, W. U.
and U.S. Forest Service (U.S.F.S.) snowpack management is shown to be the primary problem in the Northeast Vermont, forest type (hardwood or conifer). A map, graphs, and tables illustrate the wide scope of data analyzed. Flood protection through forested areas of different climatic areas in the United States.

Hoover, Martin D.*
Proc. WSC 1960: Pgs. 51-53 Santa Fe, New Mexico, April 12-14
One of four papers dealing with snow hydrology of water yield from forested areas of different climatic areas in the United States. A discussion of water yield problems from the Rocky Mountain areas of Wyoming, Colorado, and New Mexico is presented in relation to the Alpine Zone and Sub-Alpine Zone. These zones are described and their definite effect on water yield. Various methods of timber cutting effects are discussed. Wind movement of snow are mentioned as a serious problem. Studies in the White Mountains of Arizona are included in the discussion.

Western Snow Conference Bibliography

Prospects for Affecting the Quantity and Timing of Water Yield Through Snowpack Management in Southern Rocky Mountain Area

Hoover, Martin D.*
Proc. WSC 1960: Pgs. 51-53 Santa Fe, New Mexico, April 12-14
One of four papers dealing with snow hydrology of water yield from forested areas of different climatic areas in the United States. A discussion of water yield problems from the Rocky Mountain areas of Wyoming, Colorado, and New Mexico is presented in relation to the Alpine Zone and Sub-Alpine Zone. These zones are described and their definite effect on water yield. Various methods of timber cutting effects are discussed. Wind movement of snow are mentioned as a serious problem. Studies in the White Mountains of Arizona are included in the discussion.

Western Snow Conference Bibliography

Prospects in the Northeast for Affecting the Quantity and Timing of Water Yield Through Snowpack Management

Lull, Howard E.* and Pierce, Robert S.**
Proc. WSC 1960: Pgs. 54-62 Santa Fe, New Mexico, April 12-14 6 Plates; 4 Tables; 8 References
One of four papers dealing with snow hydrology of water yield from forested areas of different climatic areas in the United States. Water yield from snowpack zone for the States of New York, Vermont, New Hampshire, and Maine are discussed with relation to forest type (hardwood or conifer). A map, graphs, and tables illustrate the wide scope of data analyzed. Flood protection through snowpack management is shown to be the primary problem in the Northeast States.

Western Snow Conference Bibliography

Some Terrain and Forest Effects on Maximum Snow Accumulation in a Western White Pine Forest

Packer, Paul E.*
Proc. WSC 1960: Pgs. 63-66 Santa Fe, New Mexico, April 12-14 1 Table
One of four papers dealing with snow hydrology of water yield from forested areas of different climatic areas in the United States. An analysis of a four year study of the effects pertaining to snow accumulation. Size of year (above or below average), elevation aspect and percent canopy cover, all are shown to have a marked effect on the water yield from areas in the Northern Rocky Mountain forest covered watersheds in the Priest River Experimental Forest, northwest of Spokane, Washington. A curvilinear multiple regression formula was used to evaluate the individual effects of the several independent variables on snow water accumulation.

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Western Snow Conference Bibliography

A Look at Avalanche Control Structures in Europe

Martinelli, M., Jr.*
Proc. WSC 1960: Pgs. 67-70 Santa Fe, New Mexico, April 12-14 4 Plates
A discussion of four types of avalanche control structures observed in Switzerland, Austria and France. The first type of structure is built in the avalanche path to hold the snow in place. The second type is a set of baffles to deposit blowing snow and secure it in place. The third type is a retaining structure in the lower portion of the slide path to act as a buffer to retain the slide. The fourth type of structure is a deflecting type to turn the slide away from the ordinary path of the slide. The several structures are sketched and described on plates.

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A detailed description of plans for highway maintenance through avalanche areas across Rodgers Pass, British Columbia. Approximately 120 avalanche paths in 24 miles of highway are classified into four categories according to frequency of avalanche occurrence. A description of preventive or control measures for each category are suggested. Avalanche forecasting and warning procedures are explained together with plans for artificial release of small slides to prevent a disastrous avalanche. Maps and photographs depict the scope of the project.

A formal discussion of the paper is presented by W. M. Borland, who cites technical problems of avalanche control on highways leading over the Rocky Mountains of Colorado. Avalanche control by artificial release are discussed. Comparisons of Colorado conditions are made with those conditions found on Rogers Pass.

A detailed description of recently developed hydrographic equipment for measuring streamflow, is presented. Each of the following pieces of equipment are described and how the equipment is used to aid accuracy and economics of water measuring procedure. The electromagnetic velocity meter; the acoustical velocity meter; the bubble stream gage; the stream surface follower and recorder. The sonic flood measuring assembly and the digital recorder are depicted in photographs and diagrams. The theory of operation and performance of recorders are discussed. Plans are made for field testing these pieces of equipment and to re-design present concepts.

A statistical study of precipitation data covering a 40-year period (1917-1957). Data from 18 selected stations representing the arid west of New Mexico and Arizona. The several graphs are used to show the combined results of statistical parameters to show precipitation trends throughout the period studied. A comparison of annual summer and winter periods are made to further the trend study.

A report of extensive tests is presented dealing with drawbar pull; power efficiency; type of trackage; type of and number of grouser; type and spacing of bogie wheels. Highly efficient electronic sensing devices and recorders were used to collect the values of the various parameters above. A comparison of numerous factors involved are shown in graphs and tables with photographs of machines and various parts tested. Duplicate tests were performed on several makes, models, and sizes of vehicles.

A discussion is presented by Mr. R. A. Work, who also presented results of field tests made by snow surveyors of the Soil Conservation Service who use a variety of machines.
The Water Resources Branch, Canada Dept. of Northern Affairs and Natural Resources has made surveys of selected glaciers since 1945 to determine the effect of glacier variation on runoff. The glaciers selected for study were the Helm, Sentinel, and Sphinx, all of which are in Garibaldi Park, and the Kokanee and Illecillewaet glaciers in the Selkirk Mts. These glaciers were surveyed annually through 1950 and have been surveyed biennially since that time. In each case, reference points have been established and distances of the glacier forefoot from these points have been measured, or the forefoot has been mapped in relation to the markers. Camera stations have also been established. Since 1947, surface velocities have been measured by means of markers set in the ice. Changes of thickness have been measured by cross sections. Data on frontal variation of an energy budget conversion from climatological measurements of daily snow on the ground and precipitation gage values for a long period of record from the plains area of Alberta, Saskatchewan, and Manitoba, Canada were converted into usable data of snowmelt water yield. The lack of sufficiently long records of plains snow survey data necessitated the development of an energy budget conversion formula to make climatological records collected in the past useful for modern analysis work. Graphs, illustrations, and tables show the relationship of the parameters studied. A comparison of the Mountain snow sampling tube and the Prairie snow sampling tube are shown.

A discussion by Mr. T. A. J. Leach points out the establishment of five new snow survey courses within the Peace River catchment area to supplement the four existing courses now operating in the adjacent Fraser River Basin which have sufficient length of record to be used in forecasting. Other climatological factors will also be measured and reported.

A description of the Peace River power development project is presented with emphasis placed on the importance of economical reservoir operation. It is stated that presently developed water supply forecast schemes have an accuracy of 15 percent and that this accuracy will show an economical saving of a million dollars worth of power a year. Volumes of river flow up to 22 million acre feet are involved.

A discussion by Mr. T. A. J. Leach points out the establishment of five new snow survey courses within the Peace River catchment area to supplement the four existing courses now operating in the adjacent Fraser River Basin which have sufficient length of record to be used in forecasting. Other climatological factors will also be measured and reported.

Climatological measurements of daily snow on the ground and precipitation gage values for a long period of record from the plains area of Alberta, Saskatchewan, and Manitoba, Canada were converted into usable data of snowmelt water yield. The lack of sufficiently long records of plains snow survey data necessitated the development of an energy budget conversion formula to make climatological records collected in the past useful for modern analysis work. Graphs, illustrations, and tables show the relationship of the parameters studied. A comparison of the Mountain snow sampling tube and the Prairie snow sampling tube are shown.

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A study of runoff from reforested drainage areas in upper New York State where rehabilitated land was replanted to five species of conifers during a period of 25 years. A net decrease in total runoff is shown as well as a decrease in the size of the peak flow for most of the years of study. The reduction of peak discharges is attributed largely to the delayed melting of that portion of the snowpack which is not protected by forest cover, where 58% of the watershed had not been replanted.

Mr. Nedavia Bethlahmy presents a complete discussion of the paper, and indicates that the runoff pattern of the test basin had changed with time as compared to the control basin, also that the magnitude of peak flow had changed as much as 41 percent on the average.

Problems presented to an irrigation district manager when a critically low flow of water is forecast for the stream from which his district's supply is derived are discussed in detail. Economic problems arise either to obtain additional supplies from pumping or conserving the existing supply by rotation of demands and sometimes a loss of certain crops. The necessity of obtaining an accurate forecast of flows to the district supply point prior to occurrence so that plans can be made in advance is brought out in the discussion.
LOW-FLOW FORECASTS ON THE ROGUE RIVER

A critical low-flow forecast of the Rogue River is developed to meet demands of irrigation district management for information as to dates they could expect the river flow to drop below 900 cfs., when pumping operations must commence to satisfy water user demands. By using the date and height of peak flow the falling limb of the hydrograph is easily constructed to the 2000 cfs., and the coded number of days to reach 900 cfs., after March 20. Three graphs are exhibited to show the relation between variables used and the array of data is shown in tables with statistical parameters.

BENEFITS OF FORECASTING DATE OF LOW SNOW TO WATER USERS OF THE CARSON RIVER

Problems of the cattle rancher using water for irrigation from un-regulated streams where water rights regulations necessitate the shutting off of the use when critical flows are reached. These shut-off dates are critical to crop development and harvest, and play an important part in the operation of the economy. Also the date of probable shut-off of primary and secondary water rights can be forecast within reasonable degree of accuracy is a step towards great economy in farming the semi-arid west areas.

NEEDS FOR SPECIAL WATER SUPPLY FORECASTS TO MEET UNUSUAL WATER RIGHTS AND IRRIGATION REQUIREMENTS FOR THE SEVIER RIVER BASIN IN UTAH

A description of the Sevier River System with reservoirs and locations of gaging stations is presented. A resume of water rights by Court Decrees is included with details of a division into primary and secondary categories of rights with the water volumes proportioned by percentages. Winter storage as well as spring storage is apportioned by water rights. Return flow plays an important part in the operation of this desert river basin. Accurate volume flow forecasts are made from snow survey and precipitation gage measurements. Low-flow forecasts are very important in water apportionment.
A forecasting scheme is developed to satisfy the water rights problems existing along the Sevier River, Utah. When the river reaches its peak flow, the primary water rights are satisfied. As the streamflow gradually decreases the problem of satisfying the decreed water rights becomes more acute. The proposed forecasting will point out these deficiencies ahead of time so that rotation of irrigation demands can satisfy the demands. A percentage of the primary water rights are delivered so that all users receive their just portion of the available water. Because good records are available for most of the Sevier River, it has been possible to develop these forecasts within reasonable accuracy. In some cases, better diversion records and more streamflow records would have been helpful.

A resume of available data on the components of the heat budget of the Arctic Ocean surface shows that radiative interchange with environment is the dominant factor. The presence or absence of an ice cover influences the nature of this interchange and also the relative importance of evaporation to the budget. On the basis of these figures a conjecture is made as to the cause of events in the artificial removal of the ice cover. It is shown that the ice would re-establish itself under presently existing conditions.

