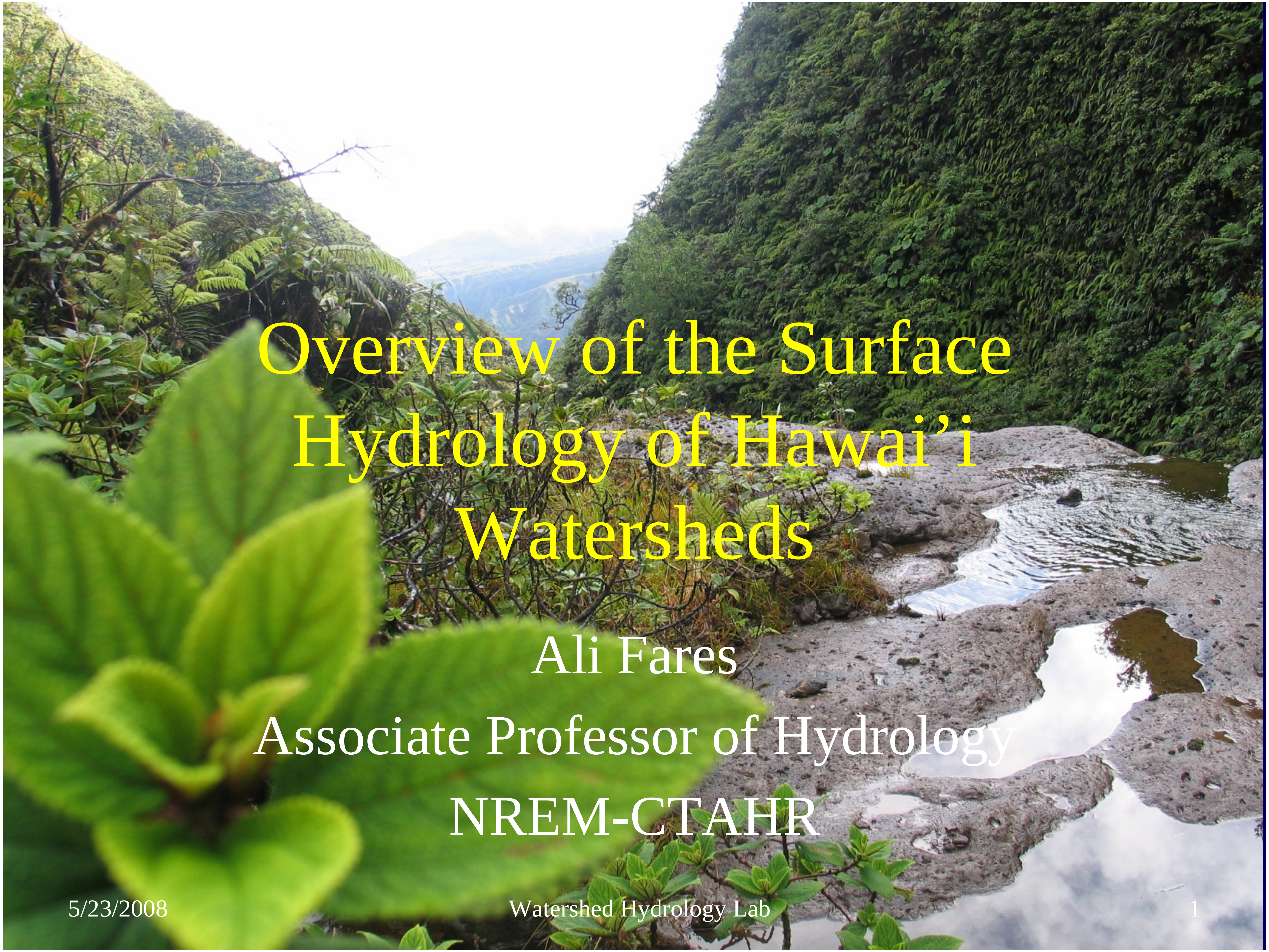


Overview of the Surface Hydrology of Hawai'i Watersheds

Ali Fares

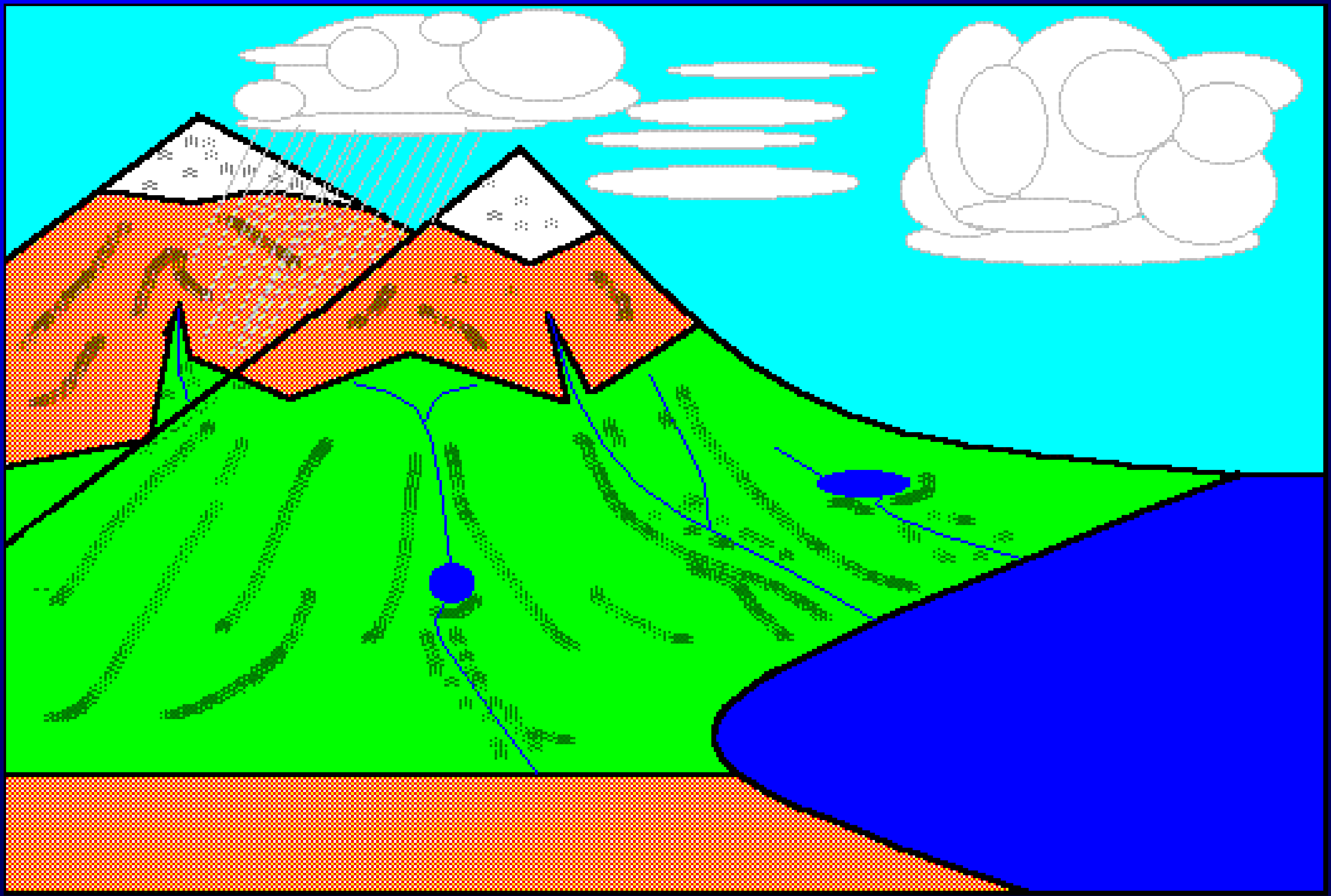
Associate Professor of Hydrology

NREM-CTAHR

What is Hydrology?

- Hydrology is the water science that is concerned with the origin, circulation, distribution and properties of water.
- There are different branches of hydrology, i.e., **surface hydrology**, groundwater hydrology, subsurface hydrology, etc…

Water Cycle



What is surface hydrology?

- Surface hydrology is the branch of hydrology dealing with **surface water**
- Surface Water is water that is on the Earth's surface, such as in a stream, lake, or reservoir.

