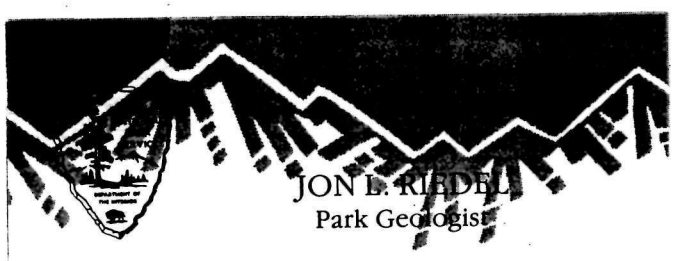
STUDY PLAN
NATURAL RESOURCE PROTECTION PROGRAM

Regional Glacier Mass Balance Variation in the North Cascades

PRINCIPLE INVESTIGATORS
JON L. RIEDEL
NORTH CASCADES NATIONAL PARK

ANDREW FOUNTAIN AND BOB KRIMMEL
U.S.G.S. WATER RESOURCES DIVISION



JON L. RIEDEL
Park Geologist

North Cascades National Park
Skagit District Office
728 Ranger Station Road
Marblemount, WA 98267

(206) 873 - 4590
Home (206) 873 - 4907

INTRODUCTION

Glaciers are one of the most valuable resources in the North Cascades National Park Service Complex (NOCA)(Figure 1). Approximately one-third of all the glaciers in the lower 48 states are within the park (Post et al, 1971). The 318 glaciers in NOCA are a vital component of hydrologic systems and aquatic ecosystems. They also influence soil development, the distribution vegetation, flooding and are unique indicators of climate change. Since the end of the Little Ice Age in the late 1800's, glaciers have retreated throughout NOCA, and several dozen glaciers have probably disappeared (Riedel, 1987).

To understand climate change, the glacier resource and the effect of glaciers on other resources at NOCA, long-term monitoring of glaciers is needed. South Cascade Glacier, located just outside NOCA, has been monitored by the U.S.G.S.-Water Resources Division for over 30 years. It is not known, however, how representative South Cascade Glacier is of NOCA glaciers in general because of the influence of non-climatic factors such as geographic position, aspect and elevation. Once the influence of non-climatic factors is understood, a long-term monitoring scheme can be developed.

The goal of this project is to develop a plan for long-term monitoring of glaciers at NOCA. To accomplish this goal two hypotheses will be tested. The first hypothesis is that synoptic climate data, annual aerial photographs and terrain characteristics from geographic information systems can be used to estimate annual glacier mass balance in lieu of detailed on site measurements. The second hypothesis is that change in mass of South Cascade Glacier is representative of change in mass of all North Cascade glaciers.

To test these hypotheses will require five years of detailed mass balance measurements on three glaciers in the North Cascades. First year NRPP funds will be used to meet three objectives:

1) Measure the mass balance of three glaciers with a 2 season methodology;
2) Survey the ice margin position of three glaciers; and
3) Construct 5m contour interval maps of the three glaciers from aerial photographs.

In years two through five, additional objectives of this project will be to:

1) Measure the thickness of each glacier along a longitudinal profile using ice radar.
2) Determine how representative South Cascade Glacier is of the health of North Cascade Glaciers in general.
3) Develop a GIS based computer model to predict changes in glacier mass balance by use of synoptic climatic data and aerial photographs.

