1. THE DESIGN AVALANCHE AND HAZARD-ZONE DEFINITIONS

1.1 General Comments

Avalanche hazard zones subdivide the probability and destructive potential of avalanches into two or more categories. This subdivision provides a dividing line between a "red zone" of high hazard and a "blue zone" of moderate hazard and acceptable risk. The subdivision is arbitrary because it depends on the level of risk individuals or government are willing to accept.

Avalanche probability is one basis for hazard zone delineation. For example, the Swiss usually exclude habitation from areas affected by the "30-year" avalanche. In contrast to the conservative Swiss approach, residents of Alta, Utah live within the boundaries of much more frequent avalanches. Some Alta buildings have been hit at least three times since the mid-1960's. Thus size of the red zone varies both with avalanche terrain, climatic conditions, and with the willingness of local residents to accept risk.

The "maximum" extent of an avalanche is usually defined as the blue zone limits. Such an avalanche is known as the "design avalanche" or "design-magnitude avalanche." When a design-magnitude avalanche occurs, it will extend beyond the red zone and reach to the end of the blue zone. Very unusual avalanches may also extend past the blue zone, but the probability of such events is small enough to be disregarded in planning and design. In Switzerland, all avalanches with average return periods of up to 300 years are considered part of the blue zone. However, Switzerland has a history of avalanches that extends back several centuries in some locations. Therefore, reasonable guesses can often be made as to the size of a "300-year avalanche," the Swiss design avalanche. Estimates of very long (e.g., 300 year) return period avalanches is much more subjective in Alaska and other areas where the historical record is short.

Hazard zone limits are also based on engineering criteria. The destructive force of avalanches decreases as one moves farther into the runout zone, toward the end of the blue zone. Therefore, although a resistant structure or other form of defense is usually impractical in the red zone where forces are large, avalanche defense may be feasible in the blue zone. The engineering criteria used to define conditions in the blue zone are based on the physical characteristics of the design avalanche.

Hazard zones define quantitatively what is intuitive: avalanche probability and destructive potential both decrease with distance into the runout zone. This behavior is akin to other geologic processes since there usually exists in nature an inverse relationship between size and frequency. In contrast, the level of risk people are willing to accept is a personal or governmental decision. Acceptable risk seems to vary with attitudes, needs, and economic pressures. With these ideas in mind, we recommend the following hazard-zone definitions in the mountains surrounding Anchorage.

1.2 Suggested Hazard-Zone Definitions in Anchorage

1.2.1. Data Base Available. Most of the mountain terrain affected by avalanches in the Chugach Mountains near Anchorage has been, or still is sparsely populated. Those areas that are presently growing in population have not been populated for long time periods. Although some records of unusually large avalanches do exist (see section 5), good data about the extents of large avalanches that affect developable areas are limited to a small percentage of all avalanche paths. Although most of the major avalanches of interest begin above the tree line, many also extend down into forests and have damaged trees. Tree damage and distinct forest trim lines provide one good indicator of the extents of relatively frequent avalanches, defined here as those with return periods of about 10 years. Effects of considerably larger avalanches with return periods of roughly 100 years are also evident in some locations where mature forests were damaged.

Several independent methods were used in this analysis to define the design avalanche limits. These methods are described in detail in subsequent sections of this report. We feel avalanche zones used in planning should only be defined to within the limits of the data base and the reliability of the analytical techniques available. Therefore, we offer the following recommendations about the detail of avalanche hazard mapping zones.

1.2.2. Order-of-Magnitude Hazard Zones. Distinctions between avalanches with similar return periods (e.g., 10-year and 20-year avalanches) cannot be made no matter how carefully we conduct our research and analysis. The data that would enable cross checks on such discriminations simply are not available in these sparsely settled areas, thus methods through which we can test the reliability of our assumptions do not exist.

Instead, in the Anchorage area we have delineated two zones of hazard intensity corresponding to return periods separated by an "order-of magnitude" or a factor of 10. The 10-year and 100-year average return period avalanches have been chosen because they will differ significantly in size and are consistent with the limited data base available in the Chugach Mountains. A similar order-of-magnitude hazard zone separation is also used in Switzerland where 30 and 300-year average return periods are used to define avalanche limits.