In discussion Mr. Clarence Pederson points out the advantages of measuring the heat balance in the Arctic Ocean, and mentions possibilities of using the theory and instrumentation for snow melt problems in reservoir control of downstream water temperatures.
AERIAL SNOW DEPTH MARKERS CONFIGURATION AND INSTALLATION

MILLER, ROBERT W. *

5 Photographs; 5 Plates

A detailed description of aerial snow depth marker poles with cross-bars at 2 ft., intervals is shown in construction drawings and pictures. Site selection specifications are included in the text.

*Chief, Snow Surveys, Calif. Dept. Water Resources, Sacramento, CA

APPLICATION OF AERIAL SNOW COVER OBSERVATIONS TO FORECASTING FLATHEAD LAKE INFLOWS

THOMS, M. E.*

Proc. WSC 1962: Pgs. 6-12 Cheyenne, Wyoming, April 16-18
2 Tables; 4 Photographs; 1 Map; 3 References

A procedure is developed to forecast the potential inflow to Flathead Lake, on the Columbia River system in Montana by using the area covered by snow obtained by aerial flight and mapping during flight over the basin. The procedure is primarily for short term forecasting after May first. This information is used in reservoir regulation and management. The snow cover data is used in connection with temperature and current precipitation values. Reconstituted hydrographs are shown in comparison with observed hydrographs.

*Hydraulic Engr., USCE, Portland, Oregon

MEASURING SNOWPACK PROFILES WITH RADIOACTIVE SOURCES

GAY, LLOYD W.*

5 Graphs; 2 Tables; 8 References

Use of both gamma and neutron probes in appraising density of the snowpack is described, including some interesting effects in ice layers on density measurements. Data from the Mt. Rose snow sampling tube showed a smaller density than the readings made with the P-20 Gamma Probe. Data was also compared with readings made with a Nuclear-Chicago Model P-19 subsurface soil moisture probe and the SIPRE 500 cc. density sampling tube. All probe measurements were made from within an 1/4" aluminum tube.

In discussion Mr. V. E. Penton mentions the importance of more development work of the gamma and neutron probes for scientific research in snow density studies. He also points out that trouble can occur in using a metal casing for the probes, such as the condensation of excess moisture on the inner surface of the metal tubing.

*Research Forester, USFS, Berkeley, Calif.
A neglected aspect of hydrology is the snow caught in the forest canopy. Meteorological conditions existing during and after a snow storm are not conducive to evaporation. Visual observations and interpretations are available but few instrumental measurements have been made. Mechanical action is short-lived and effectiveness of snowfall has been studied.

In discussion Mr. M. D. Magnuson indicates that the shape of the type of snowflake could very well effect the clogging procedure of snow in the forest trees and that evaporation factors are at a low value after a snow storm.

Diurnal fluctuation of free-water and density occurs during the day melting period when the rate of snow melt is high and exceeds the capillary capacity of the snowpack. At night when the rate of melting becomes insignificant, the excess free-water drains from the pack. Snow samples were taken horizontally at one foot intervals of depth and at four hour intervals from the face of a pit dug 65 inches to soil surface. Samples were weighed for water equivalent and calorimeter procedures were used to determine free-water content. Vertical samples were also taken to determine the average density and water content of the pack for comparison.
A mathematical study is presented involving the fluctuation in effective precipitation and resulting effects on streamflow for the water year. Effective precipitation is defined as the total precipitation minus evapotranspiration for the water year. This investigation is made by random time series as a yardstick to the effective precipitation and streamflow. The statistical technique is exclusively the series correlation process, through the analysis of range and runs. The results of the study indicate a possibility of predicting future long-range water yields from the time series computations.

Water supply forecasts computed by objective procedures can be improved by modification prior to release by using methods based on several relationships. These techniques identify the forecasts which have a great probability of large errors and provide a basis for subjective quantitative adjustment. The relations are (1) adjacent basin plots, (2) carryover plots, (3) comparisons with auxiliary procedures of basically different derivations. The value of the method suggested increases in the unusual or abnormal year and tends to eliminate the possibility or reduce the magnitude of the "big bust".

In discussion Mr. Harry I. Hunter cautions against using only procedure or independent variable for developing a water supply forecasting formula, and states that a combination of variables may produce a more accurate and a better balanced forecast.
An objective forecast of the snowmelt hydrograph

McCallister, John P.* and Johnson, Ray**

Proc. WSC 1962: Pgs. 78-85
Cheyenne, Wyoming, April 16-18
2 Tables; 12 Graphs; 1 Reference

Subject index:
1. Water supply forecasts
2. Unit hydrograph

Author index:
I. McCallister, J.P.
II. Johnson, R.
III. Miller, D. L.

*and**U.S. Weather Bureau, Kansas City, MO

Economic considerations of water yield forecasting for the Salt River Valley, Arizona

Moore, Robert E.*

Proc. WSC 1962: Pgs. 86-91
Cheyenne, Wyoming, April 16-18
2 Maps; 1 Plate; 8 References

Subject index:
1. Snow survey -economics
2. Water supply forecasting

Author index:
I. Moore, R. E.
II. Ellis, J. D.

*Assistant Engr. Salt River Project, Phoenix, AZ
A runoff forecasting procedure has been developed utilizing knowledge acquired in snow research in the past 10 years. A weakness of the method is that temperature forecast can not yet be made for periods of 5 to 30 days in advance. For several snowmelt seasons, the snowmelt was determined from actual temperature data using a simple temperature versus melt relationship. Temperature was determined by averaging data for seven index stations ranging in elevation from 2710 to 5850 ft. Reconstitution of the snowmelt hydrograph for the Feather River at Oroville was made for the snowmelt season of 1952 and 1958. Aerial reconnaissance of the basin periodically during the snowmelt season will provide useful data on the retreat of the snow-ice during the melt season. Maps and charts illustrate the procedure.

A report of field tests of snow sampling is presented, using same and different cutters, and three different types of tubes. The Federal Standard duraluminum tubes; the Bowman Plastic tubes and the Rosen thick wall aluminum tubes with smooth couplings. Data from 150 paired samples is analyzed in the test. Comparisons of water content data taken with the three different tubes varied in some respect, however in most cases the Federal sampler showed a greater amount, especially in snow of 70 to 80 inches deep and 40 percent density, where the tubes had to be rotated to cut the packed snow and ice. The Inspection ports of the Federal tubes were found to be sufficiently large to scoop in sufficient snow to make the difference, while the 5/16 holes in the Bowman and Rosen did not seem to collect snow. The inside diameter of all cutters was checked and found to be very close to the standard 1.485". The Rosen sampler was heavy and awkward. The Bowman sampler was difficult to drive in deep, dense snow due to the large couplings.

A practical and economical measurement of soil moisture and temperature of soil has been developed utilizing electrical capacitance between monel metal and fiberglass cloth and a dielectric solution for changes in temperature, for the units planted at various depths in the soil. Considerable effort has been directed towards establishing a network of soil moisture stations throughout the mountainous areas of the Western U.S. Using calibration curves, meter readings are converted to soil temperature and soil moisture. Soil moisture and temperature data are used as an index to grass forage on the cattle ranges and timber management, for potential drought or flood conditions. Graphs and tables illustrate the procedure.

Subject Index
1. Water supply forecasting day-to-day

Author Index
I. Arvola, W. A. II. Raimundo, A. L.
BIBLIOGRAPHY

USE OF LAKE ROOSEVELT STORAGE TO LOWER RIVER TEMPERATURES
KRAMER, HARRY A.* and CORLEY, J. P.**
Proc. WSC 1963: Pgs. 28-37 Yosemite National Park, April 17-19
2 Tables; 2 Photos; 1 Plate; 6 Graphs; 3 References

A discussion of procedures used to lower the temperature of the water in the Columbia River below Grand Coulee Dam by releasing water from lower, cooler levels of the reservoir. This process improves the economics of using the cool water for downstream plants and also improves the fish habitat during the warm months of the year. Graphical analysis of thermoclines of the reservoir waters above the dam makes possible this operation.


SNOWFALL EXTREMES IN THE WESTERN UNITED STATES
MAGNUSON, MARVIN D.*
16 Tables; 2 Graphs; 7 References

A summary and meteorological discussion of snowfall records covering the eleven western States, as extracted from U. S. Weather Bureau records. Tabulations of data show greatest fall in 24 hours. Maximum monthly totals and probability of occurrence of dates, and amounts. First fall and last fall with amounts and probability of occurrence.

*Area Climatologist, USWB, Seattle, Wash.

SNOW PROBLEMS ON MOUNTAIN HIGHWAYS IN WASHINGTON STATE
STACKHOUSE, J. L.* and WEBER, FRED R.**
Proc. WSC 1963: Pgs. 51-54 Yosemite National Park, April 17-19

Highway snow maintenance problems are discussed with emphasis placed on avalanche control, flood washout and earth and rock slides along with extreme snowfall rates accompanied by high winds. Problems are overcome with corrective measures at bottleneck locations, adequate snow removal equipment, emphasizing properly trained and dedicated operators of this equipment.

*Maintenance Engineer, Washington Highway Dept.  
**Idaho Highway Dept.
A summary of avalanche control needs and procedures for structures, winter sports areas and trans-mountain highways is presented. A description of a high-altitude mining company avalanche control program is included. Comparisons of protection procedures and the economics of costs versus benefits derived are analyzed. Five elements of avalanche control are outlined and applied to practical problems.

Avalanche Control Specialist, USFS, Squaw Valley, Calif.

Highspeed Snow Removal Procedures

Taylor, Edward T.*

Problems presented by the growing need for quicker removal of snow from airport runways and highways are presented. Long jet runways and increased air traffic have complicated snow removal programs as has 4 lane divided highways. The technical aspect of snow removal is illustrated in tables and are analyzed in the text.

*Vice-President, American Snowblast Corp., Denver, Colo.
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SNOW SURVEYS OF THE WESTERN UNITED STATES WITH THE AID OF SATELLITE PICTURES

TARBLE, RICHARD D.*
Proc.WSC 1963: Pgs. 77-80 Yosemite National Park, April 17-19
13 Photographs

A description and illustration of pictures taken from TIROS IV Weather Satellite are exhibited and details explained in the text. A possibility of delineating the area of snow cover in particular river basins is explained. Repeat pictures could be made available to compute rates of snowmelt.

*U.S. Weather Bureau, Sacramento, Calif.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

HYDROLOGIC DATA TELEMETRY IN THE CORPS OF ENGINEERS

HANES, FRANK.*
Proc. WSC 1963: Pgs. 81-86 Yosemite National Park, April 17-19
4 Photographs; 2 Plates

A description of operational telemetering equipment used in eastern and mid-west areas for reservoir control operations and for streamgaging stations. Highly sophisticated electronic circuits and computers are used. Although costly to install, great savings are shown from data collected with remarkable accuracy and speed. Circuitry diagrams and pictures of some of the component parts are included to illustrate the procedures.

*U.S. Army Engineers, Waterways Expt. Sta., Vicksburg, Miss.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SNOW LINE MAPPING FROM HIGH ALTITUDE AERIAL PHOTOGRAPHY

FELGENHAUER, HAROLD*
Proc. WSC 1963: Pgs. 87-93 Yosemite National Park, April 17-19
3 Photographs; 1 Plate

Ultra modern aerial photography producing pictures of extremely high resolution is described in detail. Remarkably fine detail is achieved with specially designed cameras and extremely sharp, high resolution lenses to cover a broad area are used. Highly controlled photo processing, exceptional high grade negatives are used to produce reversed negatives for enlarging on rear view projectors for visual interpretation. The paper print method is seldom used because of loss of resolution and sharpness.