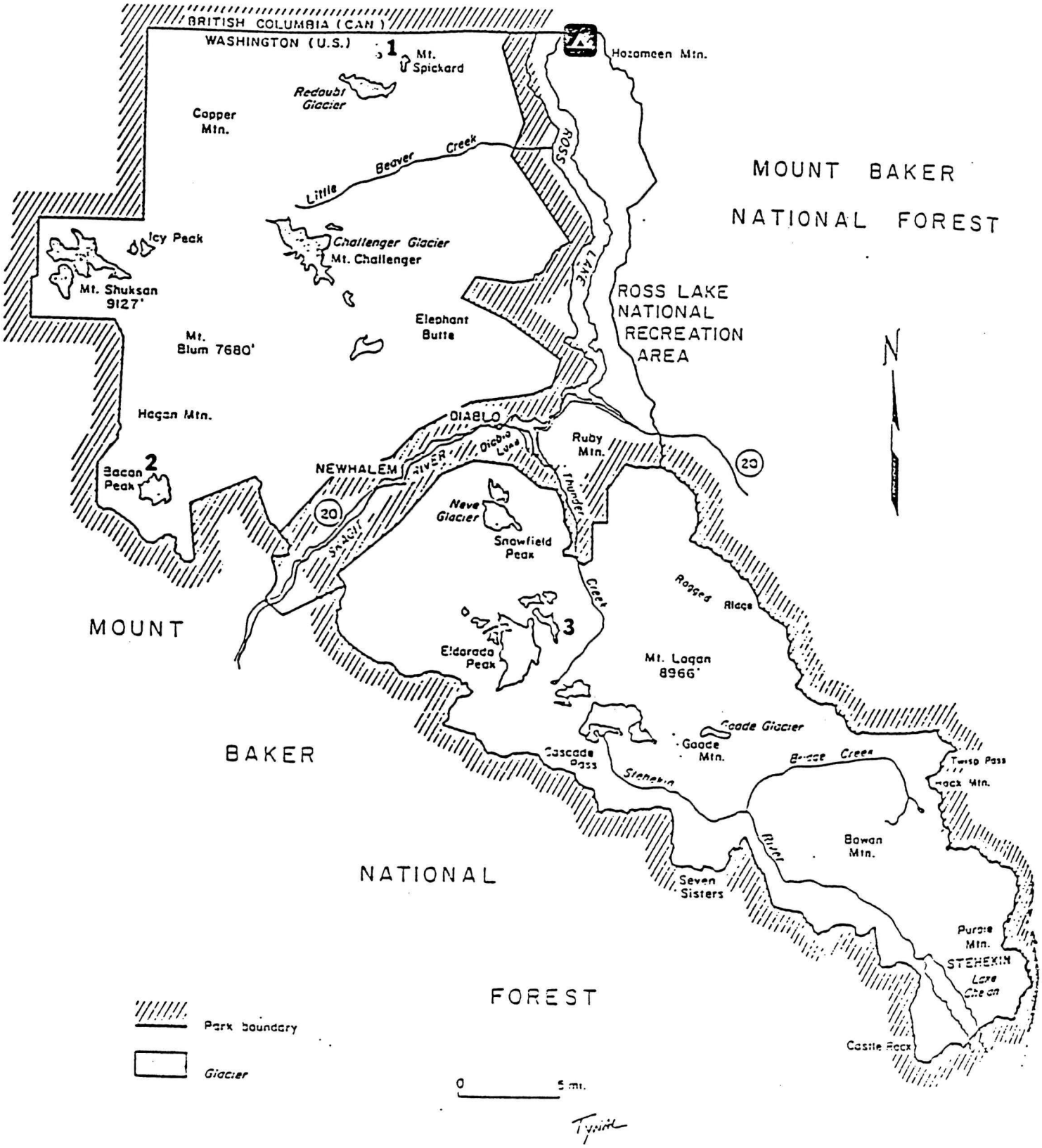


FIGURE 1. LOCATION OF STUDY GLACIERS IN NOCA: (1) SILVER GLACIER; (2) NOISY CREEK GLACIER; (3) NORTH KLAWATTI GLACIER.

METHODOLOGY

Several criteria were used to select glaciers for mass balance measurement and monitoring. They include (not in order of importance):

1) access on glacier surface - For safety and accuracy of mass balance measurements, glaciers that have most areas of their surfaces accessible and few crevasses were chosen.

2) overland access to glacier - All three glaciers are located in designated wilderness. Considering this designation, this project will avoid use of helicopters between Memorial Day and Labor Day. Therefore, glaciers accessible by maintained trail or well established cross- country routes were preferred.

3) geographic position - To meet one of the long-range goals of this project, the distribution of the glaciers is as wide-ranging as possible along both north-south and west-east axis.

4) glacier aspect - Glaciers were chosen that represented both north and south facing aspects.

5) glacier elevation range - Glaciers with a wide elevation range were chosen.

After considering these criteria and consultation with the other principle investigators, three glaciers were chosen for this study (Figures 1 and 2). The glaciers and some of their characteristics are:

1) Silver Glacier is a valley glacier located on the north side of Mt. Spickard, Mt. Spickard quadrangle. Post et al. (1971) glacier number 2236-6. Characteristics of the glacier from a 1973 inventory include: area 0.9 square km, length 1.8 km, accumulation sources direct snowfall and minor snowdrift, moderately crevassed, 1973 calved into silver lake and slight retreat, elevation range in 1968 based on the 7.5 minute quad is 2713m-1982m (731m range).

2) Noisy Creek Glacier is a cirque glacier located northwest of Bacon Peak, Bacon Peak quadrangle. Post et al. (1971) glacier number 2219-1. Characteristics of the glacier from a 1973 inventory include: area 0.5 square km, length 1.4 km, direct snowfall and minor snow drift accumulation, not appreciably crevassed, ends on moderate to gentle slopes, slight retreat in 1973, elevation range 2040m-1650m (390m range).