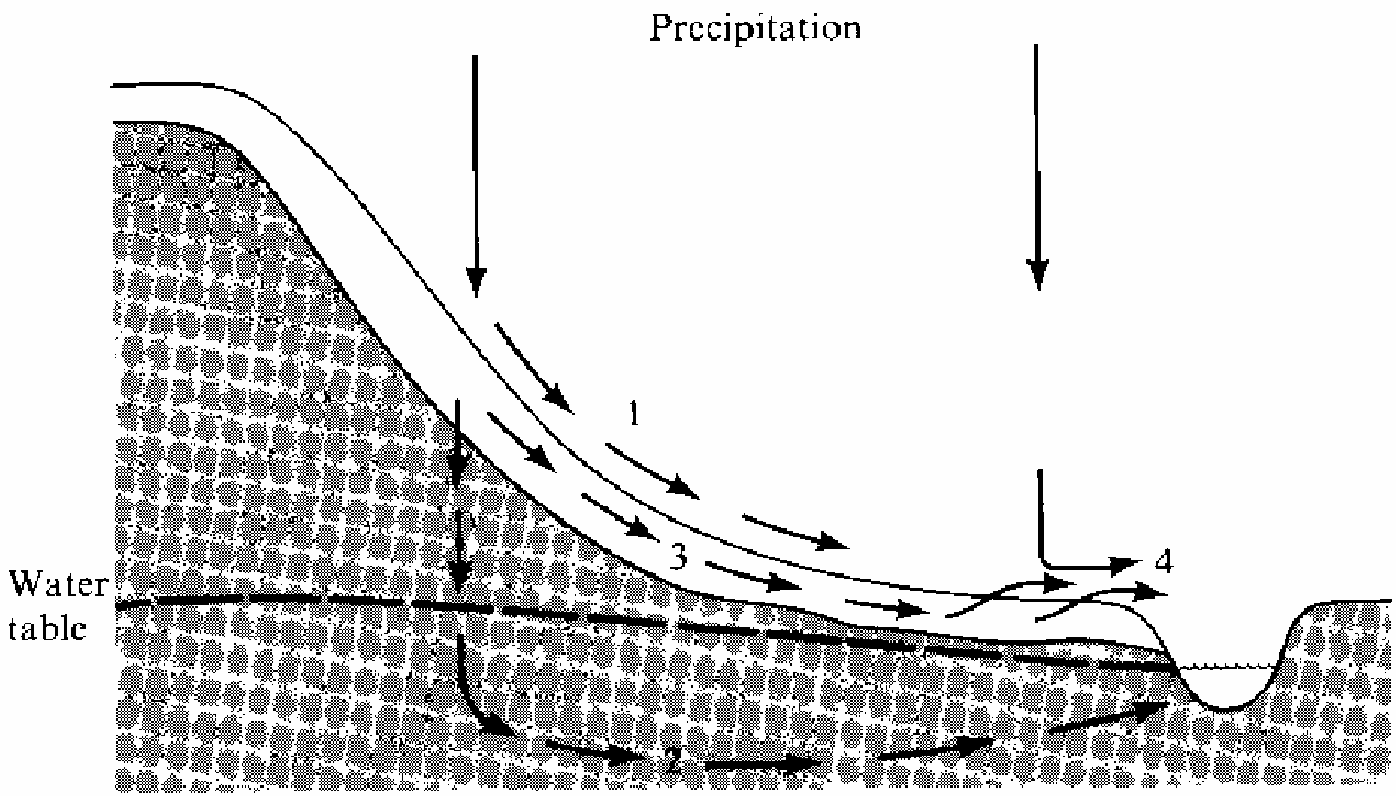
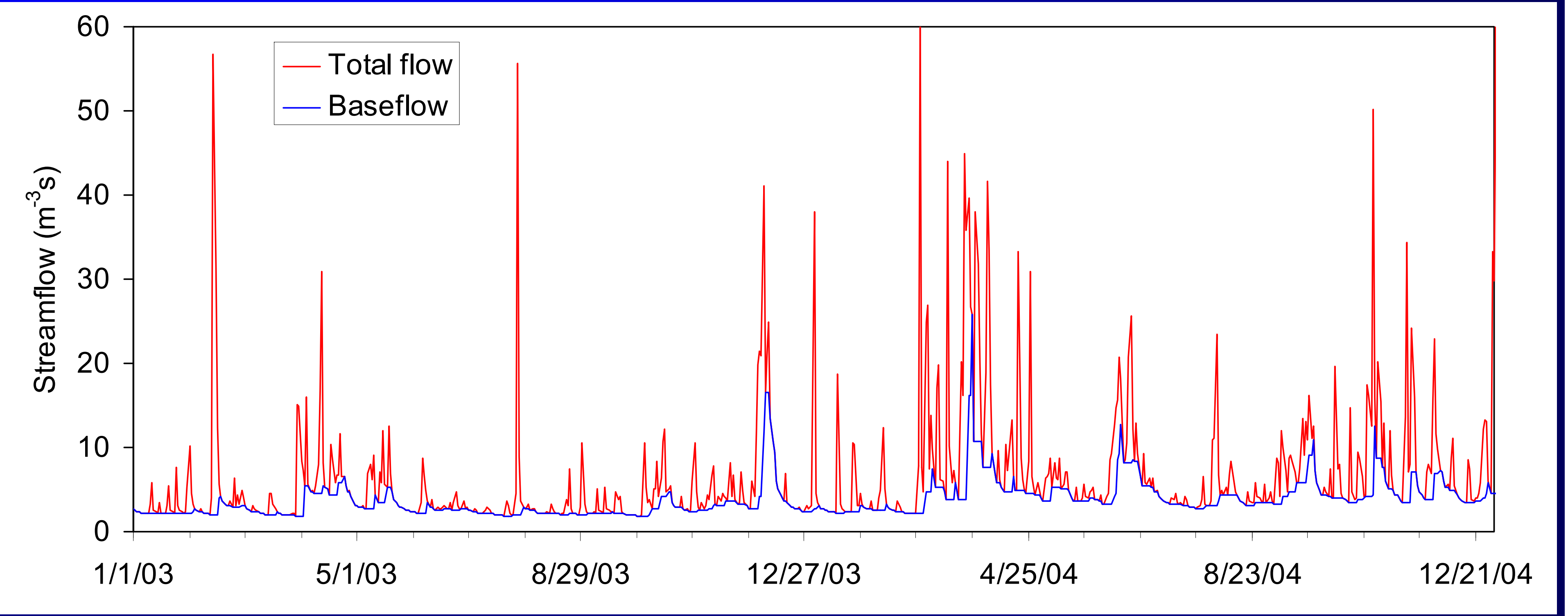


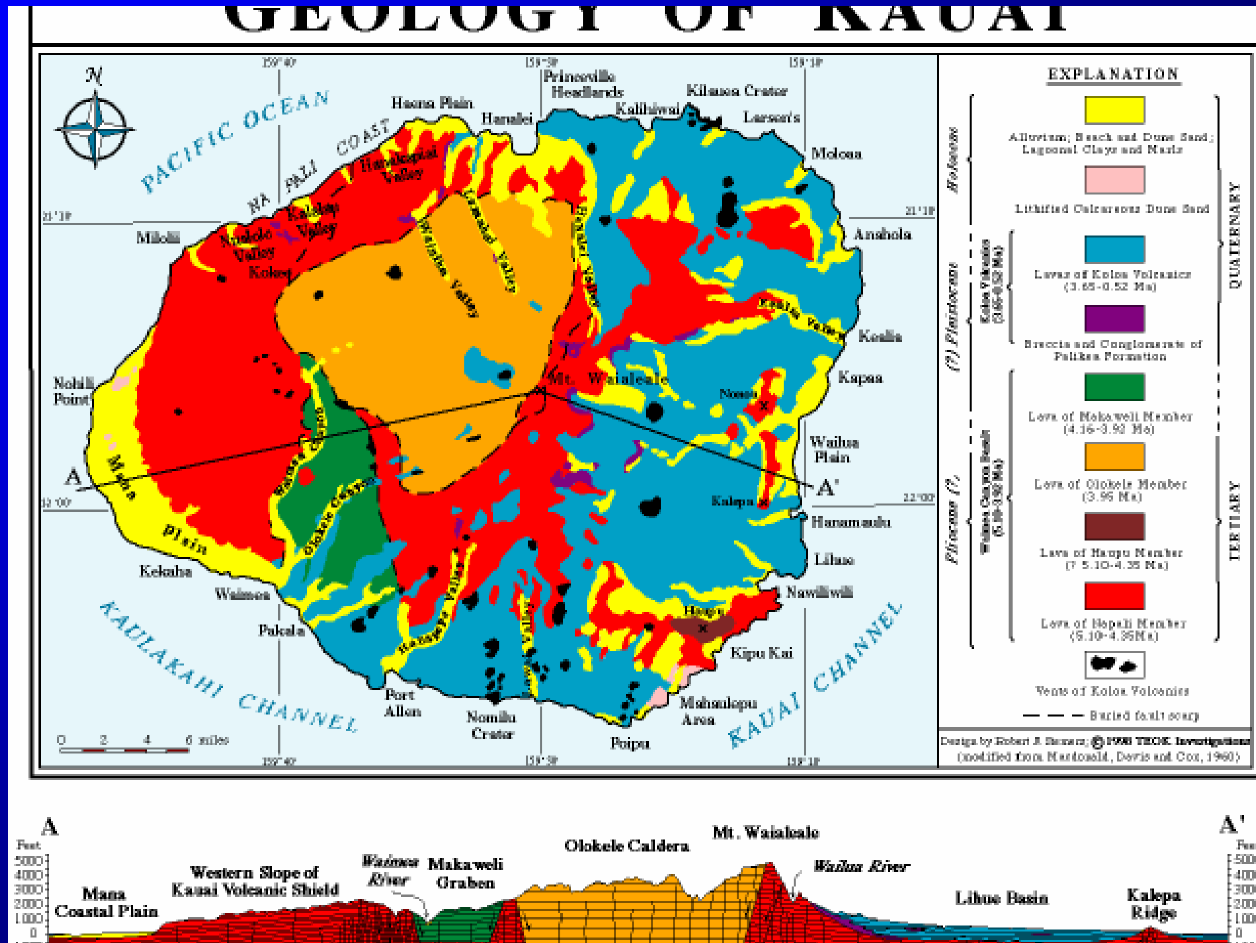
Figure 9-1 Possible paths of water moving downhill: path 1 is Horton overland flow; path 2 is groundwater flow; path 3 is shallow subsurface stormflow; path 4 is saturation overland flow, composed of direct precipitation on the saturated area plus infiltrated water that returns to the ground surface. The unshaded zone indicates highly permeable topsoil, and the shaded zone represents less permeable subsoil or rock.