*Itek Corporation, Palo Alto, Calif.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

AFTER SIXTEEN YEARS

SCHAFFER, VINCENT J.*
Proc. WSC 1963: Pgs. 94-97 Yosemite National Park, April 17-19
17 References

A resume of weather modification research from the beginning in 1949 through the rush of cloud seeders and State and Congressional debates with pro and con claims of weather consultants with statistical proofs of more or less precipitation to the continuing fact that powdered dry ice and silver iodide crystals form a nuclei about which a raindrop can form provided there is moisture in the air or cloud, and can trigger precipitation. Case histories of interesting experiments and effects of triggering precipitation are cited. An imposing list of references are included.

*Research Consultant, ASRC
ABRUPT Shifts IN SEASONAL Runoff Relationships AS RELATIVE TO CLOUD SEEDING ACTIVITIES

ELLIOTT, R. D.* and WALSER, J. T.**

5 Tables; 3 Plates; 5 Graphs

The double-mass curve procedure is applied to streamflow records for areas subjected to cloud seeding for as many as 10 years to show a positive increase in run-off during those years of artificial cloud seeding. Areas were tested in Utah, California and Oregon, all with positive shifts of the double-mass curve.

*and**North American Weather Consultants, Santa Barbara, Calif.

INDICATIONS OF RESIDUAL EFFECTS FROM SILVER IODIDE RELEASED INTO THE ATMOSPHERE

GRANT, LEWIS O.*

5 Tables; 2 Graphs; 6 References

A study of the movement of silver iodide particles after release from generators is presented, together with analysis of residual nucleating effect associated with cloud seeding over the Continental Divide in Colorado. Ice nuclei concentrations were measured with a diffusion type cold chamber from 1954 to March 1960, then with an expansion type chamber from 1959 to date. Measurements were scheduled at non-seeding intervals; non-seeding periods and non-seeding intervals of six months. Data and graphs illustrate the analysis of information gathered.

*Colorado State University, Fort Collins, Colo.
HUMAN ATTITUDES IN SNOW SCIENCE

ROCKWOOD, DAVID M.*


A talk dealing with the philosophy and reasoning applied to physical occurrences represented by mathematical relationships. The snow scientist is urged to consider his responsibilities as a professional engineer serving others in this type of artistry through creative thinking and maintaining a humble attitude with respect to our basic scientific knowledge.

*Hydraulic Engineer, USCE, North Pacific Div., Portland, Ore.
Western Snow Conference Bibliography

An economical total precipitation telemetering system
Chadwick, Duane G.* and Pearson, Gregory L.*

Proc. WSC 1964: Pgs. 1-8 Nelson, B. C., April 21-23
1 Table; 1 Photograph; 3 Plates; 3 Graphs; 1 Reference

A progress report is presented dealing with a telemetering system for collecting precipitation data from remotely located shielded storage precipitation gages in Utah. The system consists of a large capacity rain gage, charged with anti-freeze solution and mounted on a tower with shield. The gage is supported on a central spring support with potentiometer attached for varying the frequency of a battery operated transistor radio transmitting system. The radio is read by over-flight airplane 5000 to 7000 feet above the instruments. The present system is in continuous operation; however an 'On Call' system is being developed and would be triggered by operation from the airplane. Successful operation data are exhibited in three graphs. Cost estimates are included with pictures and schematic diagrams of the system are shown.

Discussion by Glenn H. Castle.

Utah State University, Logan, Utah
Soil Conservation Service, Salt Lake City, Utah

Western Snow Conference Bibliography

Relationships between snow survey and climatological measurements
McKay, G. A.

Proc. WSC 1964: Pgs. 9-19 Nelson, B. C., April 21-23
2 Tables; 1 Map; 6 Graphs; 10 References

Snow survey data on the Canadian Great Plains are compared with snow precipitation measurements made at meteorological stations in the same area. The data are found to vary with the exposure of the rain gage location and or exposure of the snow course location. Net evaporation of the shallow snowpack is explored. Degree-day snow-melt relationships are based on maximum daily air temperature. Seasonal variability controlled by 'Threshold Temperatures' (that temperature above which melting tends to occur and below which melting is not likely to occur). These computations gave good results in relation to the snowpack budget.

Discussion by Donald W. Kuehl.

Western Snow Conference Bibliography

Development of a digital river basin model
Hannaford, Jack F.*

Proc. WSC 1964: Pgs. 20-26 Nelson, B. C., April 21-23
3 Graphs; Formula Development: 5 References

A new approach to developing a water supply forecasting procedure is presented. Use is made of an electronic computer programing for 20 years of records and including at least 9 variables consisting of streamflow by months, precipitation by months and antecedent precipitation at six gaging stations. Two river basins were selected to try the system, one of low elevation headwaters where rainfall is the predominant source of supply, and a second with high elevation where the source of supply is largely from melting snowpack. These basins were to represent the digital model. The general equation: Inflow minus outflow equals change in storage, was expanded and used as a basis for computation of factors for the model basin.

Discussion by C. H. Clay covers other factors effecting fisheries management and stream control.

Western Snow Conference Bibliography

Fisheries management of Yellowstone Lake, Wyoming as related to water supply forecasting
Farnes, Phillip E.* and Bulkley, Ross V.*

Proc. WSC 1964: Pgs. 27-32 Nelson, B. C., April 21-23
1 Map; 3 Graphs; 8 References

A unique application of water supply forecasting is developed for predicting the rise of Yellowstone Lake in Yellowstone National Park, as effecting the growth or decline in the production of cutthroat trout. The need for such foreknowledge is shown in a discussion of fisheries management procedures. The forecasting procedure was first derived graphically and later refined by electronic computer, multiple correlation procedures to use 4 independent variables, height and date of peak rise in the lake are forecast accurately.

In discussion Mr. C. H. Clay covers other factors effecting fisheries management and stream control.

Western Snow Conference Bibliography

AN ECONOMICAL TOTAL PRECIPITATION TELEMETERING SYSTEM
CHADWICK, DUANE G.* and PEARSON, GREGORY L.*

WSC No. 415-64
Catalogue No. 551.508
77:528.47:631.398
CRREL No. SIP 24269

SUBJECT INDEX
1. Telemetering precipitation data

AUTHOR INDEX
I. Chadwick, D. G.
II. Pearson, G. L.
III. Chadwick, G. H.

REFERENCES

WATER SUPPLY FORECASTING

HANNAFORD, JACK F.*

WSC No. 417-64
Catalogue No. 551.579.2:528.47
CRREL No. SIP 24271

SUBJECT INDEX
1. Water supply forecasting
2. Electric computer

AUTHOR INDEX
I. Hannaford, J. F.

REFERENCES

FISHERIES MANAGEMENT OF YELLOWSTONE LAKE, WYOMING AS RELATED TO WATER SUPPLY FORECASTING
FARNES, PHILLIP E.* and BULKLEY, ROSS V.*

WSC No. 418-64
Catalogue No. 551.579
2:528.47:639.2 (78)
CRREL No. SIP 24272

SUBJECT INDEX
1. Water supply forecasting
2. Fisheries mgmt.

AUTHOR INDEX
I. Farnes, P. E.
II. Bulkley, R. V.
III. Clay, C. H.
A brief review of papers presented at the Western Snow Conference over the past 10 years on statistical approaches for solving problems in snow hydrology. Seasonal and long-term variations in high elevation - low elevation ratios or winter precipitation amounts for selected stations in the western states are analyzed. The possible effects of such fluctuations on the indices commonly used in snow hydrology studies are discussed.

Author: Peck, E. L.*

*Hydrologist in charge, Water Supply Forecast Unit, USWB, Salt Lake City, Utah

A discussion of the various factors involved in water supply forecasting is presented with emphasis placed on present day concepts of possible ways to improve basic data collection methods. An appeal is made for expansion of networks of all types of factor measuring stations, towards an ultimate aim of obtaining accurate data of all factors from water producing weather, consumptive uses and return flows for further use.

Author: Mitchell, W. Bruce*

*Studies Engineer, Idaho Power Co., Boise, Idaho
Recommendations are made for expanding the existing network behind large dams and great reservoirs. The data are to be used primarily for flood control projects anticipated by the Corps of Engineers and power development by the Bureau of Reclamation. The State Dept. of Fish and Game and the Forest Service are cooperating in the establishment and maintenance of the courses and other hydrological data measuring stations. New problems in snow surveying are presented in the wide expanse of Alaskan wilderness, extreme cold, bad weather and poor visibility during the winter and spring months. The actual snow measurement of low density snow on frozen ground presents a problem of redesign of sampling equipment. A gradual expansion of the network is planned for the Rampart Dam project in cooperation with the Canadian Government.
Shannon: The exceptionally heavy snowpack of the 1964-65 season is described with data in the text, accompanied by a series of 24 color slides of snow conditions at snow survey courses (not duplicated in the paper). Reservoir storage as of April first in the Western United States is shown graphically and in tabulation for large reservoirs. Prospective streamflow for the April-Sept. runoff period is depicted on a composite map of the Western States.

Christensen: A description of weather conditions and precipitation patterns for the 1964-65 season is presented in the form of isohyetal maps of the Western States, covering 3 separate periods; October-January; Feb.-March; and Oct.-March. A fourth map shows the percent of average forecast of streamflow for the water year. Some facts relative to the Christmas flood 1964 of Northern California and Western Oregon are presented.

A discussion of hydrologic factors involved in producing snowmelt runoff towards water supply or flood development is presented. Forecasting methods and forecast accuracy are questioned with a plea for additional research into the possibility of measuring all factors involved more accurately. The lack of public knowledge as to the cost of water supply and the need for more understanding should be overcome. More basic data can be collected from isolated locations by instruments coupled to modern telemetering equipment.

Money for such an elaborate network of stations could be obtained by sufficient publicity and a better understanding of the needs and cost of fresh water throughout the nation. More accurate forecasts could be assured by the inclusion of accurate and more basic data.

Subject Index

1. Snowpack and precipitation
2. Water supply forecasts
3. Flood damage report

Author Index

I. Shannon, W. G.
II. Christensen, E. G.

Subject Index

1. Snowpack analysis
2. Economics

Author Index

I. Kelley, L. L.
At Mt. Hood, Oregon the Soil Conservation Service has developed and conducted evaluation tests of the pressure pillow approach to measuring the water content of the snow. The evaluation has indicated this method to be a practical and accurate method of measuring the equivalent water content of the snow. Installation procedures are described and shown. Comparisons between snow water equivalent by pressure pillow data and snow sampling are tabulated. A schematic diagram is shown of the recording and telemetering devices by which a continuous record is made of the snowpack accumulation and ablation; thus providing accurate data for streamflow forecasting and snowmelt computations. When installed above avalanche terrain such data would be valuable for avalanche prediction and safety control.

The precipitation gage described is designed especially for use in remote areas where precipitation occurs as rain, snow, or a combination of both, and where accumulation may be 100 inches or more between visits, which may be made only once or twice a year. Design emphasis has been on simplicity and reliability in order to provide a system which can be maintained with a minimum use of highly skilled personnel. A gas bubble system is provided to assist in mixing the precipitation with an initial charge of ethylene glycol to inhibit freezing and help melt incoming snow. Towers are designed for maximum strength combined with lightweight and easy installation. The radio communication system which provides on-call operation and uses solar cells to trickle charge the battery power supply is described. Operating problems and site selection are discussed.

**Supervisory Hydraulic Engineer, USCE, Sacramento, Calif.**

**Staff Specialist, Snow Surveys, SCS, Portland, Ore.**

**TELEMETERING PRECIPITATION GAGES FOR REMOTE AREAS**

CASTLE, GLENN H.*

2 Tables; 2 Graphs; 11 Construction drawings

The precipitation gage described is designed especially for use in remote areas where precipitation occurs as rain, snow, or a combination of both, and where accumulation may be 100 inches or more between visits, which may be made only once or twice a year. Design emphasis has been on simplicity and reliability in order to provide a system which can be maintained with a minimum use of highly skilled personnel. A gas bubble system is provided to assist in mixing the precipitation with an initial charge of ethylene glycol to inhibit freezing and help melt incoming snow. Towers are designed for maximum strength combined with lightweight and easy installation. The radio communication system which provides on-call operation and uses solar cells to trickle charge the battery power supply is described. Operating problems and site selection are discussed.