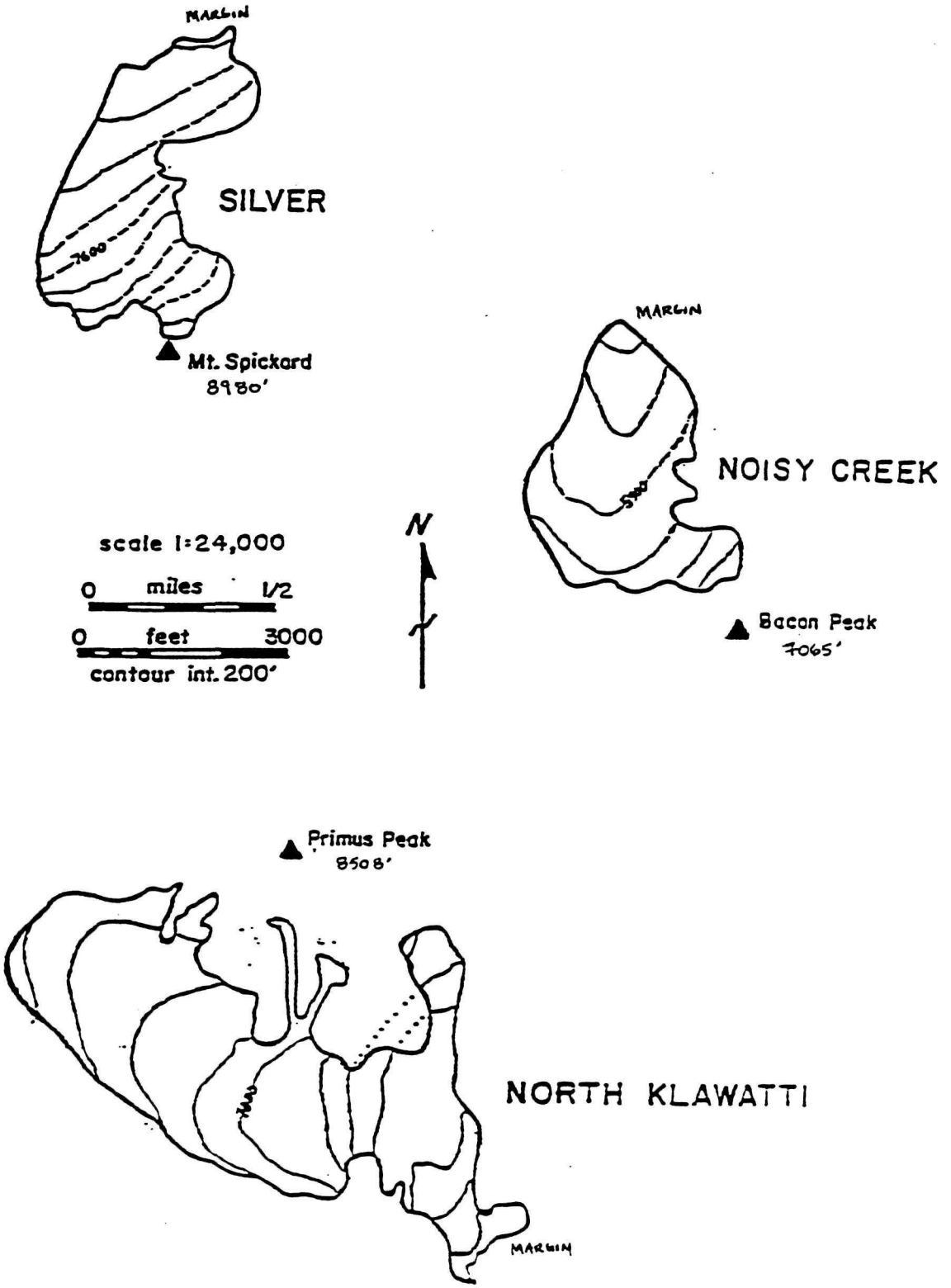


FIGURE 2. MAPS OF THREE STUDY GLACIERS FROM USGS 7.5 MINUTE QUADRANGLES. PHOTOGRAPHS FOR QUADS TAKEN AS FOLLOWS: SILVER GLACIER, 1963; NOISY CREEK GLACIER, 1979: AND NORTH KLAWATTI GLACIER, 1958.

North Klawatti Glacier is a valley glacier located south of Primus Peak, Forbidden Peak quadrangle. Post et al. (1971) glacier number 2253-10. Characteristics of the glacier include: area 1.6 square km, length 2.3 km, accumulation sources direct snowfall and minor snow drift, moderately crevassed, ends on moderate to gentle slopes, 1973 slight retreat, elevation range 2270m -1540m (730m range). The glacier has recently been studied by the USGS (Tangborn, Fountain and Sikonia, 1990; Meier, 1966). Topographic maps and data gathered during these investigations will be useful to this study.