The "10-year" and "100-year" avalanches are order-of-magnitude estimates defined as follows:

$$\text{10-year:} \quad \sqrt{10} \leq T \leq 10\sqrt{10} \text{ years,}$$

$$\text{100-year:} \quad 10\sqrt{10} < T \leq 100\sqrt{10} \text{ years,}$$

where T is the average return period.

According to these definitions, a "10-year avalanche" may have a return period of approximately 3 to 30 years, by definition, and the "100-year avalanche" approximately 30 to 300 years.

The expressions "10-year avalanche" or "100-year avalanche" are probability concepts not necessarily related to the actual time interval between events. Thus, a "10-year" avalanche has a constant annual probability of 10%, may occur on successive years without changing the probability on succeeding years, or may not occur for

10, 20, 30 or more consecutive years. Events of a given size are unevenly or randomly spaced through time.

1.2.3. The Red Zone. Avalanches that extend to the outer red zone limits in Anchorage are defined as having return periods of approximately 10 years.

Some Anchorage residents have a good understanding of the sizes of 10-year avalanches because many people have lived in the area for more than 10 years and have observed avalanches that appear to have been of exceptional magnitude. Examples of 10-year avalanches probably include those destroying three Eagle River houses in 1979 and 1980, and probably also include the well-documented Seward Highway avalanches between Bird Creek and Girdwood in 1979. The avalanches reaching the Alyeska Ski Area base were also 10-year avalanches. Furthermore, because 10-year avalanches occur several times during the life of mature trees, areas affected by these relatively frequent slides will be devoid of mature conifer forests. The 10-year avalanche limits will be obvious to many people who are not avalanche specialists. In many cases, the hazard areas will be easily identifiable in the field and on photographs. All types of avalanches, ranging from slow-moving wet slides to faster dry-snow avalanches can cover the red zone.

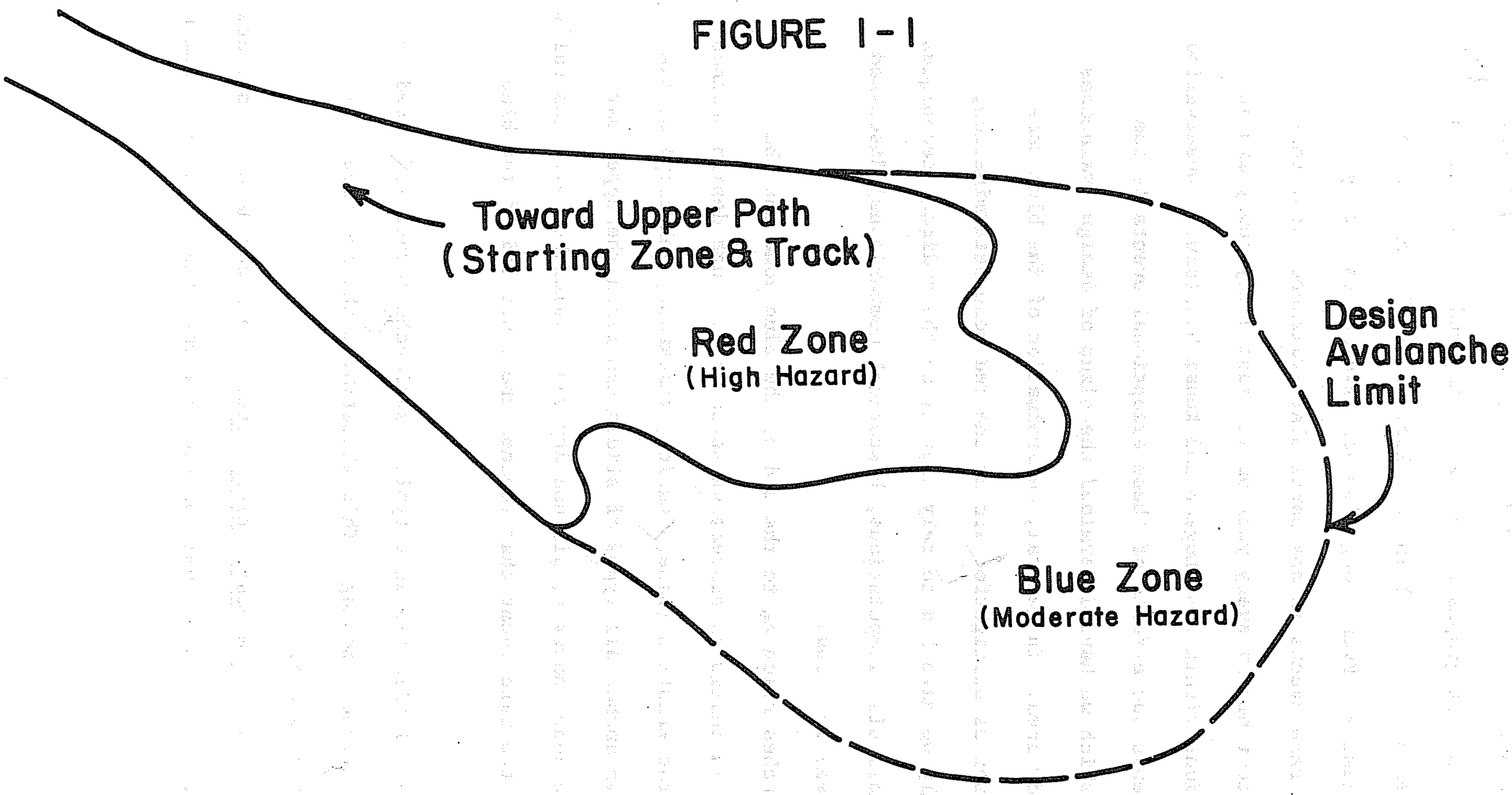
1.2.4. The Blue Zone. Avalanches reaching the end of the blue zone are by definition very unusual and infrequent events. The blue zone includes avalanches with return periods of up to 100 years (1% annual probablity). These very large events have rarely been observed in Anchorage because the observational record is short and discontinuous. In most cases, blue zone limits will not be obvious in photographs or on the ground, and in some cases, mature forests will have been re-colonized within the 100-year avalanche limits. Even though 100-year avalanches are by definition rare events in any particular avalanche path, they probably occur nearly every year or at least every few years at some locations within the Chugach and Kenai Mountains. Observation of the extents and effects of these exceptional events is one method by which we have determined the sizes of design avalanches in the study area. In general, determination of the blue zone limits is not as straightforward as the red zone determination, consequently we have had to rely heavily on the indirect techniques (terrain analysis, computations, historical comparisons) discussed in subsequent sections.