**Hydraulic Engr.,** **Meteorologist, USBR, Denver, Colorado**
An extensive network of storage precipitation gages covering the upper reaches of the Saskatchewan River system is described in detail. Recent developments have increased the network to include snow survey courses in the higher elevations. Analysis of existing records has made possible the adjustment of data for under-catch at the storage gages, due to wind effects. Normal isohyetal maps covering the area have been constructed. Double mass diagrams and statistical methods were employed for this adjustment of data. Precipitation elevation relationships were also taken into account.

I. Stockwell, H. J.

II. Mann, A. S.
Man's interventions in Nature's atmospheric process result in interventions in his socio-economic, political and legal processes. The legal aspects of weather modification are not as tangible as water rights legal rules and regulations. Although 22 States have regulations dealing with weather modification, there have been only 6 court cases on record of which 5 were decided in favor of the weather modification operator. These cases are explained in the text of the paper. Attempts are underway to set up State, intra-state, and Federal regulations to govern and license weather modification operators either for profit or research.

Successful weather modification (cloud seeding or rain making) is brought about by either of two processes. (1) by coagulation of moisture droplets in the cloud by use of pulverized dry ice, or (2) by use of silver iodide smoke particles that have the property of nucleating ice particlés in the clouds. There must be abundant moisture or moisture laden clouds in order to produce artificial rain or to trigger the process of rainfall. Research dealing with the physical properties of the most likely cloud formations and atmospheric conditions for successful weather modification has been carried on in the past, is still continuing, and must be extended into the future.
A program of barometer watersheds will provide the basis for: (1) determining the effect of management practices on hydrologic behavior, (2) developing and refining watershed precipitation, (3) making water yield predictions, and (4) comparing predictions with actual performance. The Lake Creek Barometer watershed is described as an alpine and sub-alpine watershed. The proposed instrumentation of this watershed to measure hydrologic factors is explained. The water yield improvements which may be used on the watershed are outlined. These include improvements in water quality, water yield, and water yield timing. The barometer watershed program will determine the feasibility of using techniques originated by research on a project basis. It will also provide a basis for appraising cost-benefit relationships.
The accuracy of measuring snow water equivalent is apparently the most efficient way to increase the accuracy of measuring snow water equivalent. The sharpness of the steel cutter on the standard snow survey gage; pressure pillow and pressure platform. All types are explained, and the data collected are analyzed in the summary of tables and graphs. An analysis of the effects of vegetation changes on water yield from block-cut and un-cut timber areas. Snow accumulation and water content are measured by snow survey course and standard sampling procedures. Courses were strategically located as to cut and un-cut areas on different slopes, aspect and altitude. An attempt is made to establish a pattern of snow accumulation and melting in adjacent cut-over areas and un-cut areas with regard to aspect. Details of methods are explained and the data collected are analyzed in the summary of tables and graphs.
Snowpack conditions were observed for the period January 14 to May 20, 1965 at the Fraser Experimental Forest near Fraser, Colo. Temperature, density, cold content, and moisture deficit were measured during this period. The freezing calorimetric method was used to measure thermal quality in several layers of the snow cover. During the four diurnal sequences observed, the fluctuations of free water were directly correlated with air temperature 3 feet above the snow surface. This suggests that snowpack conditions during active melt can be estimated from the temperature regime on a watershed. The maximum free water content observed during clear weather melt was 12 percent by weight. During cloudy conditions with light snow and rain, free water contents did not exceed 8 percent. The water holding capacity of the snowpack varied from 3 to 5 percent by weight during the snowmelt period.

It is admittedly true that the measurement of unconfined compressive strength is not an ideal test particularly in low density snow, however, it does have the advantage of being simple to perform. It is to be hoped that other strength parameters can also be related to the important variables so that accurate predictions can be made about the state of a snow cover.

**Hydraulic Engineer, USFS, Fort Collins, Colo.**

**SOME PHYSICAL PROCESSES IN DRY SNOW AS SEEN IN LABORATORY EXPERIMENTS**

Keeler, Charles M.* and Ramseier, Rene O.**


7 Plates; 16 References

Recent laboratory experiments and field work in the Antarctic have been conducted by various investigators at USA CRREL in an attempt to define some of the physical processes occurring in dry snow. The primary emphasis of this work has been to relate the strength of snow to such variables as time and temperature. This paper reviews the results of this work and suggests some applications in areas of deep seasonal snow cover.

It is admitted true that the measurement of unconfined compressive strength is not an ideal test particularly in low density snow, however, it does have the advantage of being simple to perform. It is to be hoped that other strength parameters can also be related to the important variables so that accurate predictions can be made about the state of a snow cover.

**AUTHOR INDEX**

1. Keeler, C. M.
2. Ramseier, R. O.

*and**U.S. Army Cold Regions Research & Eng. Lab., Hanover, N. H.

**AUTHOR ABSTRACT**

A discussion of the minute particles of trace elements and trace radionuclides found in snow flakes and rain droplets as they reach the earth's surface is presented. The measurement of these particles is described together with a brief description of recent developments of highly sophisticated Multidimensional Gamma Ray Spectrometers are included. The possibility of detecting radioactive nuclides from an atomic explosion and the type of material used is explained. Also the detection of silver iodide particles from cloud seeding operations is made possible by these new spectrometers.

<table>
<thead>
<tr>
<th>Subject Index</th>
<th>Author Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Snow - research</td>
<td>I. Keeler, C. M.</td>
</tr>
<tr>
<td>2. Snowmelt - research</td>
<td>II. Ramseier, R. O.</td>
</tr>
</tbody>
</table>

**REFERENCES**

1. Perkins, R. W.
2. Engelmann, R. J.
A NEW GENERATOR FOR SILVER IODIDE USING ISOPROPYLAMINE AS THE CARRIER

STEEL, ROGER L.*

1 Location Map; 3 Photos; 1 Plate; 3 Graphs

A new system for producing silver iodide ice nuclei is described. Isopropylamine, instead of ammonia, is employed as the carrier. Silver iodide complexes readily with the amine and has the following advantages: (a) high concentrations may be used without corrosion or deposition, (b) solution preparation is simple and direct, (c) single isopropylamine may be used to purify the system after use, (d) no support fuel is needed. The system produces high effectiveness over the temperature spectrum, e.g. 1.5x10^-5 and 8x10^-3 nuclei per gram at -20 and -10 C respectively. Disadvantages are: (a) dispersion costs may be 12% higher than when used with aceton, (b) the amine is more toxic than an acetone. However, with minor precautions, the complex is easily stored and handled at ambient pressure temperature. Carbon steel or aluminum are used for containment. Simple, reliable storage and thermal processing system is described in detail. This is composed of a storage tank, connecting piping, hydraulic nozzle and combustion chamber. Satisfactory tests were made.


A HYDROMETEOROLOGICAL ANALYSIS OF A MAXIMUM PROBABLE FLOOD FOR THE PORITAGE MOUNTAIN PROJECT PEACE RIVER, BRITISH COLUMBIA

DAVIES, L.B.* and ROCKWOOD, D. M.**

 Proc. WSC 1966: Pgs. 57-68 Seattle, Washington, April 19-21
 3 Location Maps; 2 Tables; 7 Graphs; 7 References

A detailed report on the factors involved in the spillway design for the subject project. A 600 foot earth fill dam and storage of 60 million acre feet of water are involved. Due to the remote location of the project only minimum length of records are available. A suitable network of snow survey courses, precipitation, temperature and stream gaging stations have been installed. A discussion of available hydrometeorological data is presented. Probable maximum snow melt, rainfall and temperature occurrences from existing records were processed through electronic computers to obtain probable spillway design and flood routing procedures.

*Hydraulic Engineer, International Power & Engineering Consultants, Vancouver, B. C.
**Hydraulic Engineer, USCE, Portland, Oregon

A RADIOISOTOPIC SNOW DENSITY GAGE

SMITH, JAMES L.* and WILLEN, DONALD W.**

9 Figures; 6 References

A radioisotope snow density gage is described. This procedure measures the snow water content and depth of the snowpack as frequently as desired. The component parts and field procedures have been tested and found workable and accurate. A radioisotope source (5 Milllicuries of Cesium-137) and a detector (iodide Crystal Photomultiplier) are lowered simultaneously in separate aluminum or stainless steel tubes planted vertically, about 12 to 18 inches apart, at the measuring point. The tubes can be sunk into the soil for reading the soil moisture content. The two units are lowered by a pulley and cable arrangement, either by motor or manually, keeping absolute level positions for each unit. Electrical leads from the two units are connected to a recording for continuous records of the snow and soil moisture. This scanning of the snow and soil profiles can be made as frequently as desired and also can be fed into a telemetering unit for transmission by radio or telephone wire to headquarters office. Initial costs are estimated at $10,000 for the field equipment and $2,000 for reception equipment.

*and**U.S.F.S. Experiment Station, Berkeley, Calif.

A RESUME OF PRECIPITATION GAGE MODELS AND TYPES USED BY THE U.S. WEATHER BUREAU

WARNER, O. R.*

Proc. WSC 1966: Pgs. 78-81 Seattle, Washington, April 19-21

A resume of precipitation gage models and types used by the U. S. Weather Bureau in their vast network of meteorological stations over the entire United States and cooperating foreign countries, is presented. A description of new types of gages is included. Many highly refined telemetering systems and automatic recording equipment are described, together with automatic feeds into electronic processes for printing out the information in many offices throughout the network of headquarters offices of the cooperating agencies involved in the operation of the large multiple-use-water management projects on the large river basins of the country.

*Chief, Operation Western Div., U.S.W.B., Salt Lake City, Utah
How many snow sampling points should be used on a snow course to obtain the most accurate streamflow forecast? This question has been asked in several ways as quotations from references. Statistical methods are applied to obtain correlation coefficients and coefficients of determination by using streamflow for periods: April-June and April-Sept. as dependent variables and several independent variables: snow course averages (all points); average of groups of 5 or 10 points; random selected points; individual sampling points; the average of those points with a correlation coefficient of 0.85 or higher. Conclusions indicate:

1. Each snow course must be analyzed separately.
2. Each course has one or more points of significant value.
3. More accurate forecasts can be made by using only those points with high coefficients above 0.85.
4. New courses should be located carefully, although no general criteria was evident from this study. A study should be made after a reasonable record has been collected and the course points reviewed to obtain the most accurate forecast.

*Asst. Snow Survey Supervisor, SCS, Boise, Idaho

# Abstract
**Snowpack Density Variation in a Snowpack of Northern New Mexico**

**GARY, HOWARD L.**

Proc. WSC 1967: Fgs. 6-10 Boise, Idaho, April 18-20
2 Tables; 2 Photos; 3 References

A better understanding of the metamorphic process in snowpacks must depend on the accurate measurement of many variables in and near the snow cover. The primary objective of this study was to explore sample variability in density measurements. Two procedures were used, the pit wall and 8"x1-3/4" I.D. plastic and also steel samplers, samples were taken vertically through the entire depth of the snowpack with the standard snow sampling tubes. A great number of the small samples were taken at 4 to 5 inch intervals in the face of a pit dug to soil surface. All cores were taken to headquarters in tarred plastic bags and there weighed. Differences were at a minimum and largely accountable to field practices and differences in procedures. Data are tabulated for examination.