Should these three glaciers become unsuitable for any reason, either Banded Glacier on Logan Peak or Colonial Glacier on Colonial Peak will replace them.

Mass balance measurement methods used in this study will follow those outlined by Ostrem and Stanley (1969) and Patterson (1981) and refined during 30 years of research on the South Cascade Glacier by the USGS-Water Resources Division (Meier, 1961; Meier and Tangborn, 1965; Meier et al.,1971; Tangborn et al., 1971). Scientists from the USGS will be consulted about problems that arise during data collection.

To measure the net annual gain or loss in mass on each glacier requires at least two seasonal measurements (Patterson, 1981). Snow accumulated on the glacier during the previous winter will be measured in late-winter early-spring. Snow depth will be measured with a copper probe provided by the USGS as a longitudinal traverse is made down the glacier.

Snow density will be measured by sampling the snow stratigraphy in a snowpit. A metal cutting tube will measure volume and a spring scale will measure the mass of the snow in the pit walls. Snow depth and density determines the mass of the snow pack. Density measurements in two snow pits will be made to account for density variation with elevation. A helicopter will be used to access the glaciers during accumulation measurements.

To measure summer mass loss, stakes will be set into the snow and ice using a steam drill during the spring field trip. The height of the remaining snow, or level of ice, against the fixed stake determines (with density) the mass loss. Stakes will be constructed of 3/4" PVC conduit cut into 1.5m sections. Based on previous summer melt rates measured at South Cascade Glacier, the sections will be joined into 6m and 7.5m lengths with 1/2" diameter pieces of wood dowel. The wooden dowel should swell when wetted and keep the sections of PVC together. To prevent the stakes from floating in the hole they will be perforated and plugged at their lower ends. A steam drill has been given to the NPS by the USGS.

Fountain and Vecchia (1992) recommend that a minimum of five ablation stakes be used per glacier. Six stakes will be used on the Silver and North Klawatti glaciers because of their wide elevation range. Each stake will represent a range of 122m in elevation on each glacier. Five Stakes will be used on the Noisy Creek Glacier, with each stake representing a 78m range in elevation. The elevation of the stakes will be determined by a digital altimeter with 3m accuracy.

Depending on the temperature and cloudiness of the summer, ablation stakes may have to be redrilled in July or August. On the lower end of the South Cascade Glacier as much as 8m meters of ice can melt in a given summer (Krimmel, personal communication). If high melt rates are observed at South Cascade Glacier, a mid-summer visit will be made to each glacier and the stake holes redrilled using a hand auger. Access to the glaciers will be by foot during any visit between Memorial Day and Labor Day.

Final 1993 measurements will be made during a late-September early October trip to each glacier. Access will be by helicopter and/or foot. During this visit total summer ice and snow melt, equilibrium line altitude and ice margin position will be measured and ablation stakes retrieved. From the vertical change in glacier surface along the stakes the mass lost will be calculated. This value will be averaged for the elevation zones represented by each stake. Combining winter snow accumulation and summer melt measurements gives the net mass change of the glacier.

Vertical aerial photographs of all three glaciers will be taken during the late summer of 1993 by the USGS or an appropriate contractor. Where possible, elevation markers will be set near the glaciers to assist photogrammetric methods of contour map construction. The photos will be used to construct five meter contour maps of the glaciers. Photogrammetric map construction will be performed by the Washington Department of Transportation or private business.

PUBLICATION OF RESULTS

First year results will be presented at the annual meeting of the Northwest Glaciologists. Data will be contributed to the World Glacier Monitoring Service and the World Data Center for Glaciology for wide distribution. At the end of this five year project the results will be published in a suitable professional journal and a detailed, long-term glacier monitoring plan for NOCA will be developed.

APPROXIMATE BUDGET

ITEM	APPROXIMATE COST
SALARY	
1) 8 weeks for principal investigator (Park Geologist GS-9-3)	$6,000
2) 3 weeks for field assistant (NPS Climbing Ranger GS-5)	$1,000
HELICOPTER TRANSPORTATION -12 hours flight time at $486/hour	$5,900
EQUIPMENT	
1) miscellaneous (shovel, ablation stakes, hand auger,scale, etc.)	$300
SERVICES	
1) aerial photographs and photogrammetry	$6,800
TOTAL	$20,000

COMPLIANCE

NEPA Categorical Exclusion would apply to this project. The actions proposed in this statement are judged to be categorical exclusions based on 516 DM2, App.1 (1.6), "Non-destructive data collection, inventory (including field, aerial, and satellite surveying and mapping), study, research and monitoring activities." Further, these projects are consistent with the provisions and requirements of the Endangered Species Act, PL 93-205, 87 Stat. 884 (as amended, 1982 16 USC 1531 et seq.)

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