Avalanches reaching to the end of the blue zone must be considered in design of protective structures. Such design depends on the characteristics (mass, density, thickness, velocity) of the 100-year avalanche. All types of slides can reach the upper part of the blue zone, however, diffuse dry-snow avalanches will generally constitute the rare event that reaches the lower end of the blue zone.

Figure 1-1 illustrates a typical avalanche hazard zone used in Anchorage avalanche zoning. This illustrates the red/blue subdivision discussed above.

1.2.5. Avalanche Destructive Force. Avalanche hazard zones are also defined in terms of their destructive potential. Within certain

FIGURE 1-1


Toward Upper Path
(Starting Zone & Track)
Red Zone
(High Hazard)
Design
Avalanche
Limit
Blue Zone
(Moderate Hazard)

parts of the study areas (Girdwood, for example), the design avalanche may have very high energy nearly to the end of the blue zone, beyond the limit of the 10-year avalanche. When our analysis has shown this to be true, then the red/blue boundary was defined in terms of destructive potential, or energy of the design avalanche, rather than return period.

In some other areas, even design avalanches never achieve high energy, thus "avalanche-proof" structures could be built nearly any place in the avalanche path. When this is true, avalanche frequency becomes the controlling factor in the location of the red/blue zone boundary. The objective here is to avoid human exposure adjacent to structures located within the path of small, frequent avalanches.

1.3 Avalanche-Hazard Maps

Areas of avalanche hazard on private property within the Municipality of Anchorage are indexed in the following maps (see Figures 1-3, 1-4 and 1-5). For detailed information on the location of avalanche hazard areas and their relationship to property boundaries, the reader is referred to the individual avalanche hazard maps. For example, should one require information on avalanche hazards in the upper Meadow Creek drainage near Eagle River, the appropriate index map should be consulted (Figure 1-3) and the area of concern located. In this instance, Map 8 would be the appropriate map. To aid in locating areas, township section and range indications are given on the index maps. Most of the individual avalanche hazard maps are at a scale of 1"=500' and are available for purchase at the Department of Community Planning. Review copies of these maps are also available at the libraries in Eagle River, Girdwood and the Loussac Library in Anchorage.