Stream flow separation

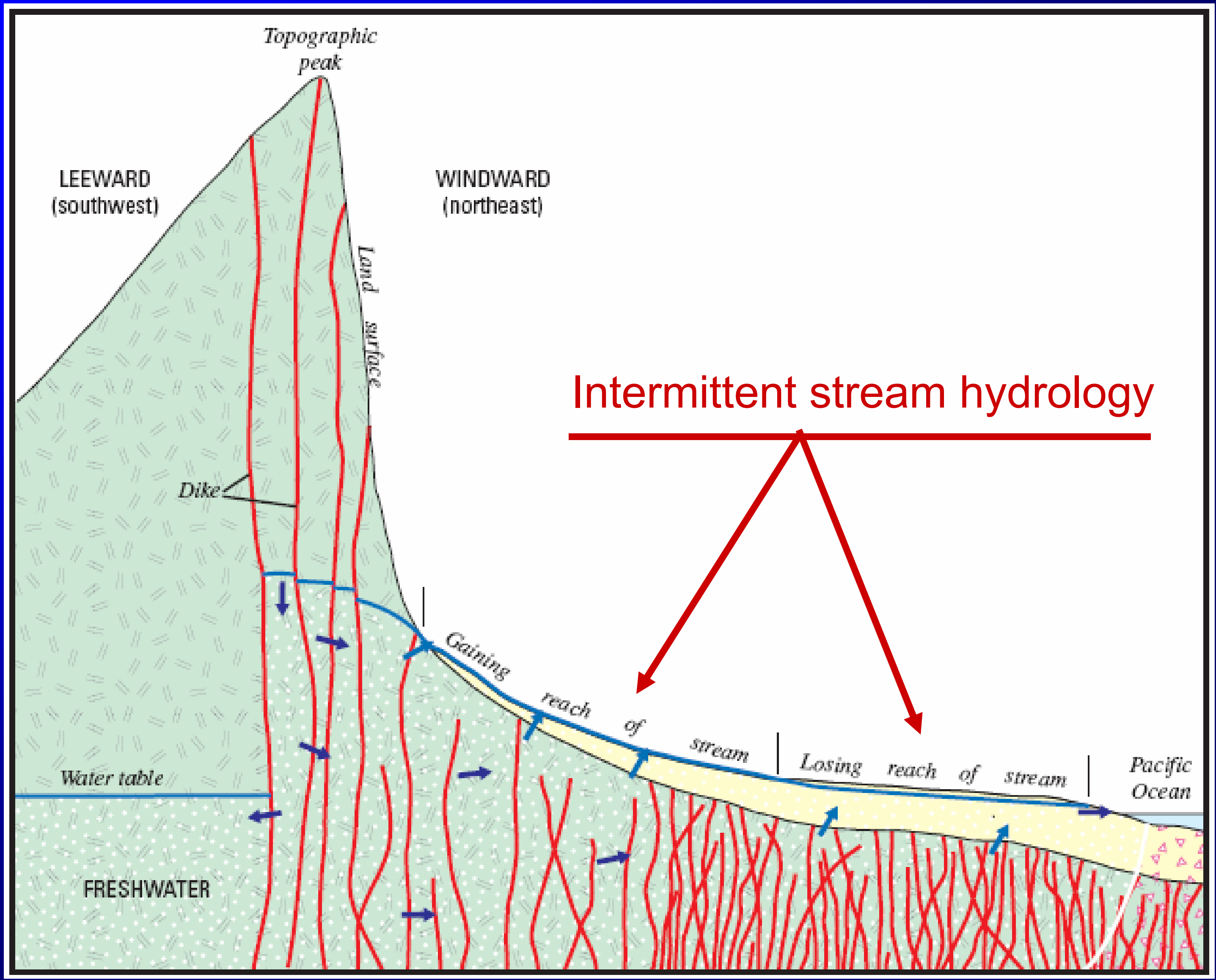


- Base flow and direct runoff were 62% 38% of total stream flow, respectively.

Geology of Hawaii



Hawaiian island chain consist of one or more shield volcanoes which are primarily composed of extremely permeable, thin basaltic lava flows.



Dike impounded system

Natural Stream & Ditch Systems

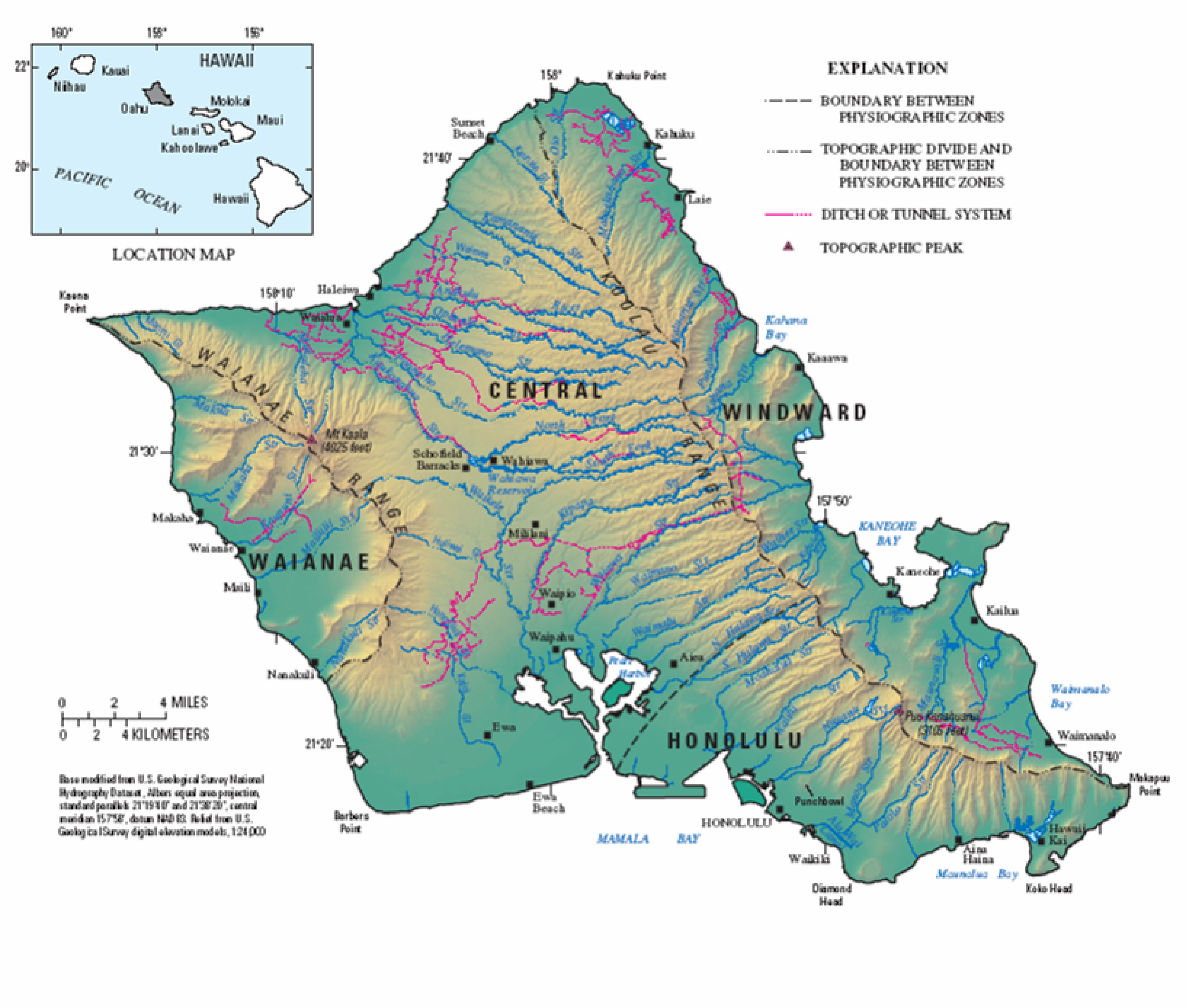
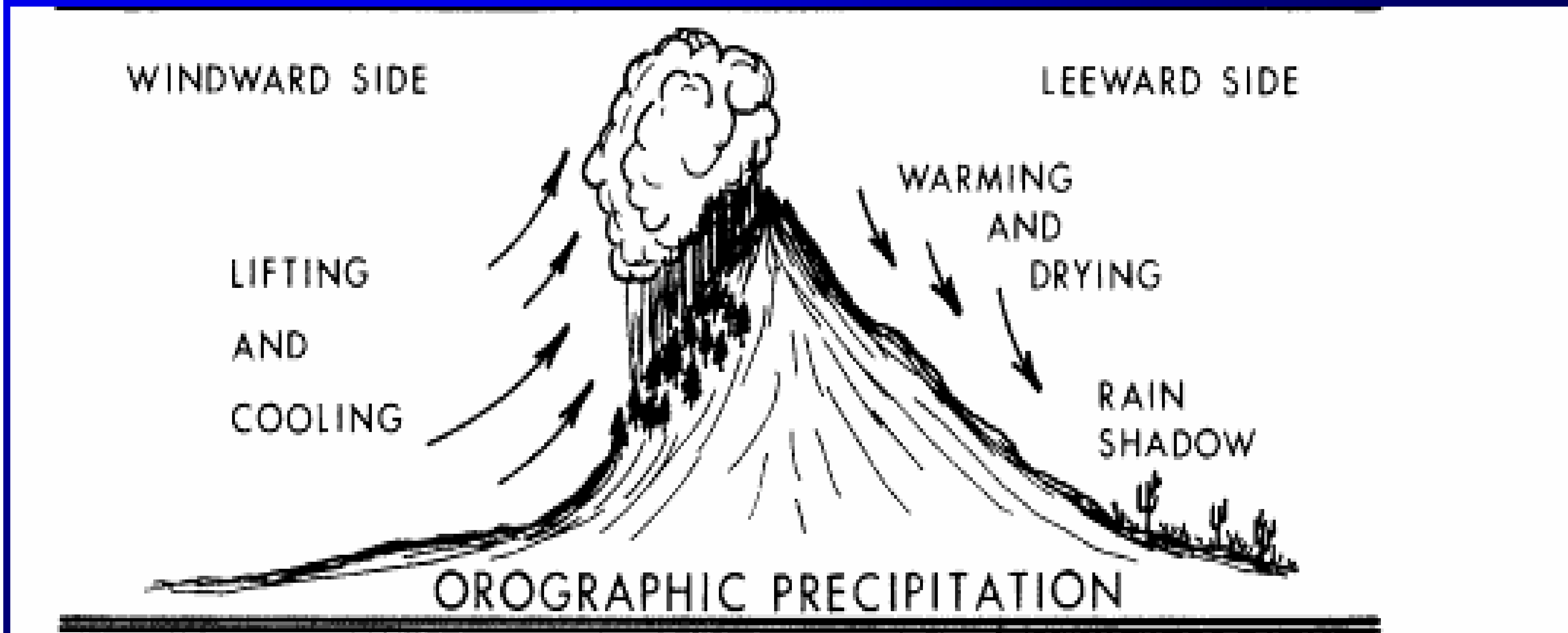