**Subject Index**
1. Snow density
2. Snowpack density

**Author Index**
1. Gary, H. L.

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**Use of Snow Surveys to Forecast Inflow to Snake River Between Milner and King Hill, Idaho**

**THOMAS, C. A.**

Proc. WSC 1967: Fgs. 1-5 Boise, Idaho, April 18-20
2 Location Maps; 7 Graphs

Snow surveys are widely used to forecast flows in streams to which snowmelt is directly tributary, and to estimate the magnitude and duration of water supplies fed by such streams. A proposed method is described and results discussed in the text and illustrated by plotted data on graphs. The main problem is to account for the large amount of return irrigation water and the amount of water from huge springs along the river banks in this reach of the river. This flow amounts to approximately 7,500 cfs, during a good portion of the year, and especially during the snowmelt season.

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**Precipitation Variations in a Highly Instrumented Experimental Watershed in the Rocky Mountains in Southwestern Alberta Canada**

**STORR, D.**

Proc. WSC 1967: Fgs. 11-17 Boise, Idaho, April 18-20
1 Table; 1 Photo; 2 Graphs; 5 Maps; 15 References

Precipitation variations in a highly instrumented experimental watershed in the Rocky Mountains in Southwestern Alberta Canada are studied and illustrated. The study is pointed towards watershed management practices to evaluate and improve land management on the Eastern slope of the Rocky Mountains for better water yield. Instrumentation began in 1962 and has been in operation since that time. Methods for simplifying the measurement of many factors are described and recommendations for further studies are presented.

**Author Index**
1. Storr, D.

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**Microwave Radiometric Sensing of the Physical Parameters of Snow**

**KENNEDY, J. M.**; **Sakamoto, R. T.**; **EDGERTON, A. T.**

Proc. WSC 1967: Fgs. 18-23 Boise, Idaho, April 18-20
2 Photos; 3 Graphs; 1 Figure

A field and laboratory measurement program sponsored by the Office of Naval Research and CRREL, is being conducted to determine the response to microwave radiometers to various snow conditions. The field portion of the program was carried out within the confines of Crater Lake Nat. Park, with data obtained from new fallen powder snow and old metamorphosed snow. The measurements were made at three frequencies, 13.5 GHz, 37 GHz, and 94 GHz, (one GHz equals 10^9 cycles per second), with microwave temperatures recorded for both horizontal and vertical polarizations at viewing angles ranging from nadir to local horizon. Similar laboratory measurements were made of artificial snow made in an environmental chamber in which snow temperatures and moisture content are controlled. The results of these studies show that different microwave frequencies do not behave in the same manner as the moisture content of the snow. The measurement of these parameters from a remote sensing platform over broad areas of major watersheds would greatly aid in the management of water resources.

**Author Index**
1. Kennedy, J. M.
2. Sakamoto, R. T.
3. Edgerton, A. T.

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**Author Abstract**

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**Subject Index**
1. Snow - research
2. Radiomicrowave sensing

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**Author Abstract**

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**Subject Index**
1. Precipitation - analysis
2. Watershed mgmt.

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**Author Index**
1. Thomas, C. A.
2. Storr, D.
A method for multipoint snowpack temperature measurement using the Bridger Data System has been developed and tested. Data taken from a closely spaced array of thermistor thermometers has been used to delineate the snow surface and the diurnal heat wave through the snowpack.

The thermometry technique is also used in determination of the accumulation rate of new snow and in measurement of total pack settlement. Computer analysis and plotting of the data permits easy interpretation of a variety of physical and hydrological parameters. Data from the mid-winter snowpack and the spring isothermal pack has been analyzed by the above technique.

Subject Index

I. Bowles, D. K.

Author Index

I. Bowles, D.

*Electronic Engineer, USCE, Washington, D. C.

**Director, Engineering Research, Montana State Univ., Bozeman, Mont.
An empirical relationship found to exist between integrated ramm hardness number, N, in Joules and Load, L, in g-cm² at the base of the pack at the USA CRREL Goose Lake Snow Study Site is presented. It is suggested that the rammsonde may offer a practical approach to the study of the snow-water equivalent in areas where other techniques are not feasible. Considerable discussion is presented relative to highly technical difficulties of obtaining suitable snow samples in the study of snow loads of low density snow at below zero °C temperatures. Instrument procedures are discussed and the rammsonde process data are plotted and tabulated. Similar data collected in Greenland studies are compared with those made in Southwestern Montana at Goose Lake. The so-called "fit" technique, where a large number of samples are taken from the walls of a pit dug to soil surface, is described. The average of a large number of samples are used.

Snow loads on roofs of buildings and other structures are studied by use of models of buildings under water in a flume where fine sand is added to assimilate blown snow. The pattern of drifting sand in water is remarkably similar to snow deposited by wind. Researchers at the University of Guelph in Guelph, Ontario, Canada, have established laboratory procedures to study quantitatively the deposition of white sand injected into flowing water in the flume. Data and photographs are included to illustrate the quantity of the sand deposited and to qualify the changes recommended for building codes for orientation of structures and highways as well as landscaping features through the knowledge obtained from this procedure.

Snow pillows and radio telemetry sites in remote mountainous areas are more costly to locate than regular snow courses. Considerably more time and effort is necessary for selection of good data collection sites which will provide a sound basis for streamflow forecasting. Criteria for site selection are outlined and multiple regression analysis provided for snow courses on five Montana streams. Findings for determining good snow course locations are cited.
AERIAL PHOTOGRAMMETRY IS USED TO MEASURE SNOW DEPTH OVER A 100 ACRE STUDY AREA WITHIN THE KOLOMÚMNE RIVER BASIN. THIS PROCEDURE WAS DEMONSTRATED SUCCESSFULLY AND SHOWS THAT THE SAME PROCEDURES USED IN MODERN AERIAL TOPOGRAPHIC MAPPING CAN BE APPLIED TO SNOW COVERED TERRAIN. HOWEVER, SOME ADDITIONAL PROGRESS PROBLEMS HAVE BEEN ENCOUNTERED. A BASE CONTROL SYSTEM IS NECESSARY TO DEVELOP A POINT GRID SYSTEM FOR SUBTRACTING THE SNOW SURFACE ELEVATIONS FROM THE DEEPER SNOW PANEL ELEVATIONS. THE TECHNIQUE IS BEING TESTED AND OPTIMIZED TO INCREASE ITS ACCURACY AND EFFICIENCY.

**Director Atmospheric Water Res., Fresno, Calif.**

**El Dorado Engineering Co., El Dorado, Calif.**

**Author Index**

I. Smith, F. M.

II. Cooper, C. F.

III. Chapman, E. G.

**Subject Index**

1. Snow measurement
2. Aerial photogrammetry
3. Hydrology
4. Water resources
5. Hydrology flow analysis
6. Snow measurement
7. Aerial photogrammetry
8. Hydrology
9. Water resources
10. Hydrology flow analysis
11. Snow measurement
12. Aerial photogrammetry
13. Hydrology
14. Water resources
15. Hydrology flow analysis
16. Snow measurement
17. Aerial photogrammetry
18. Hydrology
19. Water resources
20. Hydrology flow analysis

**Abstract**

A report dealing with the Bureau of Reclamation's Atmospheric Water Resources Program is presented, for practical application of weather modification techniques for improving the water supply of the nation. Since its inception in late 1961, Project Skywater, as it is now known, has enjoyed almost a 40-fold increase in efforts embracing a broad spectrum of applied research. The operational research program is divided into three categories, field experiments, field support, and laboratory studies. Descriptions of each of the problems and some of the important results are presented. Field experiments involve investigations of orographic and convective clouds during winter and summer in six major water basins of the West. Field support of various types is provided by three government agencies. A variety of problems is being studied in the laboratory, including instrumentation, cloud physics and evaluation techniques, many in conjunction with field experiments.

**Author Index**

I. Stinson, J. R.

**Subject Index**

1. Weather modification - research
2. Project Skywater
3. Hydrology
4. Water resources
5. Hydrology flow analysis
6. Snow measurement
7. Aerial photogrammetry
8. Hydrology
9. Water resources
10. Hydrology flow analysis
11. Snow measurement
12. Aerial photogrammetry
13. Hydrology
14. Water resources
15. Hydrology flow analysis
16. Snow measurement
17. Aerial photogrammetry
18. Hydrology
19. Water resources
20. Hydrology flow analysis

**Abstract**

A progress report is presented for a hydrologic study dealing with the runoff produced by summer precipitation over the High Sierra, from the Kern River Basin north through the Mokelumne River Basin. This study was necessary to complete the knowledge of the hydrologic cycle for the runoff from the Central Sierra Nevada Mountains western slope. Data are presented of precipitation and runoff data from gaging stations as shown. Runoff analysis is shown graphically covering some 35 stations for a period of 25 years, 1940-64. The time period of year ran from the end of snowmelt to the beginning of each new snow season. Items covered are: hydrograph characteristics; volume of runoff; timing; storm characteristics; and precipitation values. All items are discussed in the text of the paper.

**Author Index**

I. Banneford, J. F.

II. Williams, M. C.

**Subject Index**

1. Hydrology flow analysis
2. Hydrology
3. Water resources
4. Hydrology flow analysis
5. Hydrology
6. Water resources
7. Hydrology flow analysis
8. Hydrology
9. Water resources
10. Hydrology flow analysis
11. Hydrology
12. Water resources
13. Hydrology flow analysis
14. Hydrology
15. Water resources
16. Hydrology flow analysis
17. Hydrology
18. Water resources
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20. Hydrology
21. Water resources
22. Hydrology flow analysis
23. Hydrology
24. Water resources
25. Hydrology flow analysis

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EFFECT OF TEMPERATURE ON WINTER RUNOFF

SIMONS, WILBUR D.*

7 Graphs; 7 References

The effect of temperature on the October through March runoff of the Clark Fork River at St. Regis, Montana was examined in a preliminary manner. The runoff potential for each winter season of water years 1930 through 1963, was evaluated and compared to historical records. Temperature records for the October through March period of water years 1931 through 1960 for East Anaconda, Montana were used to develop two simple indices: (1) the minimum monthly mean temperature and (2) the number of consecutive days the maximum daily temperature was 32°F or lower. The critical flow of the 1936-37 year resulted from a runoff potential in the lower quartile in combination with the occurrence of record-breaking cold temperatures. I. Simons, W. D.

*Research Hydrologist, USGS, Menlo Park, Calif.

THE CANADIAN IHD PROGRAM

CLARK, R. H.* and FULTON, F. J.**

Proc. WSC 1967: Pgs. 105-111 Boise, Idaho, April 18-20
2 Tables; 4 References

Canadian efforts in hydrology have, as in most countries participating in this scientific undertaking, been stimulated as a result of the International Hydrologic Decade (1965-1974) IHD, with attention focused on the need for more complete understanding of the inter-relationship between components of the hydrologic cycle. Although Canada has been blessed with an estimated one-third of the world’s fresh water supplies, the lack of uniformity in its distribution results in problems for hydrologists and water management experts equal in magnitude to most regions of the world, since Canada’s land mass encompasses environments ranging from humid to semi-arid and arctic to temperate.

The Canadian program, in addition to administrative problems being faced by the Canadian National Committee, is reviewed to provide some appreciation of how Canadian hydrologists are striving to meet the challenge of the Decade Program by undertaking studies which, collectively, will cover all aspects of the hydrologic cycle.

*and**Canadian National Council, Comm. on Hydrology, Ottawa, Canada
A universal surface precipitation gage has been developed that measures total precipitation and records the precipitation remaining in storage as snow. A 2-foot-diameter platform made of lightweight concrete, supported by a liquid-filled 100-foot coil of butyl tubing. An opening in the center of the platform allows for the collection of atmospheric melt, rain percolate and melt, or a combination of these and rainfall. A mechanical dual-pen recorder continuously records the rate of water collected in an underground tank and the water equivalent of snow on the platform. The recording system satisfies the longstanding need for surface measurement of total precipitation, snowmelt rates, and snow water equivalent required in hydrologic research and water yield and flood forecasts.
The analysis presented in this paper indicates that, in the Pacific Northwest, a combination of snow water equivalent and winter precipitation, coupled with fall and spring precipitation indexes, appears to yield better forecasts than with either index alone. The proportion of snow water equivalent and winter precipitation in each forecast relation varies with the basin involved. The proportion appears to range from 70-90 percent snow water equivalent plus 10 to 25 percent winter precipitation in predominantly pure snow-fed streams to 25 percent snow water equivalent plus 75 percent winter precipitation in predominantly rain-fed streams.