As indicated on the index maps some of the avalanche hazard maps vary from the 1"=500' standard. Those maps that do depart form this scale are identified and their scale indicated. The Crow Creek area in Turnagain Arm is mapped at the relatively small scale of 1"=2640'. At this scale, identifications of avalanche hazard zone boundaries cannot be precisely made relative to individual subdivision lots. Consequently, only the outline of the Raven Mountain Estates subdivision is depicted in Map 26 with the corresponding avalanche hazard boundaries in that area. The extent of the avalanche hazard for any given parcel must then be estimated. The avalanche areas along the Seward Highway are not included in the study because this area is already covered by a study of the Alaska Department of Geological and Geophysical Survey.

The index map (Figure 1-2) of Turnagain Arm and vicinity also locates large known avalanches discussed in the historical section 5.4. The numbers of various known avalanche incidents are circled on Figure 1-2 refer to the numbers in the text.

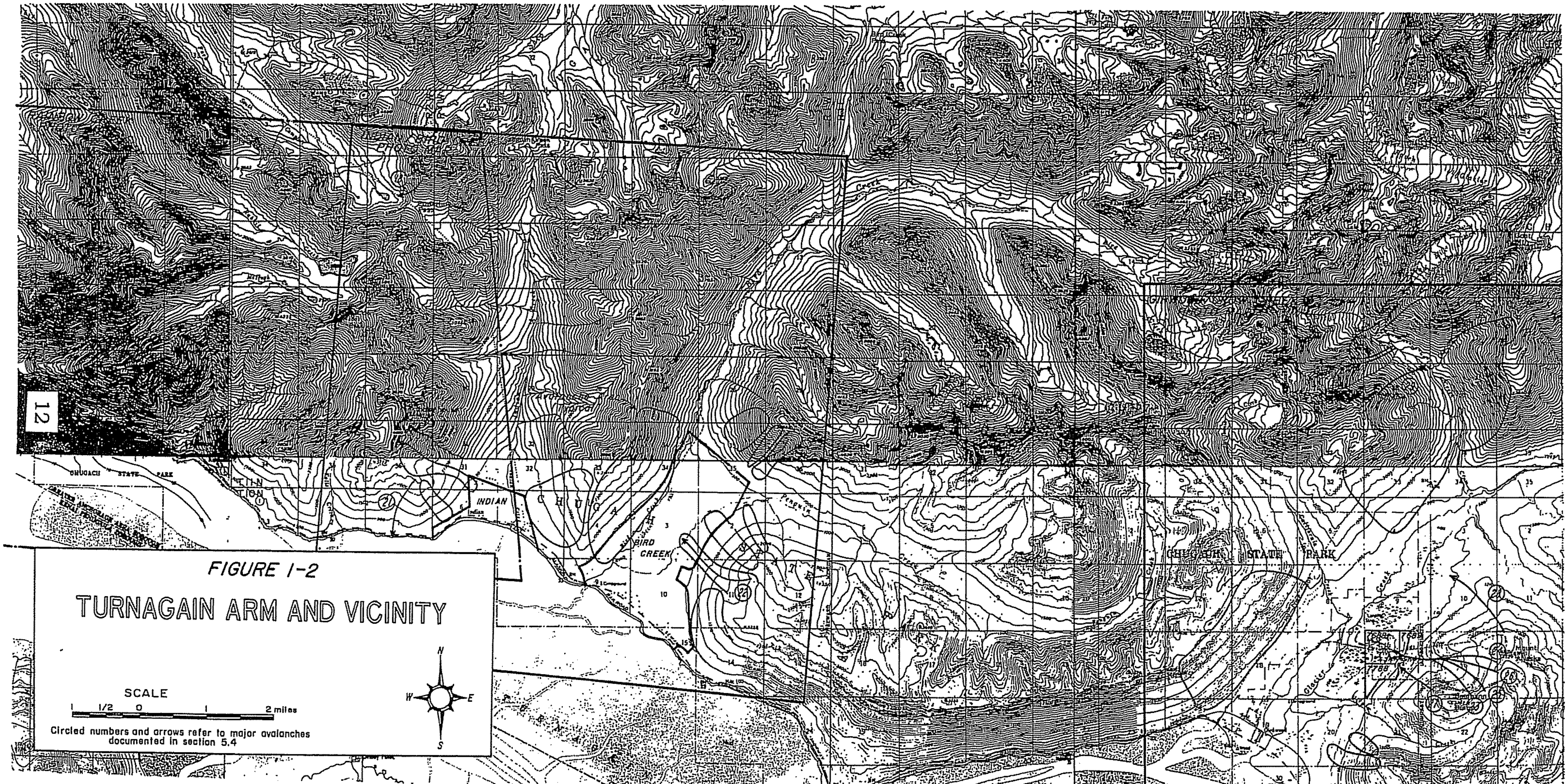
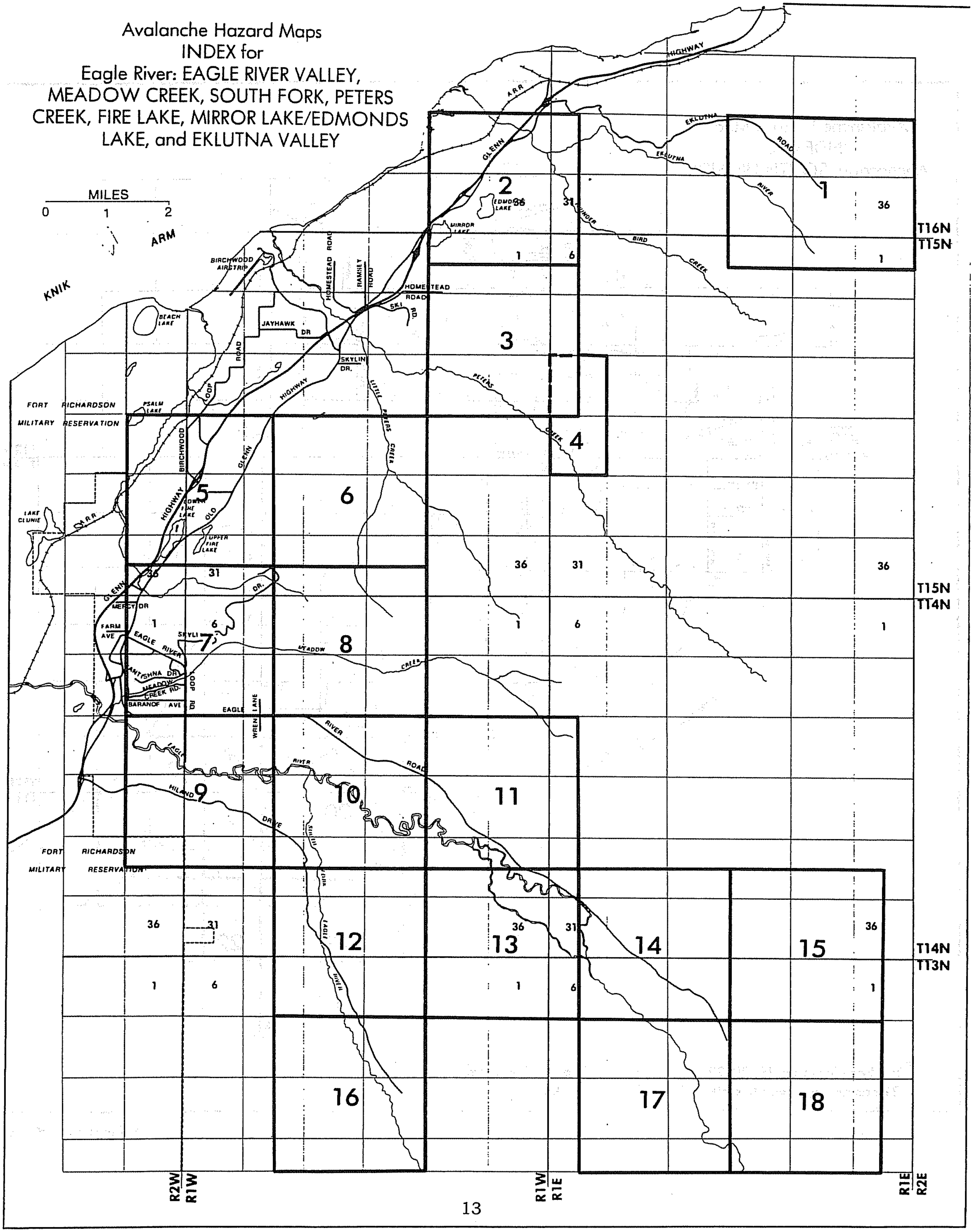