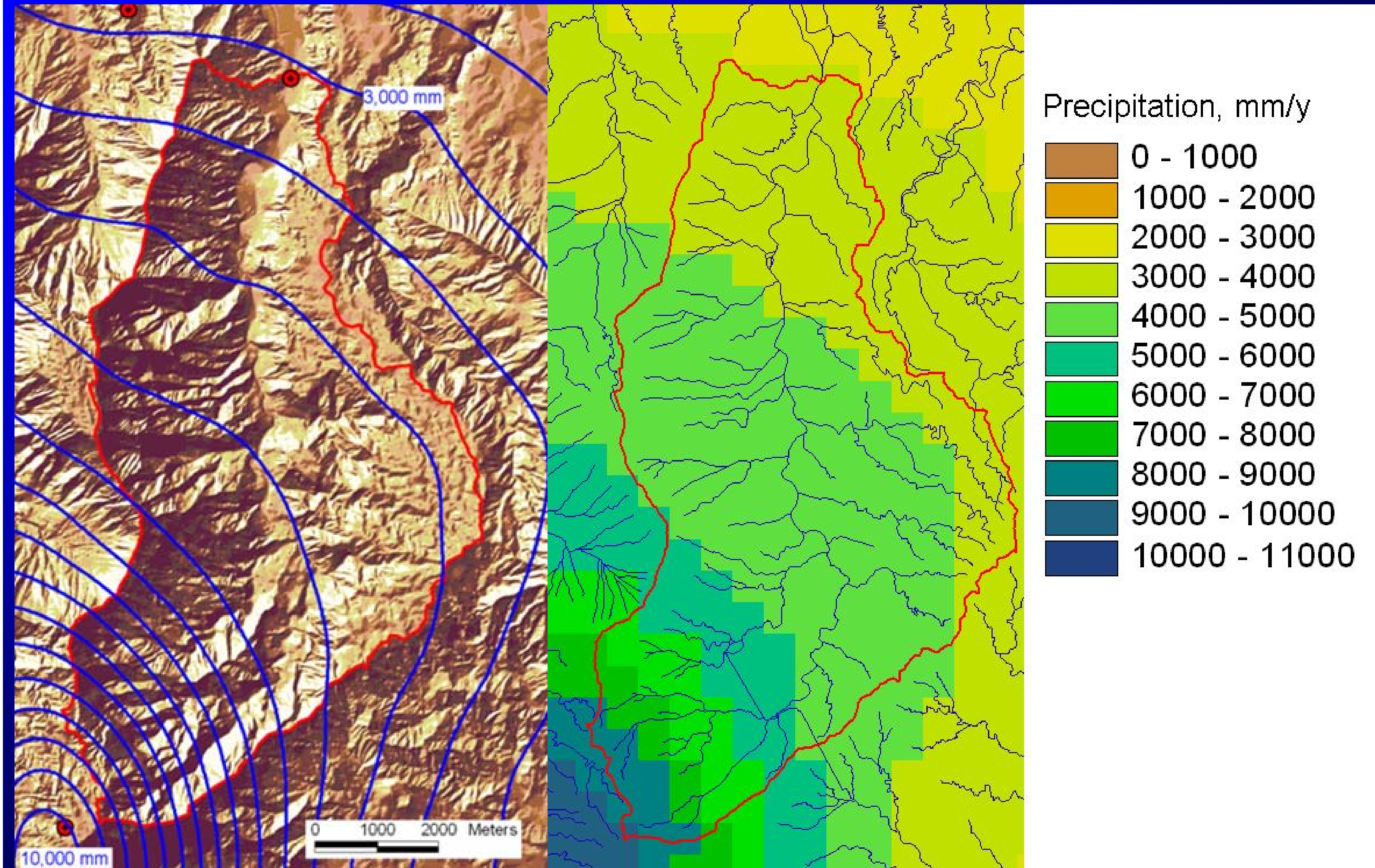
Figure 1. Selected streams, ditch systems, and other geographic features, island of Oahu, Hawaii.