The weighting methods retain the simplicity of the "index" method of water supply forecasting while permitting easy comparison and combination of the two winter indexes. Each stream must be studied in detail in order to determine the proportion of snow water equivalent and winter precipitation. "Locking in" all variables except the one being tested aids in this determination, particularly when analysis time is reduced to a minimum by computer techniques.

This paper demonstrates the use of regression on principal components to develop prediction equations for water supply. A general description of water supply forecasting and principal component analysis is presented. Two actual examples are given, one with details of analysis procedures. Statistical procedures are presented for use with electronic digital computers for solving the multiple regression formula values of the coefficients and their significance. The details of analysis of Yakima are included in an appendix.

This paper describes development of a computerized water supply forecasting system with day-to-day up-dating of forecast data available. The Sacramento Municipal Utility District operates this power and water supply project from the upper basins of the South fork of the American River. There are seven drainage basins involved at nine levels of probability being involved.
A randomized cloud seeding experiment was conducted on the Lake Almanor watershed near Mt. Lassen, Calif., during five winter seasons, 1962-67. The target area extended approximately 20 miles east-west and 15 miles north-south, and ranged in elevation from 4,500 to 6,400 feet, MSL. Silver iodide was released from ground based acetone solution generators which were located between 6,000 and 7,400 feet, MSL. Silver iodide releases were made for 12 hour periods and these periods were subsequently divided into four weather categories, three of which together produced approximately 85% of the total precipitation, no response to the seeding was observed in the target area. In the remaining category, characterized by westerly winds and cold temperatures, the increase peaked at approximately 59% between 5 and 11 miles downwind, and averaged 27% throughout the 21 mile distance. Both results were statistically significant at the 5% level.
A report dealing with variations in measurement of snow water equivalent received by telemetering equipment from several stations under operation by the Corps of Army Engineers at the Walla Walla District Office is presented. At remote locations on the Clearwater River in Idaho, isotope snow gages and pressure pillows had been installed and operated by telemetering equipment for five years. A brief description of the radio reporting network and preliminary comparisons of the operation of the two types of gaging apparatus is included. Comparisons are made from the standpoints of accuracy of measurement, dependability, cost of operation, and the initial cost of equipment.
For the past three winters, (1965-66 to 1967-68) the Weather Bureau, in cooperation with the California Dept. of Water Resources, has been conducting studies in the use of snow sensors for obtaining real-time data for river and flood forecasting. Various sizes of rubber pillows, metal disks, and platforms have been installed at varying exposures and elevations. This paper points out the advantages and limitations of different types of sensors and exposures in several elevation regimes in the Sierra Nevada of California. Tables and graphs illustrate the type of data collected and advantages of current information from the mountains.


A scheme is described for processing and tabulating hydrographic and hydrologic records into standard data processing procedures. Punch cards and magnetic tapes are used for river stage field data. An X-Y chart reader was used to machine read values from the Stevens A-35 River Stage recorder charts, and also from rating tables for each of the stream gaging stations. Programs were prepared for complete computation of streamflow volumes, and tabulations. Hydrologic data were also processed and compiled, such as snow survey data, precipitation, temperature, etc. Fifty years of records were completely recomputed and compiled for AEP procedures for the Southern California Edison Company.

Throughout the Rocky Mountain region, there are thousands of square miles of heavily productive watersheds lying in the alpine and subalpine zones. These areas are completely unprotected from the enormous evaporative and sublimative losses produced by wind, temperature, and solar radiation. A snowmelt runoff equation is developed using these independent variables along with soil moisture deficit and spring precipitation. The paper consists of three parts: 1) the development of evaporation and sublimation formulae; 2) automatic data processing with these formulae, wind and temperature data from Boise USWB, and Lander, Wyo.; and 3) the application of this processed data to the snowmelt-runoff analysis of a watershed. Snowmelt-runoff forecasting formulae for headwater basins with alpine areas where little protection from forests is felt, must include the factors of evapo-sublimation losses along with solar radiation.

A method is developed for predicting and simulating the snowmelt runoff hydrograph by using aerial photographs taken vertically, then measuring, piece-meal, the percent of the basin covered with snow on the total basin. The procedure is developed by means of empirical correlations between snow cover depletion and runoff. In addition the application is made to daily simulation of streamflow depletion-runoff relationship and can be used effectively as a basis for advanced estimates of residual volume of flow during the remainder of the snowmelt season. Photographs are taken at about 10 day intervals, with a scale of 500 feet to the inch. The confines of the basin are divided into elevation zones and totals are derived from tabulations where the snow cover depletions are summarized. Relationships between the several variables are determined by multiple regression correlations solved by electronic computer procedures.

A research project is discussed dealing with snow density and the development of an index to snow "ripening" during the snowmelt season producing varying quantities of runoff. The object of this study was to obtain basic inventory data on the spatial and temporal variations in snowpack density and associated water content, and to relate these variations to hydrograph characteristics. Also, an attempt is made to determine how peak snowpack density and water content are affected by differences in timber stocking, elevation and insolation. The study was carried out on a 425-acre ponderosa pine watershed located in north-central Arizona. Snow samples were taken at 195 sampling points located in a grid fashion over the basin. Sets of samples were taken at regular intervals during the melt season.
The use of satellite photography to map snow cover distribution in the mountainous regions of the western United States are described in this paper. The techniques presented for identifying and mapping snow were developed from meteorological satellite data representative of that currently being received operationally. Differences between satellite snow mapping in flat and mountainous terrain are reviewed, and the outlook for operational snow surveillance from space is discussed. A survey of snow and ice on a world-wide basis, as planned in the International Hydrological Decade, appears economically feasible only through satellite observations.

Water holding capacities of snow at various densities are examined by study of in situ density profiles obtained with a profiling snow gage. Water holding capacity of snow is shown to depend upon compression, and previous water absorption of the profile in question. Increases in density up to 20 percent through water absorption are demonstrated. Studies are described of freewater in the snow profiles of 50 to 107 inches thick and changes in density by use of the profiling snow gage for density measurements. The water values are measured by electric isotopes similar to the isotope snow gage and demonstrated.

A research project was conducted in northern Utah, 30 miles east of Logan. Snowpack evaporation and condensation were measured by removing cylinders of snow, weighing them and replacement between periods of time. Snow areas in various types of forest canopy cover and open areas were selected for measurement. Many cylinders were used from the various areas. Meteorological instruments were also installed to measure those physical factors. Results indicate that the amount of winter evaporation was compensated for in the amount of condensation. Results in the conclusion that the small amount of evaporation from the winter snow surface is practically negligible. Graphs of the data collected are shown for the several sites. Formula development are shown using the data collected.

A preliminary mathematical model of the snowmelt process has been developed in which processes such as pack settlement rates and energy flow in the pack by means of both conduction and liquid movement are considered. Factors such as temperature, surface albedo, and degree and direction of slope are also included. A temperature criterion is applied to predict the form of precipitation input (snow or rain) to the model. Equations of the various processes are synthesized into a dynamic model of the total system by means of an electronic analog computer. Field data from snow laboratories operated by the Corps of Engineers and highly instrumented watersheds of the ARS are being used to test and verify the model. Initial results have indicated close agreement between observed and computed results. Sensitivity studies have been conducted, and work is continuing to further test and improve the model. A completely adequate description of the entire physical process of snowmelt is the prime goal of this work.
Snowpack collapse in the Northern Rockies shows a frequency distribution reaching a peak in January on areas generally sheltered from insolation and in April on areas exposed to the sun. In both cases the collapse results from an excess of load over snow strength in some zone within the pack, usually in the basal layer. The two event periods, otherwise, are quite different from each other as may be seen in: 1) the distribution of pertinent physical properties within the pack at the time of collapse; 2) sensitivity to influences from outside the pack; 3) the general involvement of the snow column in the collapse; and 4) the physical changes in the pack brought about by the collapse. These differences appear to have important implications regarding avalanche safety and snowpack hydrology.

A procedure of cloud seeding operations by using a "stepwise" computer program for determining the best possible seeding effects with many meteorological factors presenting themselves for examination. The computer program is designed statistically to assure steadiness of generator operations. The decision as to which variable to use is still left to the operators discretion and relying on his experience, but the computer will compute so rapidly that several trials can be made in a short period of time. Final runs are made to check the decisions as to equations dealing with cloud physics. The cloud seeding area of effect model embodies in a somewhat simplified form nearly all of the existing knowledge about mountain air flow, plume dispersal, cloud physics and water budget. This knowledge is organized into a unified computerized prediction system. The model can therefore be employed in making evaluation tests more sensitive, and as a real time source of guidance for the conduct of seeding operations.

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A photoelectric snow particle counter has been developed to measure the concentration of snow in the air during blowing snow conditions to test theories of turbulent transport. The counter uses high-speed, very compact photo-transistors, a very compact light source, and an integrated circuit differential amplifier. It transmits a large, high-quality signal to a remote tape recorder. Design features of the instrument include: (1) a small sampling area; (2) a very short sampling time; (3) minimum air stream interference; and (4) relative ease of operation under adverse conditions.

The counter transmits a large, high-quality signal to a remote tape recorder. Time rates of melting by snowmelt lysimeter provided direct measurements of melt output during clear weather, as well as rain percolating through the pack plus melt during rainy periods. By following the installation and operation procedures outlined in the report, accurate data can be obtained at relatively low cost.
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

MONTANA TELEMETRY SYSTEM

FARNES, PHILLIP E.* and ROMPEL, JOHN**

Proc. WSC 1969: Pgs. 102-107 Salt Lake City, Utah, April 15-17

A snow hydrology data telemetering system designed by the SCS with considerable assistance of the Electronic Research Laboratory at Montana State University, has worked successfully for the past 5 years. Hydrologic data from snow pressure pillows, precipitation, and air temperature has been transmitted by radio throughout the snow accumulation and ablation periods (November through May) of each year. Snow pressure pillow and precipitation are collected by potentiometer sensors and temperature is measured by thermistor units. This data is recorded on a Leupold-Stevens Type-F recorder and is also transmitted at timed intervals by radio to receiving station through repeater station to office in Bozeman, Mont. and computer. The coding system for the several quantities transmitted is explained. Other details of the system are explained. An on-call interrogation system is needed for an expanded system, and other recommendations are listed. The pillow data from the falling limb is vitally important in the water management problems of snow-fed rivers.

*Snow Survey Supervisor, SCS, Bozeman, Montana
**Research Engineer, Montana State University, Bozeman, Mont.

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

NEVADA’S FANTASTIC SNOWMAN

MOLER, MURRAY M.*

Proc. WSC 1969: Pgs. 108-110 Salt Lake City, Utah, April 15-17

As part of a recollection of his association with Dr. Church, the banquet speaker Murray M. Moler, presented the keynote address made be Dr. Church at the first meeting of the Western Snow Conference, Reno, Nevada February 18, 1933.

*Associate Editor, Ogden Standard-Examiner, Ogden, Utah
SNOW AND RESERVOIR MANAGEMENT IN CANADA FOR THE COLUMBIA RIVER TREATY DECISION

HANNAFORD, J. F.; BUSH, R. H.; BARSON, R. E.