FIGURE 1-2

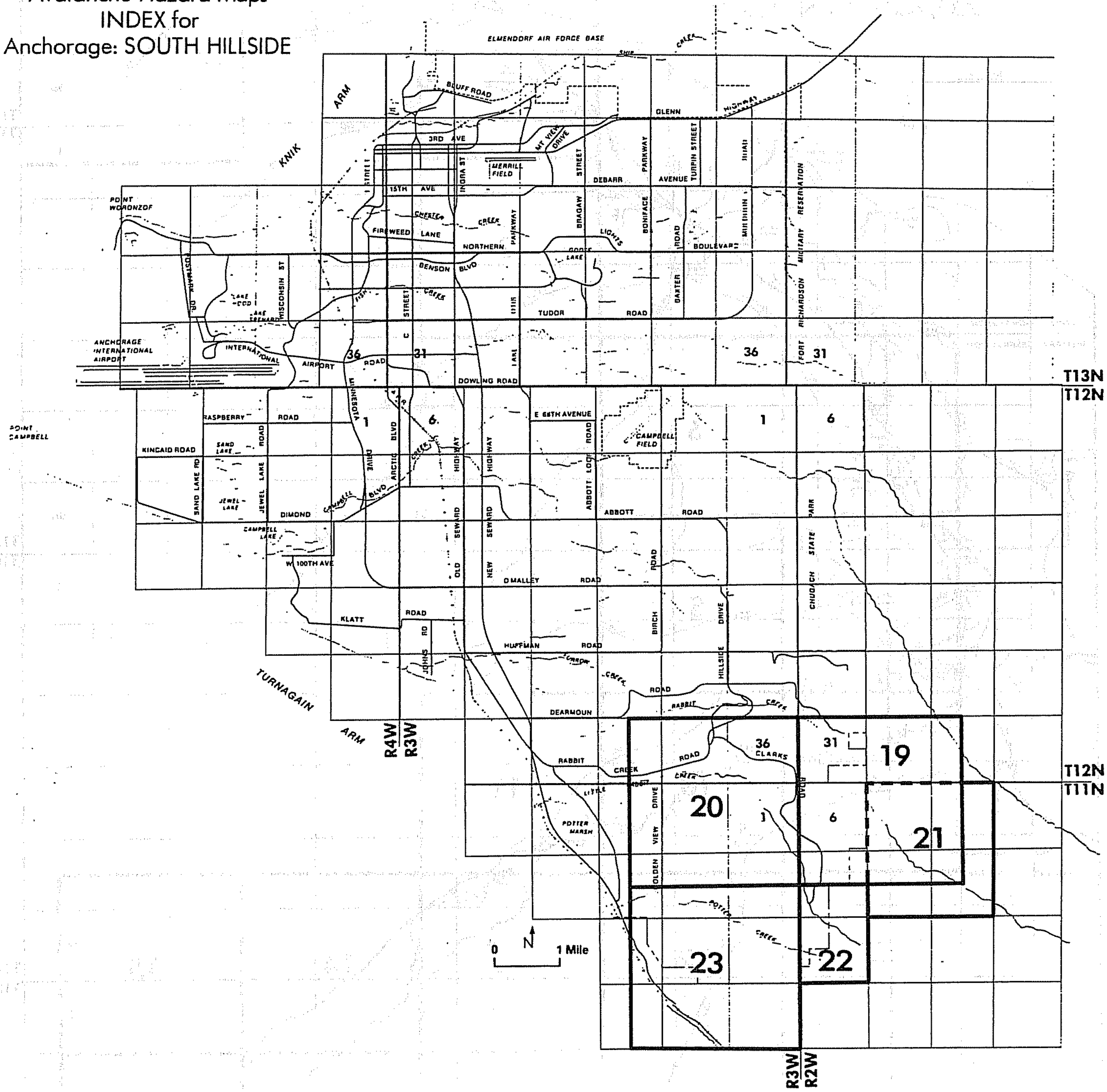
TURNAGAIN ARM AND VICINITY



*The base for maps 1 through 18, has a scale of 1"=500'.