Effect of Spatio-temporal variation of Rain at the Island and Watershed Scales

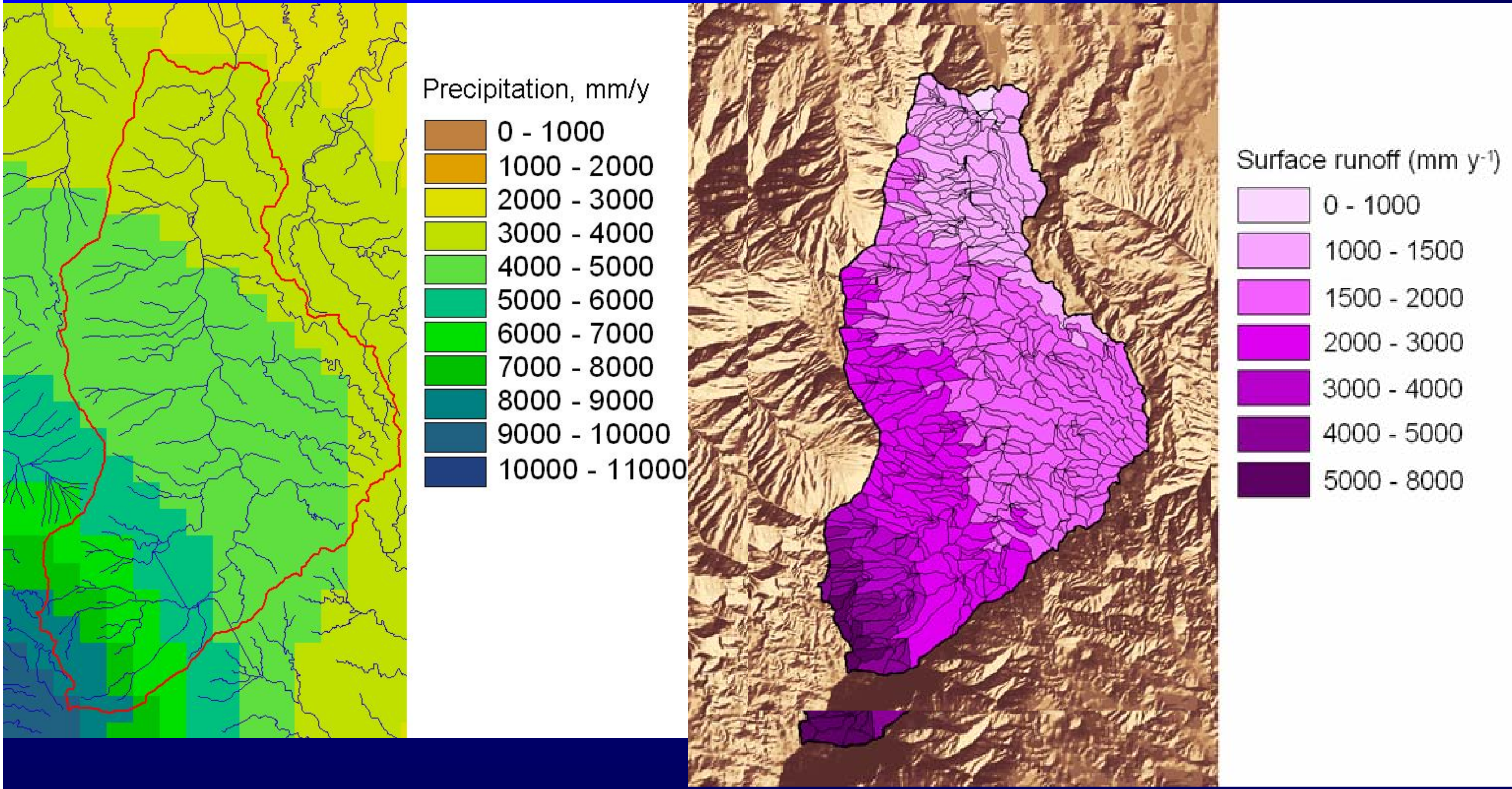
Orographic Precipitation



Elevation and Rain Distribution



Spatial rain-runoff variability



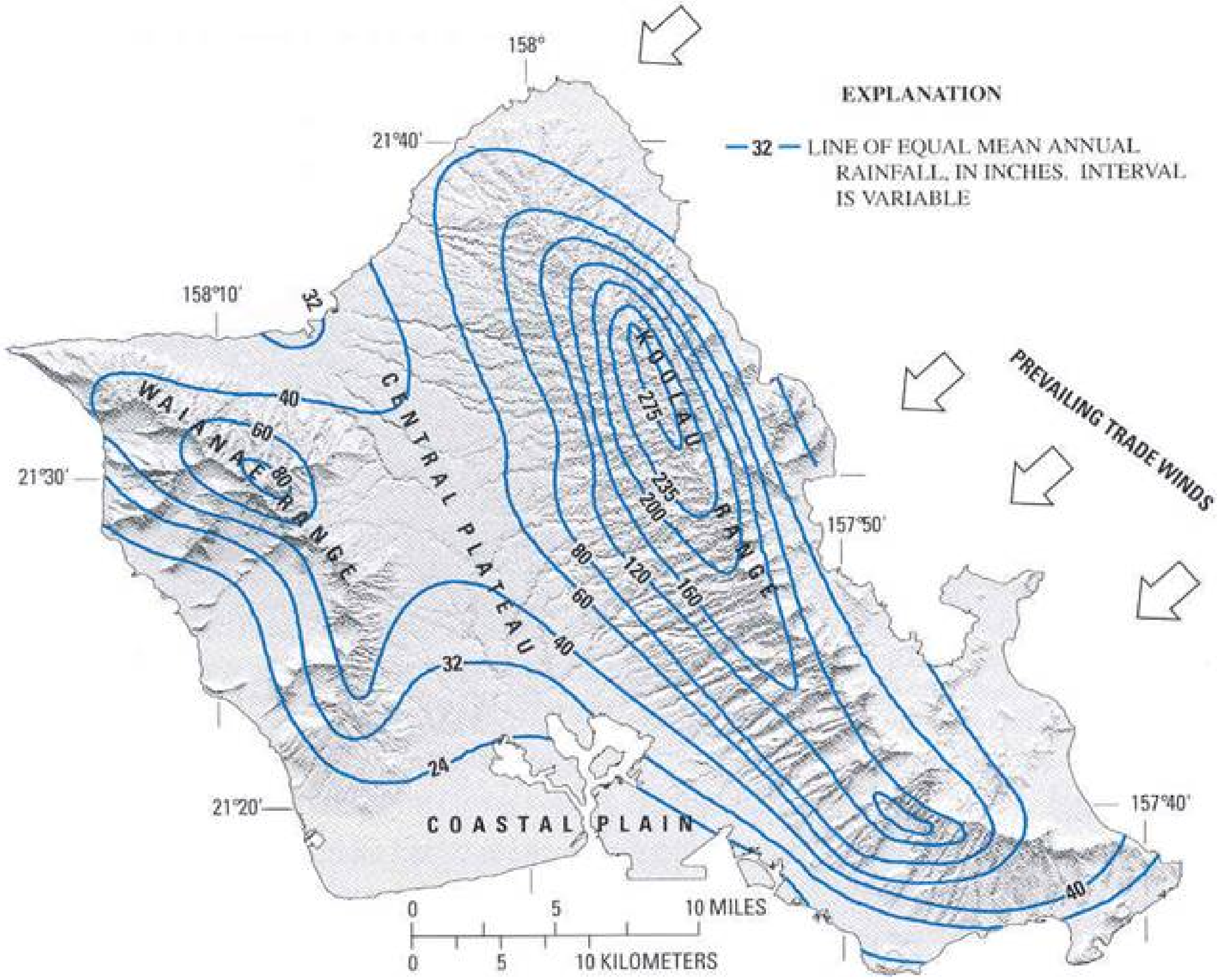


Figure 2. Oahu's mountainous landscape and moist trade winds cause steep rainfall gradients. (Modified from Giambelluca and others, 1986).

Rainfall variability: monthly total

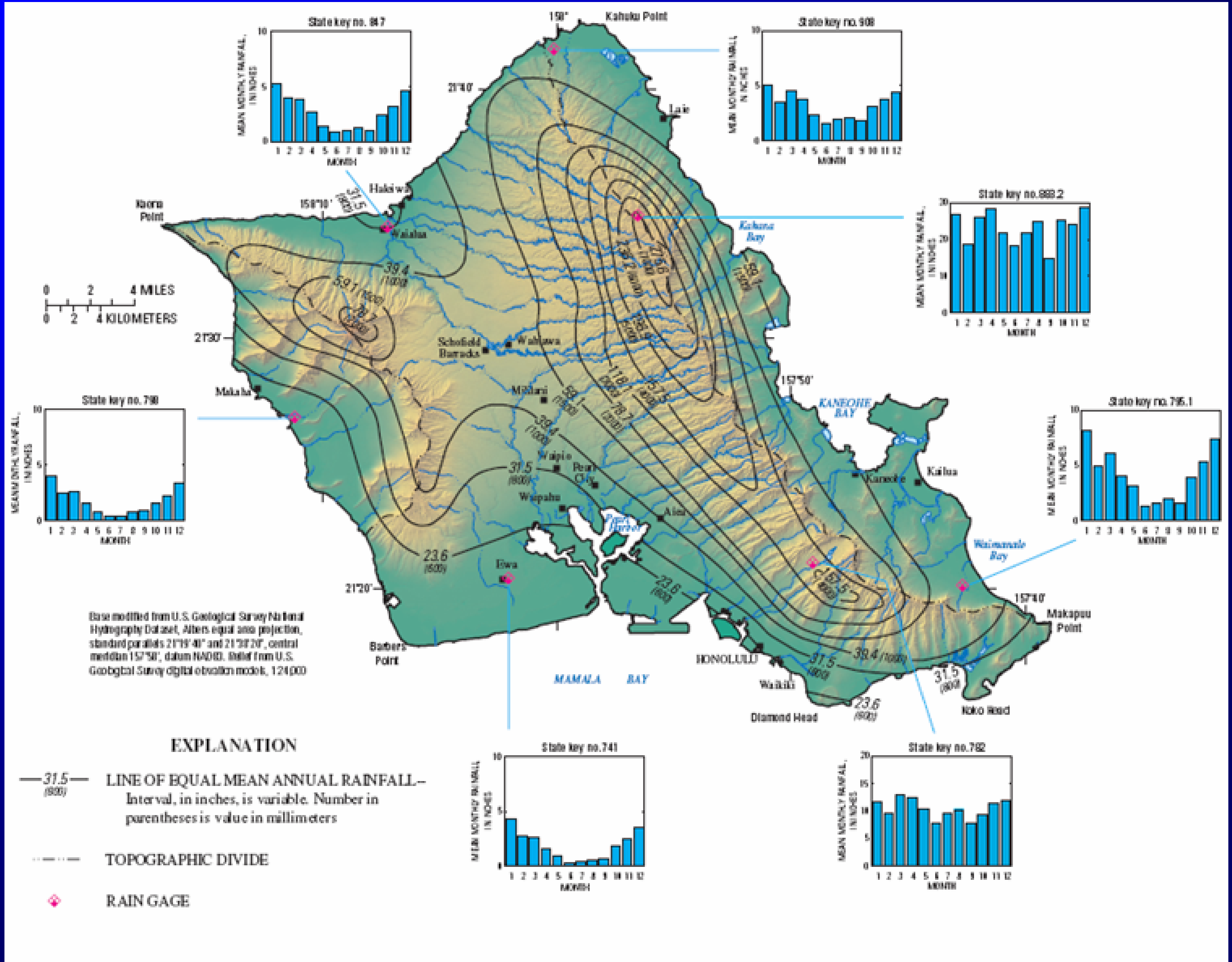
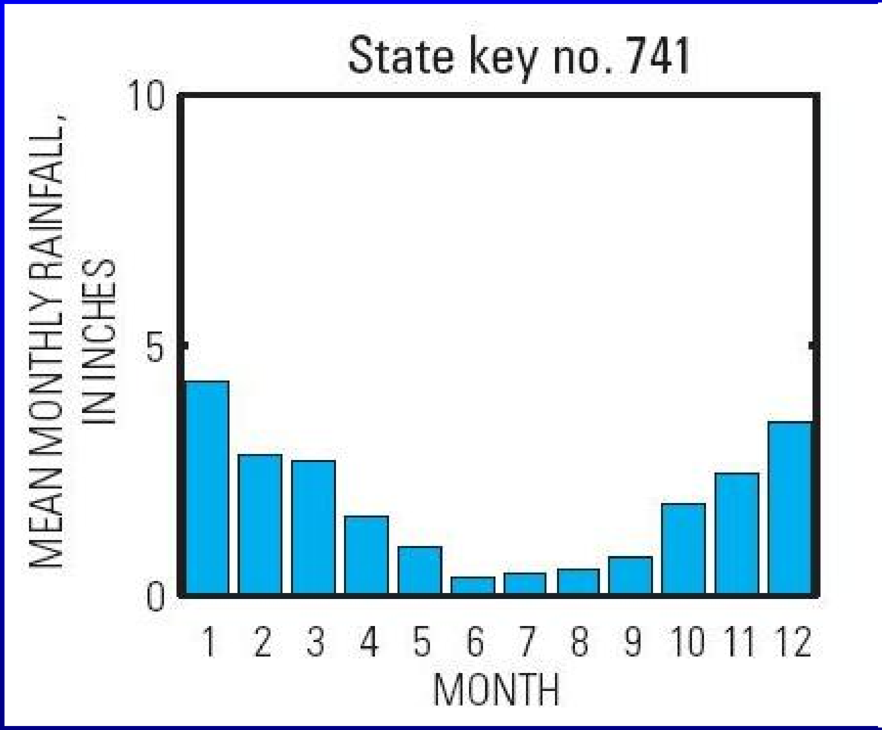