Proc. WSC 1970: Pgs. 1-8 Victoria, B. C., April 21-23

3 Figures; 5 References

Management of Columbia River Treaty storage reservoirs in Canada to increase hydropower generation and flood control in the United States and Canada is described. Water management criteria are presented, consisting of operating rules, seasonal runoff forecasting procedures and short-term streamflow forecasting methods. The criteria, primarily derived by empirical methods, attempt to optimize the storage operation. Draft of the storage is governed by power generation requirements and seasonal runoff forecasts; refill of the storage is governed by seasonal runoff forecasts, short-term forecasts and power generation requirements.

The seasonal runoff forecasts consider combined winter precipitation and snowpack water equivalent, spring and summer precipitation, antecedent precipitation and mean monthly maximum temperatures of the forecast period. Glacier melt is considered in the Mica drainage basin.

**THE DEVELOPMENT AND APPLICATION OF A HYDROLOGIC MODEL AS AN OPERATIONAL TOOL**

HANNAFORD, JACK F.*; BUSH, RICHARD**; BARSON, RAYMOND E.***

Proc. WSC 1970: Pgs. 7-15 Victoria, B. C., April 21-23

Describes development of a runoff simulation technique, originally prepared for use on the American River and then applied to operational problems on the Kings River watershed during the record snowmelt runoff of 1969. Includes descriptions of hydrologic concepts and processes which have been modeled, basic data which were required to achieve simulation of these processes, and characteristics of the watershed. The paper is concluded with a description of how the modeling technique was used as a management tool to provide basic information for making operational decisions in the Kings River watershed during 1969.

**MEASUREMENT OF PRAIRIE SNOWPACKS**

GRAY, DON M.*; NORUM, D. I.**; DYCk, G. E.***

Proc. WSC 1970: Pgs. 24-30 Victoria, B. C., April 21-23

4 Figures; 4 References

The paper is concerned with the physical measurement of the snow water equivalent of shallow prairie snowpacks under flat, highly exposed cold conditions. Consideration is given to the relationship between "ground catch" and measurements recorded by shielded automatic precipitation gauges. Physical measurement of shallow snowpacks, their distribution and retention by ground sampling techniques are discussed. Time changes in density of freshly fallen snow caused by drifting and seasonal variation in density of shallow snowpacks are evaluated. The performance of twin-probe gamma nuclear system for detecting abrupt physical changes (greater than 1/2 inch) in snow density within a deep profile at scanning rates up to 15 inches per minute under cold weather operation is evaluated.

**WRITTEN SCIENCE CONFERENCE BIBLIOGRAPHY**

SNOW AND RESERVOIR MANAGEMENT IN CANADA FOR THE COLUMBIA RIVER TREATY DECISION

HANNAFORD, J. F.*; BUSH, R. H.; BARSON, R. E.

Proc. WSC 1970: Pgs. 1-8 Victoria, B. C., April 21-23

3 Figures; 5 References

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An approach to the use of both meteorological and streamflow data has been developed by S. J. Solomon et al., and applied in Labrador. In this method, a river basin is divided into a number of squares, physiographic parameters are determined for each square, meteorological data are correlated with these parameters and from the resulting equation estimates are made of precipitation, evaporation and runoff for each square. Accumulated runoff is compared with measured runoff.

This paper describes an attempt to apply the method to a mountainous area in the interior of British Columbia to determine the areal variation in runoff and also to extend the method by using snow course data as well as meteorological and stream gauge data. The results are promising and the technique has important implications for data network design.

**Author Abstract**

Quick, M. C.*

*Assistant Professor, Hydraulics & Hydrology, The University of British Columbia, Vancouver, B. C.

Snowmelt is the major input to high flow runoff in the Fraser River system, and it is necessary to have good understanding of factors affecting snowmelt before an adequate flow forecasting system can be constructed. To study the basic physics of snowmelt, a type of low speed wind tunnel has been built in which temperature, humidity and radiation can be controlled and melt rates of 16 cu. ft. samples of snow can be measured. Results of some of these experiments are presented and the validity of such small scale tests to the calculation of melt rates in the large scale natural situations is discussed.

**Author Abstract**

**SUBJECT INDEX**

1. Hydrology - basin characteristics
2. Flow analysis

**AUTHOR INDEX**

I. Quick, M. C.
AN APPROACH TO SNOW LOAD EVALUATION

BROWN, JOHN WEBSTER*
Proc.WSC 1970: Pgs. 52-60 Victoria, B. C., April 21-23 5 Plates

The development of the 1964 Washoe County, Nevada, Snow Load Code is presented. Comparison is made with the 1965 National Building Code of Canada, together with comments indicating the general applicability of same to other regions. A general method of evaluating snow load values is outlined, including consideration of recurrence interval. Recommendations for additional snow courses in urbanizing mountainous areas for correlation to longer term stations are set forth.

*President, John Webster Brown Civil & Structural Engineers, Inc., Reno, Nevada

FORECASTING A HYDROGRAPH FOR THE DESCHUTES RIVER

GEORGE, TOMMY A.*
Proc. WSC 1970: Pgs. 68-73 Victoria, B. C., April 21-23 5 Figures; 2 Maps; I Table

This paper explains the procedure used to forecast critical flow levels and the dates that these levels will occur on the Deschutes River at Bend, Oregon. It discusses the value of the forecast to water users in relation to their water rights, and the problems involved in reconstructing the streamflow hydrograph used in deriving the forecast equations. Examples of forecasted versus actual hydrographs for the past several years are included. The information is used by the watermaster and irrigation districts in managing the river and their water use.

*Snow Survey Supervisor, SCS, Portland, Oregon

A SNOW COURSE WEIGHTING METHOD

COULSON, C. H.*
Proc. WSC 1970: Pgs. 74-81 Victoria, B. C., April 21-23 5 Figures

This paper describes the derivation and use of a method of combining interdependent variables into a single variable for use in multiple regression analyses. The method is statistical and not directly related to any physical parameters. Use of this method to solve a given problem requires the use of a digital computer with a plotting arm auxiliary. The combination of water equivalents at different snow courses is emphasized but the method could be extended to other independent variables. An example of weighting snow courses for a Columbia River forecast procedure is illustrated.

*Water Investigations Branch, B. C. Water Resources Service, Victoria, B. C.
The Streamflow Synthesis and Reservoir Regulation (SSARR) model is designed to simulate the hydrologic processes in a watershed and hydraulic phenomena in lakes, channels and reservoirs. This presentation summarizes a report prepared for the International Hydrologic Decade which describes the streamflow synthesis portion of the SSARR model and illustrates reconstitution of streamflow resulting from rainfall or snowmelt or a combination of the two on the Willamette Basin Snow Laboratory in the Cascade Mountains of western Oregon. The watershed area was divided into five elevation bands; rainfall, snowfall, and snowpack accumulation, depletion and melt are computed separately for each band.

I. Rockwood, D. M.
II. Anderson, J. A.
A simulation algorithm that can predict daily snow water equivalent and delivered meltwater on-site in the Central Sierra Nevada of California has been developed. The model uses data on precipitation, snowpack condition, and snowmelt process. The input variables are daily values of precipitation, maximum and minimum temperature, incoming short wave radiation, albedo, and vegetative cover density. The output is daily delivered meltwater on-site. Options for estimated radiation and albedo can also be used. Results of tests using two years of data showed a close correlation between predicted and actual daily snowpack water equivalent and melt.

I. Willen, D. W. II. Shumway, C. A. III. Reid, J. E.

A simple graphical method for updating streamflow forecasts during the melt season is described. The procedure, developed from data on three small forested watersheds in the Fraser Experimental Forest, is based on: (1) aerial photographs of snow cover depletion acquired during 1964-68, and (2) a precipitation index derived from April 30 storage gage measurements adjusted for subsequent precipitation input during the snowmelt runoff season. Trial forecasts with 1969 data indicate the method gives acceptable results.

I. Leaf, C. F. II. Haeffner, A. D.
Selected snow course data in Oregon and Utah was analyzed by computer using Log-Pearson Type-3 method for determining percent-

chance of occurrence. The characteristics of the physical location help interpret the snow frequency data. The generated data can be used to predict expected snow loads, locate potential winter recreation areas and related uses.

*Assistant Snow Survey Supervisor, SCS, Portland, Oregon

**Snow Survey Supervisor, SCS, Salt Lake City, Utah

A 12-by-12 foot square pressure pillow was modified by the addition of drains to collect the snowmelt from the pillow. This meltwater was collected in tanks and monitored by stage recorders. The daily runoff amounts from the catchment pillow was compared to average annual precipitation for gaged drainage basins and comparing this to average runoff. By using these relationships the average runoff for any basin can be estimated by using average annual precipitation over the basin.

*Principal Hydrologist, Rocky Mountain Forest & Range Experiment Station, Fort Collins, Colo.
The development and operation of a research project developed by the Wyoming Water Resources Research Institute under contract with the National Oceanic and Atmospheric Administration is described. Preliminary information on precipitation data, statistical analysis, snow drift profiles, and wind characteristics is presented. The data shows that there is a distinct possibility of shielding precipitation gages from the adverse effects of wind by using artificial barriers (snow fences).

**Director, Water Resources Research Institute, **Ph.D candidate, Civil Engineering Dept., University of Wyoming, Laramie, Wyo.

**Hydraulic Engineer, USGS, Water Resources Div., Tacoma, Wash.**

This paper describes the extent of the hydrologic data telemetry network, the type and capability of equipment used for reporting and processing the data, the types of sensors being employed, and some of the many problems experienced in installing and operating the network in western Washington. The equipment was installed by the U.S. Geological Survey in cooperation with the City of Tacoma and the Puget Sound Power and Light Company. At present it consists of a computer-operated base station, two repeater radios, four remote telemetry stations reporting data from snow survey courses, and six remote telemetry stations reporting data from stream gages. The form of data reporting is analog and processing is digital.

*Assistant Snow Survey Supervisor, SCS, Fort Collins, Colo.*

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**PROJECTS Coordinator, Forest Hydrology Branch, Canadian Forestry Service, Edmonton, Alberta

**Hydrogeologist, Research Council of Alberta, Edmonton, Alberta**

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**Hydraulic Engineer, USGS, Water Resources Div., Tacoma, Wash.**

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**Assistant Snow Survey Supervisor, SCS, Fort Collins, Colo.**
The universal surface precipitation gage has proved to be an excellent research tool for making ground surface measurements of precipitation, snow water equivalent, and melt rate. Experimental results indicate that the gage provides a more realistic measure of the snowmelt process than does the conventional 12-foot butyl pillow and has the advantage of providing coincident measurements of water equivalent and the volume rate of flow from the base of the snowpack. These quantities include any water added by rainfall. The universal surface precipitation gage appears to have excellent potential as an operational instrument because of the completeness of data obtained and the relatively inexpensive installation and maintenance costs.

For many years, radio engineers have sought to overcome severe environmental conditions encountered in remote mountainous areas and have dreamed of a radio station which would require no access roads, no power lines, no battery charging, and after a quick, easy and economical installation, would provide extremely high reliability and require no attention for at least five years. This dream evidently has been realized in British Columbia by the development of the special VHF radio stations described in this paper. The presentation of the paper included a series of 98 colored slides illustrating the historical background of the development, a description of the radio station equipment as well as some field installations of mountain top repeater and snow course base stations.

The efficient management of water resources has long recognized the requirement for evaluating the magnitude of the seasonal "water crop". Increasing demands on the available supply and proper management of temporary over and under supply situations have demonstrated a requirement for additional information on the potential volume and anticipated distribution of the water resource. Historical studies have also shown the importance of forecasting the amount of water available during the critical snowmelt period. The forecast cannot account for additional factors that will control the melt of the heavier snowpacks at higher elevations. Seasonal inflow forecasting will have to rely on statistical techniques early in the inflow season, since the evaluation of groundwater recharge can only be made after the snow has melted at the 3,000 foot elevation.
The concern about the environment in the snow resource is changing with the spirit of the times. This is the keynote of the seminar on "Environment and the Snow Resource".

