1963, 1965; United States Weather Bureau, 1970; Zurndorfer and others, 1986). The procedure is described in section 3.4 and Chapter 5.

3.1.6.3 Direct orographic correction of PMP in orographic regions

This method proposes the direct transposition of the PMP (storm) in an orographic region to a particular position (the storm centre and the storm area axis) in a specific watershed, and then the performance of specific corrections based on the potential influence of the orographic differences on PMP in the two regions. Section 7.4.5 provides details of the methodology.

3.1.6.4 Examples of procedures

The remainder of this chapter presents details on procedures used in applying the methods mentioned in the two preceding paragraphs. The general principles involved are discussed, and examples given from published reports. Thus, the examples necessarily are for a particular set of conditions: namely, a certain amount of available data, certain terrain characteristics, and last, but just as important, the meteorological characteristics of the major storms in the regions for which the studies were made.

3.2 THE OROGRAPHIC SEPARATION METHOD WITH A LAMINAR FLOW MODEL

3.2.1 Introduction

In PMP estimation using the orographic separation method, an orographic model is used to calculate orographic storms. There are only a small number of cases in which the model is applicable for mid-latitude regions, so it must be used with care. Despite its limited application, the method is introduced in detail here because of a dearth of information published elsewhere. Approaches for calculating precipitation convergence components of a weather system using the orographic separation method are also presented in this section.

Sections 3.2 and 3.3 provide results of studies made by the then United States Weather Bureau on PMP for California in 1961 and 1966. Despite the fact that more recent results of PMP for that region are now available (Corrigan and others, 1999), sections 3.2 and 3.3 still use the earlier estimates, figures and tables for consistency with earlier editions of this manual.

3.2.2 Orographic laminar flow model

Precipitation released when moist air is forced over a relatively unbroken mountain ridge is the result of a basic process which can be idealized and treated as a two-dimensional problem. The air passing over the mountain crest must accelerate since there is a shallower layer within which air from a deeper upwind layer must be passed. This process has led to an orographic precipitation model in which the airflow, assumed to be laminar, is lifted over the mountain ridge. In regions with a significant amount of convective activity during major storms, this model will not provide reliable results because of the assumption of laminar flow. Another result of this characteristic of the model is to limit its use to temperate regions where tropical storms are not important causes of large storms. The laminar flow model is a storage evaporation model in that the resulting precipitation is the difference between the water vapour inflow at the base of the mountain range and the outflow above the ridge.

At some great height, called the nodal surface, airflow is assumed to be essentially horizontal. The height at which this occurs can be computed theoretically (Myers, 1962). In general, this height is between 400 and 100 hPa for moderately high barriers. A simplified diagram of inflow and outflow winds over a mountain barrier is shown in Figure 3.1.

This model considers the flow of air in a vertical plane at right angles to a mountain chain or ridge. It is what is termed a two-dimensional model. The plane has a y coordinate in the direction of flow and a z coordinate in the vertical. The flow may represent an average over a few kilometres or tens of kilometres in the transverse, or x, direction, which does not appear explicitly in the model. The wind at ground level moves along the surface. The slope of the air streamlines above a given point on the mountain slope decreases with height, becoming horizontal at the nodal surface.

3.2.2.1 Single-layer laminar flow model

If it is assumed that the air is saturated, that temperature decreases along the rising streamlines at the moist adiabatic rate, and that the flow is treated as a single layer of air between the ground and the nodal surface (Figure 3.2), the rate of precipitation is then:

$$R = \frac{\overline{V}_1 \left(\overline{W}_1 - \overline{W}_2 \frac{\Delta P_1}{\Delta P_2} \right)}{Y} \qquad (3.1)$$

where R is the rainfall rate in mm/s; $\overline{V}_1$ is the mean inflow wind speed in m/s; $\overline{W}_1$ and $\overline{W}_1$ are the inflow and outflow precipitable water (liquid water