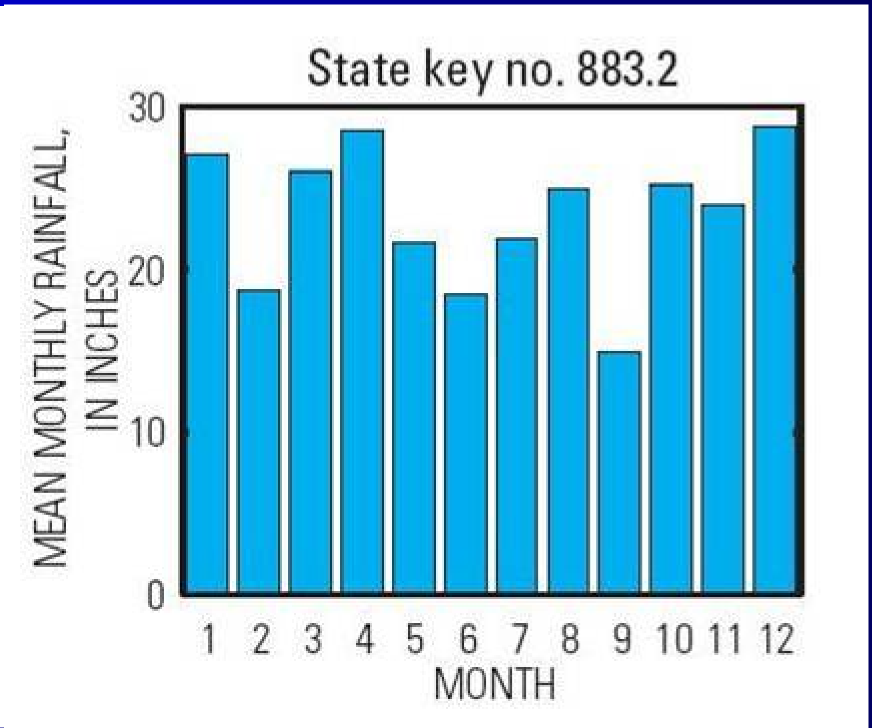
Figure 3. Mean annual rainfall, island of Oahu, Hawaii, and mean monthly rainfall at selected rain gages (modified from Giambelluca and others, 1986).

Rainfall variability: monthly total

Ewa (leeward)



Koolau (windward)



Runoff variability: monthly stream discharge

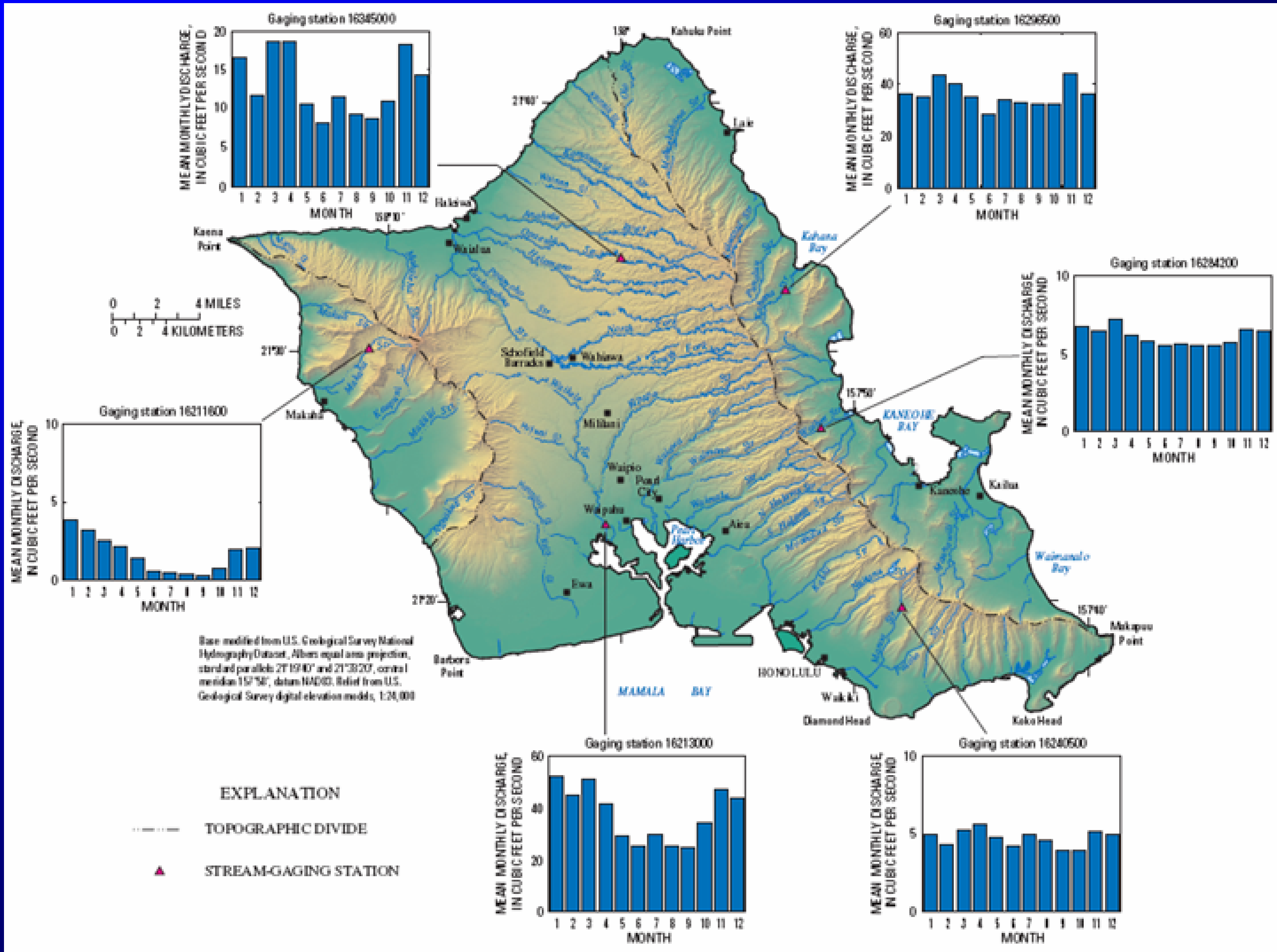


Figure 11. Mean monthly discharge during water years 1975–2000 at selected stream-gaging stations, island of Oahu, Hawaii. (A water year begins in October of the preceding year and ends in September.)