Figure 1-3

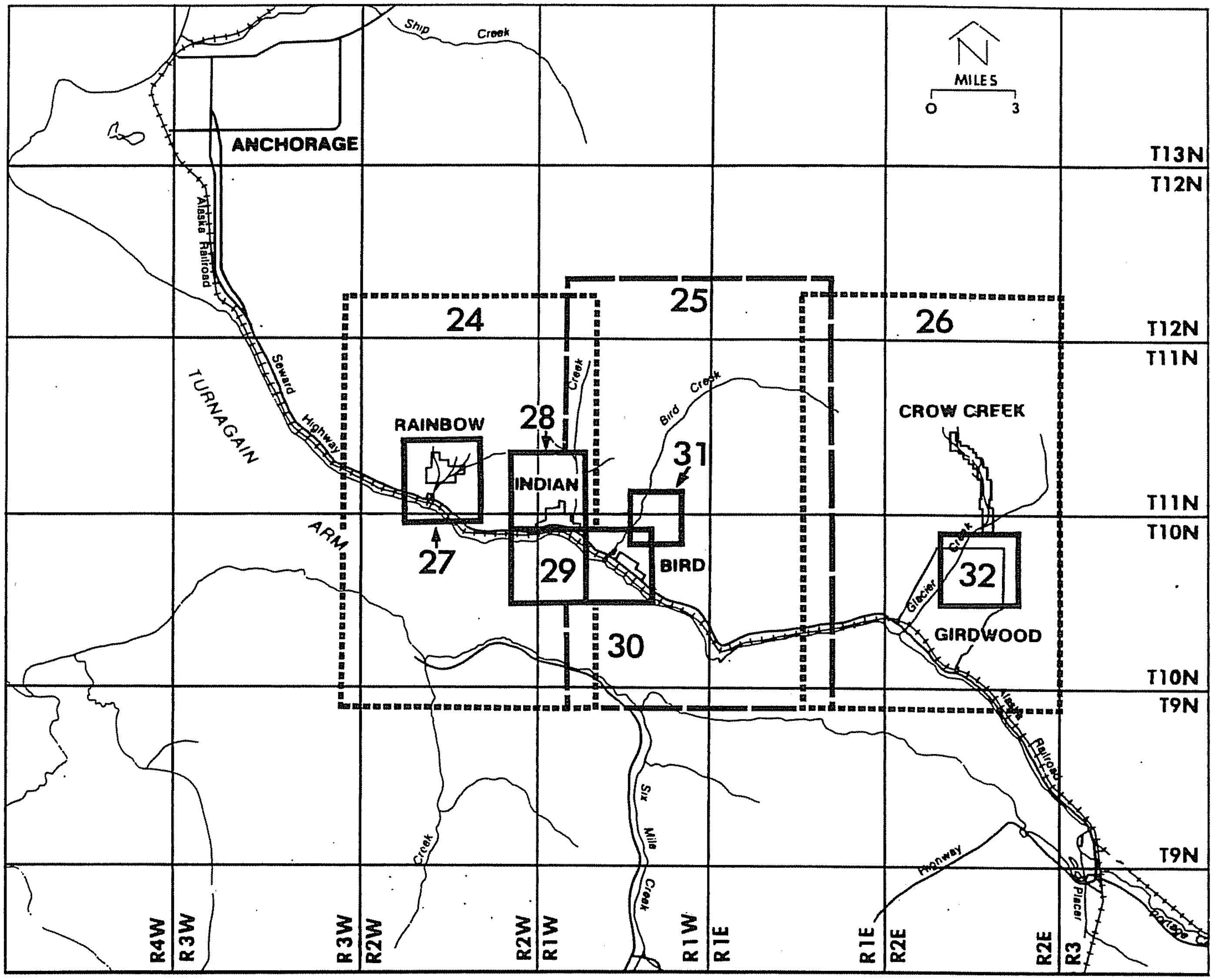
Avalanche Hazard Maps
INDEX for
Anchorage: SOUTH HILLSIDE



*The base for maps 19, 20, 22 and 23 has a scale of 1″=500′; map 21 has an approximate scale of 1″=2083′ or 1:25,000.

Figure 1-4

Avalanche Hazard Maps
INDEX for
Turnagain Arm: RAINBOW, INDIAN,
BIRD, GIRDWOOD and CROW
CREEK VALLEY



* The base for map 24 through 26 is a differentially rectified high altitude aerial photograph with a scale of 1"=2,640' or 1"=½ mile, maps 27 through 32 have a scale of 1"=500'.

Figure 1-5