It is not the basic resource, water, that is changing but man's influence on this resource that is producing an ever-increasing change. The effects of man on natural patterns of water supply in the case of urbanization may be largely inadvertent. But man's intentional activities may improve the environment for either more direct benefit or greater aesthetic advantage. Man's influence can improve his environment, particularly with respect to the intelligent influence on the natural patterns of supply by means of weather modification.

In the Salt River Valley, in central Arizona, the performance of a system for renovating waste water by groundwater recharge depends upon the local conditions of climate, soil and groundwater. The hydrological conditions in Salt River Valley, central Arizona are favorable for groundwater recharge with infiltration basins in the river bed. It is estimated that tertiary treatment by this method would cost about $5 per acrefoot or less than one-tenth of equivalent in-plant treatment. This would be an additional source of water to meet future agricultural and other demands.

A computerized system analysis, using a series of optimization and simulation models, to prepare recommendations of water allocations was developed for use in the State of Arizona. The system was divided into three subsystems: economic, hydrologic-engineering, and one which interfaces the first two. These fit together in a closed loop which can be continuously operated until all inputs are internally consistent. This method has been used to develop technical evaluations of specific areas for use by decision makers.
The problem of nitrogen supersaturation on the Columbia River, which is alleged to have resulted in severe fisheries losses, is discussed. The cause of nitrogen supersaturation and its effect on fish are reviewed, and several structural solutions to the problem are presented. An effective means in reducing the problem lies in the regulation of upstream reservoirs, and snowmelt forecasting plays an important role in this regulation. Two types of forecasts are utilized, volumetric forecasts determined by multiple regression procedures, and daily simulation of runoff using the SSARE computer model. These procedures are briefly described and examples of their application in combating the nitrogen supersaturation problem are given.

The Prairie Provinces Water Board has spearheaded a study to improve and coordinate the water supply forecast for Alberta, Saskatchewan, and Manitoba. Initial forecasts for the April to October period are based on winter storage precipitation data, summer rainfall and winter base flows. Further the use of percent correction factor, based on data for three integrating loss basins, significantly improved the accuracy of forecast for the South Saskatchewan River. Extreme residuals were reduced from ±23 percent to ±8 percent.

The 1970 Labor Day Storm caused more loss of human life than any other storm in Arizona's recent history. In addition, many dwellings, roads, bridges, and other structures were damaged by record flooding. The meteorological and hydrological features of tropical storm Norma, and the resulting damage to human, cultural, and natural resources have been documented and analyzed. Such analyses contribute to improved estimates of the magnitude and frequency of future storm and flood events, and assist engineers and planners in the design and location of new communities, drainage systems, bridges, dams, and other cultural features.
Hydrologist, and to develop patterns of man's use studies are required to evaluate the changes that are occurring ecological systems.

The recent large increase in people engaging in wintertime on-the-snow activities has resulted in the altering of snow redistribution changes on forest

Snowmelt from accumulated snow on the Grand Mesa, plays a very important role in the agriculture pursuits of western Colorado. The recent large increase in people engaging in wintertime on-the-snow activities has resulted in the altering of snow redistribution patterns and the changing of snow density. The effects of these changes on forest and range ecosystems is largely unknown. Further studies are required to evaluate the changes that are occurring and to develop patterns of man's use that is compatible with the ecological systems.

A wilderness studies program has been underway in the National Park Service since 1964 when the Wilderness Act directed the service to study all roadless areas of 5,000 acres or more in the parks and other areas of the system that existed in 1964. This would include a total of 65 areas. Public hearings have been held on 43 and up through fiscal year 1972, reports on 40 of these areas have been completed. Substantial progress on the balance has been made and completion by 1974 is anticipated. To date, Congress has created wilderness units in the Petrified Forest National Park and Craters of the Moon National Monument.
The hydrometeorological data in five western mountain watersheds were reviewed and deficiencies in existing data required for planning of large scale research weather modification projects were noted. Ideally the additional data needed for each major watershed includes a base station for project control, several climat stations to record areal coverage of precipitation and standard meteorological parameters and one mountain observatory unit for the observation of special meteorological parameters and snow quality data. Studies of existing data revealed little or no tendency for snowpack to level off or to decrease at higher elevations. Estimates of a ten percent increase in precipitation during the October through April seeding periods could increase the average annual runoff by 2.5 million acre-feet within the five large watersheds and an additional 1 million acre-feet around the periphery of these watersheds. Extending the seeding period into May and June could increase the runoff from the five study basins by 410,000 acre-feet, but caution is needed in seeding during this period because of undesirable flood potentials.

# Sierra Hydrotech, Placerville, Calif.

## Western Snow Conference Bibliography

### Watershed Hydrometeorological Data Required for Weather Modification

**Elliott, R. D.*** and **Hannaford, J.***

Proc. WSC 1972: Pgs. 61-66 Phoenix, Arizona, April 18-20

2 Figures; 2 References

The hydrometeorological data in five western mountain watersheds were reviewed and deficiencies in existing data required for planning of large scale research weather modification projects were noted. Ideally the additional data needed for each major watershed includes a base station for project control, several climat stations to record areal coverage of precipitation and standard meteorological parameters and one mountain observatory unit for the observation of special meteorological parameters and snow quality data. Studies of existing data revealed little or no tendency for snowpack to level off or to decrease at higher elevations. Estimates of a ten percent increase in precipitation during the October through April seeding periods could increase the average annual runoff by 2.5 million acre-feet within the five large watersheds and an additional 1 million acre-feet around the periphery of these watersheds. Extending the seeding period into May and June could increase the runoff from the five study basins by 410,000 acre-feet, but caution is needed in seeding during this period because of undesirable flood potentials.

**Sierra Hydrotech, Placerville, Calif.**
WILLIAMS, MERLIN*  

A description of the current weather modification program as currently being carried out in South Dakota, and how it has developed over the past 10 years. The results of early uncoordinated weather modification efforts for hail suppression and summer rainfall increases experimentation are theorised. The growth of the program from individual efforts and trials to a total Local-State-Federal cooperative effort is detailed.

*Director, Weather Control Commission, State of South Dakota, Pierre, South Dakota
A discussion of the problems a large city has supplying water to its customers both domestic and commercial. Exploration of other sources of water such as desalinization, weather modification, reuse of waste water, and transport from other areas such as Canada or Alaska.

*Manager, Denver Water Board, Denver, Colorado

A discussion of the Metropolitan Water District of Southern California: how it was organized, how it operates, what has been accomplished, major problems, and current plans.

It includes a brief history and statistics concerning size of members, people served and amount of water delivered.

*Principal Engineer, Metropolitan Water District of Southern California, Los Angeles, California

*Supervisory Hydrologist, Forest Service, USDA, Denver, CO
**Forester, Forest Service, USDA, Denver, CO

The 1969 Federal Legislation and (in California) 1970 State Legislation made mandatory Environmental Impact Statements (EIR) on all public work projects. In 1972, the California Supreme Court, in its decision "Friends of Mammoth v. Board of Supervisors of Mono County" imposed the requirement that public agencies prepare an EIR on all private (as well as public) projects having significant effect on the environment "for which a permit or other similar entitlement is required". This has had impact on local government and industry unparalleled in recent history. The legislation and effect is briefly reviewed and outline is presented of guidelines for an EIR in the form of a Logic Diagram. Comment is made as to future requirements yet to come.

*Consulting Civil Engineer, Strauss Engineering Services, Porterville, Calif.
The paper identifies land use policy currently being formulated by California Office of Planning and Research and provides an evaluation of feasibility of supplying adequate water of good quality now and in the future. Provides statistical information on the use of land in the 1970's and forecasts of changing patterns. Includes data on the scope of undeveloped land in the state and those lands under discussion for inclusion in the National Wilderness Preservation System.

*Principal Engineer, W. R., State of California, Sacramento, CA

Discussion of short and long term studies of silver iodide in soils, including determination of microbial silver transformation reaction, and evaluation of specific silver form and level effects on microbial activities in laboratory and field environments, microbial ability to reduce silver, together with evidence for sub-lethal effects of low-levels of silver forms and microbial decomposer processes indicate considerable more study needed.

*Professor in Charge, Environmental Engineering Program, Civil Engineering Dept., Colorado State Univ., Fort Collins, CO 80521

This publication contains an overview of the snow avalanche research activities being conducted by the Institute of Arctic and Alpine Research, University of Colorado, in the San Juan Mountains of southwestern Colorado. The research is funded by the U. S. Bureau of Reclamation with the objective being to develop a forecast model for avalanche occurrence in an area of the San Juan Mountains being considered as a possible target area for the cloud seeding operations of Project Skywater. The field methods being used to acquire data regarding avalanche occurrence are described. In addition, research directed towards establishing an Avalanche Zoning Plan for San Juan County and the town of Silverton is described.
WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SNOW SAMPLING TECHNIQUES ON A SMALL SUBALPIDINE WATERSHED

BARTOS, LOUIS R.* and RECHARD, PAUL A.**

Proc. WSC 1973: pgs. 52-61  Grand Junction, CO April 17-19
2 Maps; 9 Tables; 5 References

Discusses the advantages of a transect method of snow measurements in a subalpine watershed in Wyoming. Stratified for elevation and between forest and open wind influenced areas was found necessary. It was found that snow density was uniform and only required a few measurements to define this parameter.

*Hydrologist, U. S. Forest Service, Provo, Utah
**Director of the Water Resources Institute, University of Wyoming
Laramie, Wyoming

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

A COMPARISON OF TECHNIQUES OF SAMPLING THE ARCTIC-SUBARCTIC SNOWPACK IN ALASKA

CROOK, ARTHUR G.* and FREEMAN, TED G.**

1 Table; 5 Figures; 3 References

Description of a comparison test for measuring snow of a Bowman type Federal sampler and a technique described as CRREL method. Crrel plot was measured by digging a pit and extracting snow samples from each horizon of the profile. Provides data of the test and makes conclusions about the two systems.

*Snow Survey Supervisor for Alaska, Anchorage, Alaska
**State Resource Conservationist, SCS, Anchorage, Alaska

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

SNOW LOAD ANALYSIS AND RECREATIONAL USES OF SNOW DATA

GEORGE, TOMMY A.* and MCANDREW, DONALD W.**

6 Figures; 12 References

Snow loads were computed from past records and maps depicting weight of snow by elevations was developed in Nevada and Oregon. These maps satisfied needs to architects, building officials and winter recreational developers.

*Snow Survey Supervisor for Oregon, Portland, Oregon
**Snow Survey Supervisor for Nevada, Reno, Nevada

WESTERN SNOW CONFERENCE BIBLIOGRAPHY

EVAPORATION LOSSES OF WINDBLOWN SNOW, AND THE POTENTIAL FOR RECOVERY

TABLER, RONALD D.*

Proc. WSC 1973: pgs. 75-79  Grand Junction, CO April 17-19
3 Figures; 3 References

Paper demonstrates potential of snow fences to increase storage on wind swept areas. Rm (transport distance) is defined and used in various snow storage formulas. Rm was found to be about 4000 feet at sites between 7000 and 8000 feet in elevation before the wind completely sublimates the snowflake.

*Principal Research Hydrologist, Rocky Mountain Forest and Range
Expt. Sta., Univ. of Wyo., Laramie, Wyoming
As part of an environmental impact study, the climate of the mountainous areas north and west of Vancouver, Canada were studied to assess possible climatic limitations to urban development of the mountain slopes. A model of mean annual precipitation based upon available data and meteorological theory is presented. A mean annual snowfall map is derived in part from relationships between mean annual snowfall and mean annual precipitation at various altitudes. Implications for urban planning are discussed.