Runoff variability: instantaneous stream discharge

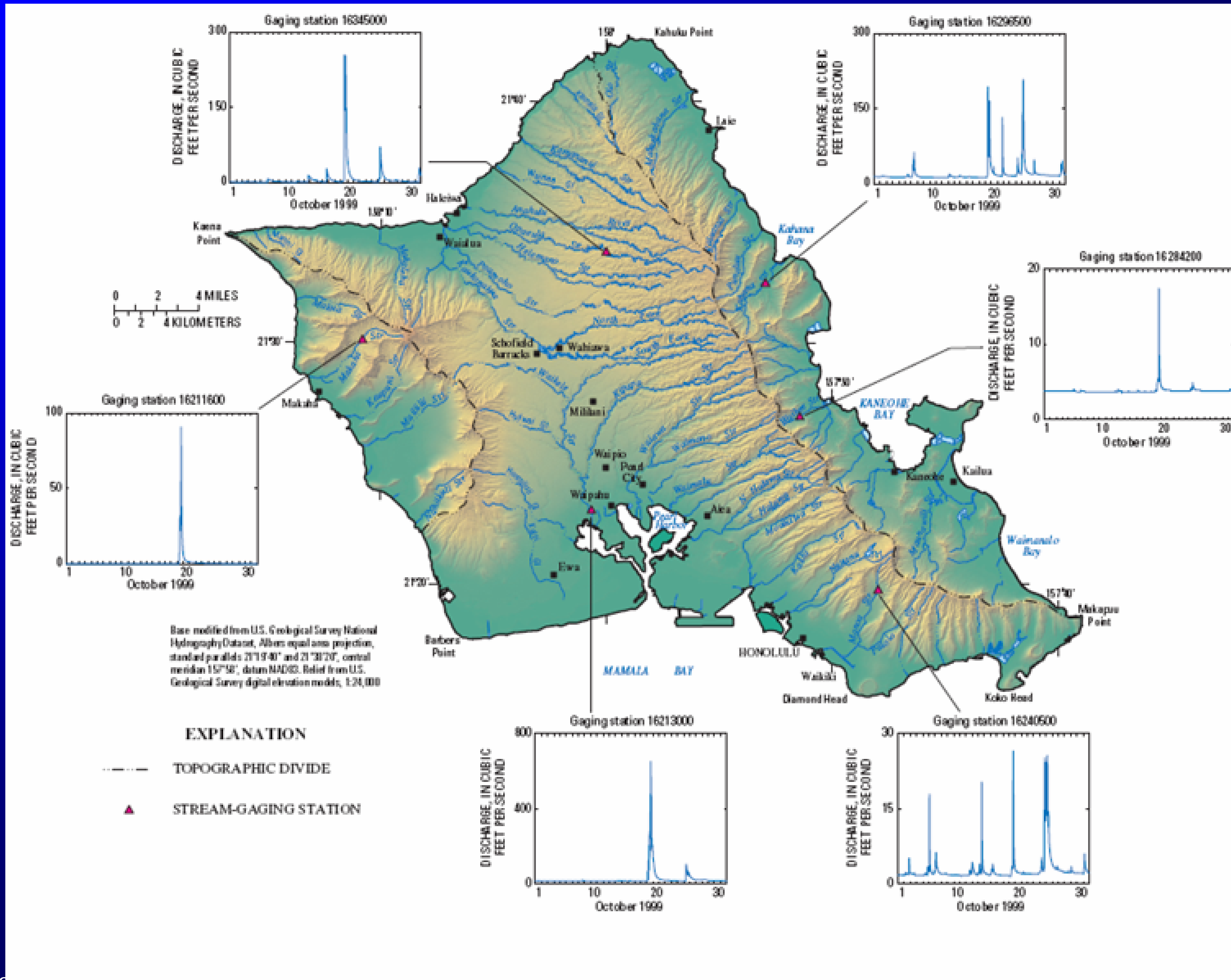
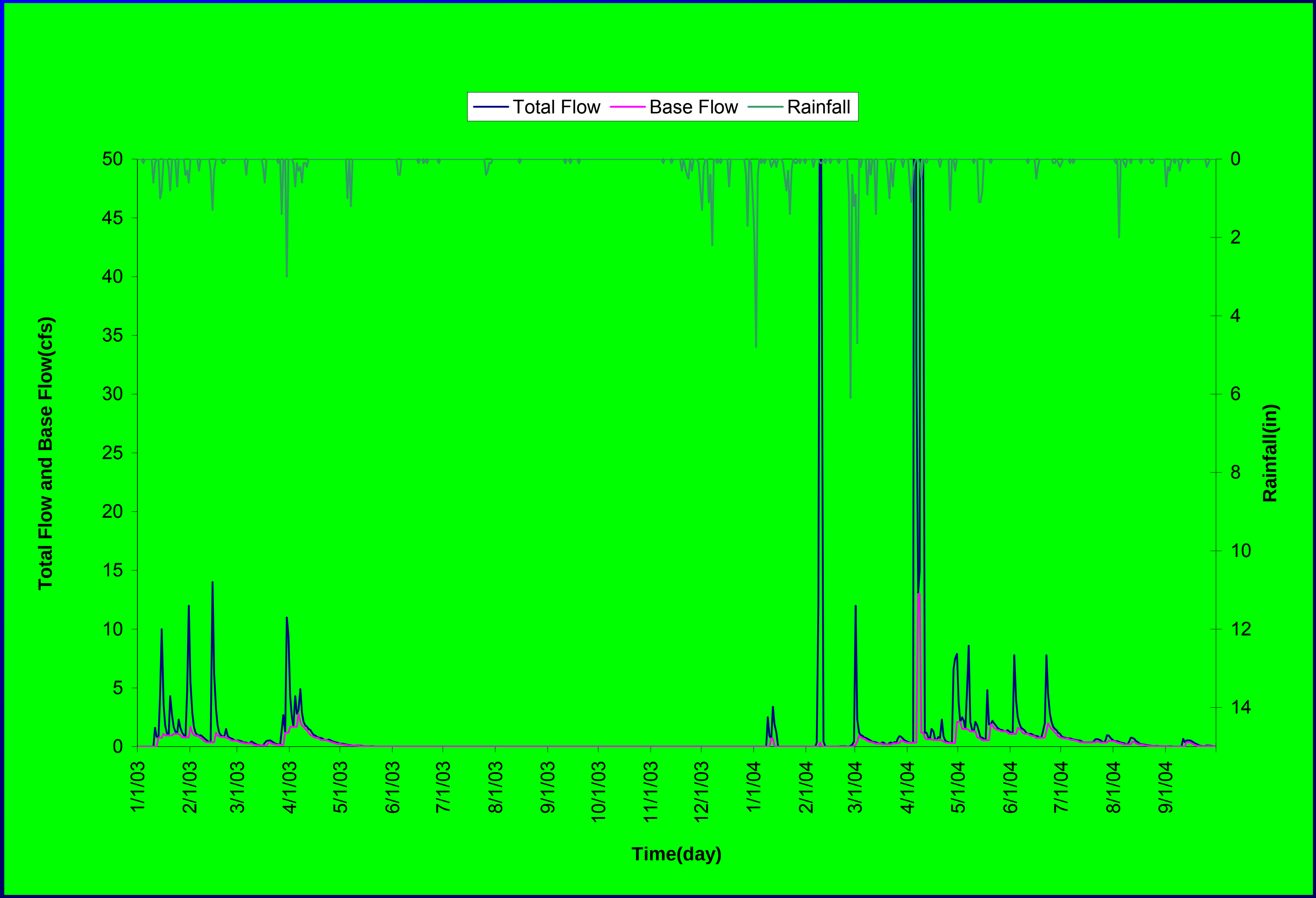
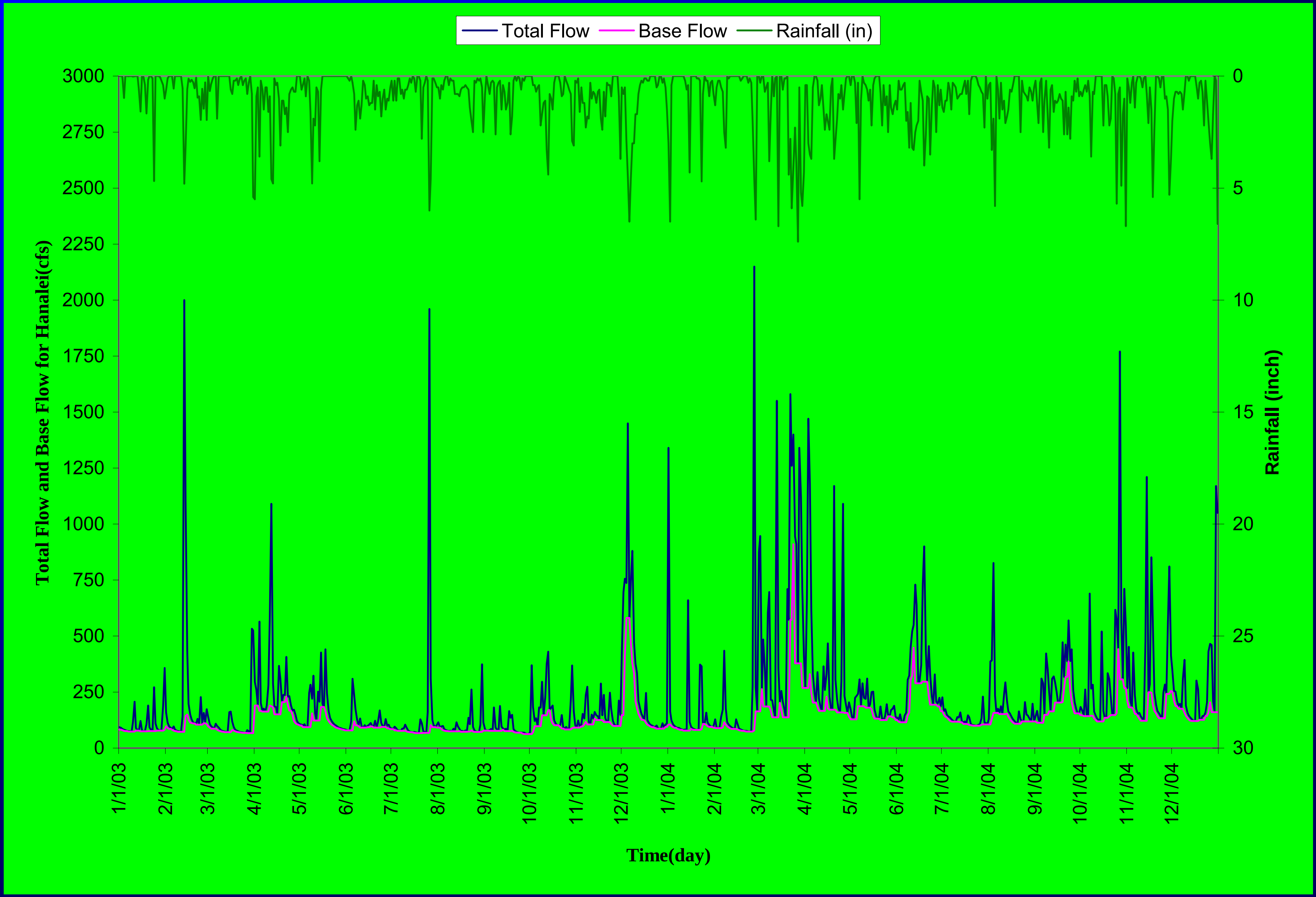


Figure 9. Stream discharge during October 1999 at selected stream-gaging stations, island of Oahu, Hawaii.

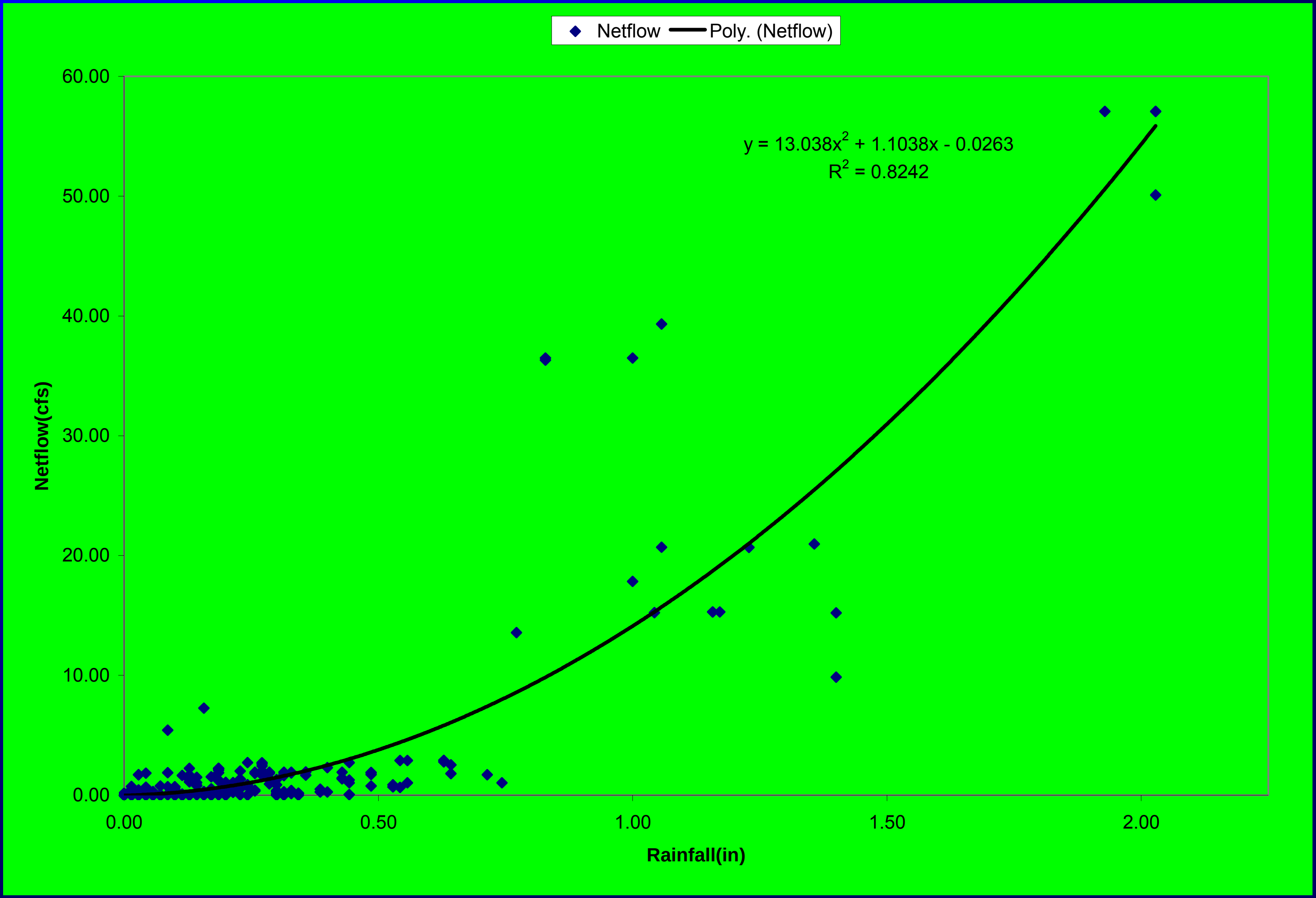
Rain, and Total & Base Flow, Makaha



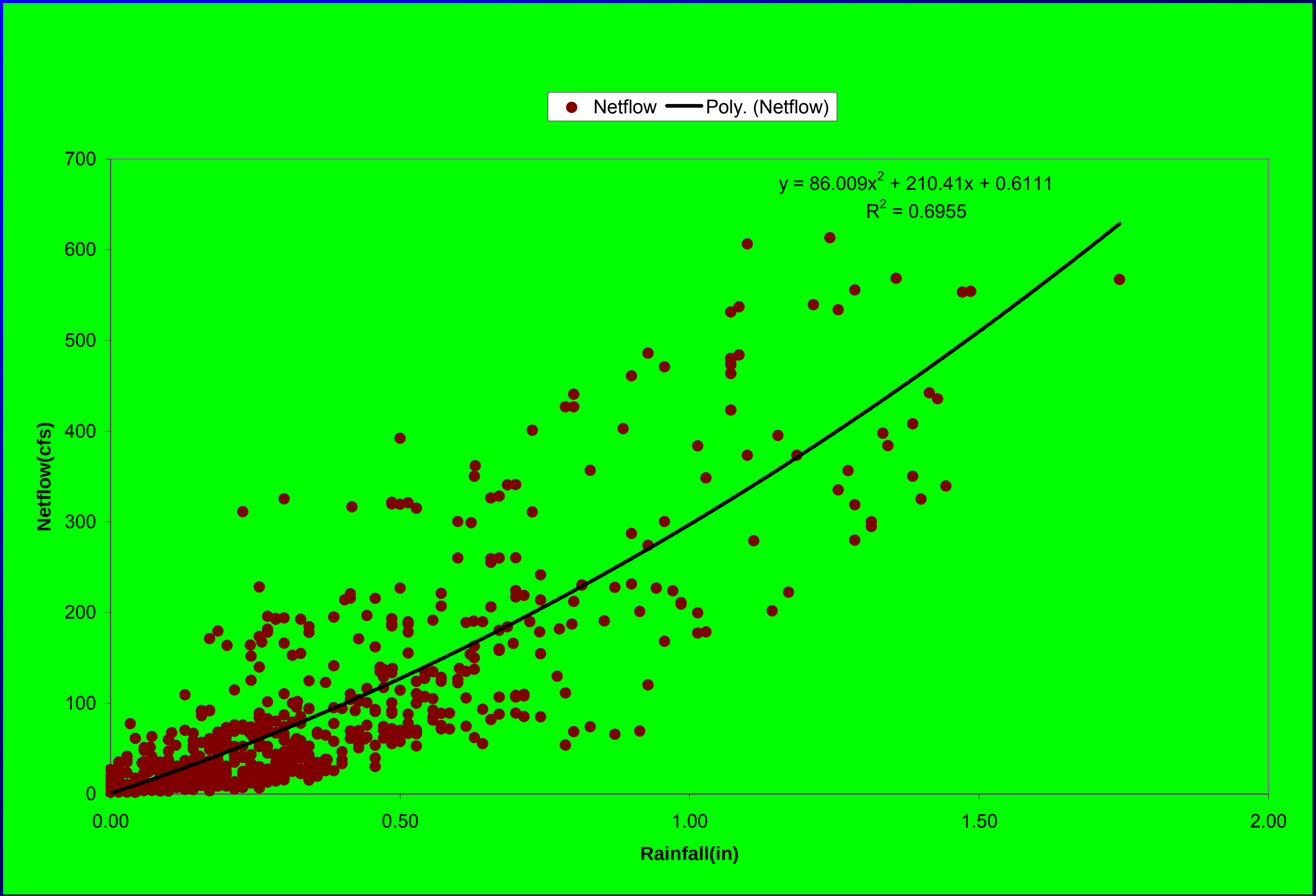
Rain, and Total & Base Flow, Hanalei



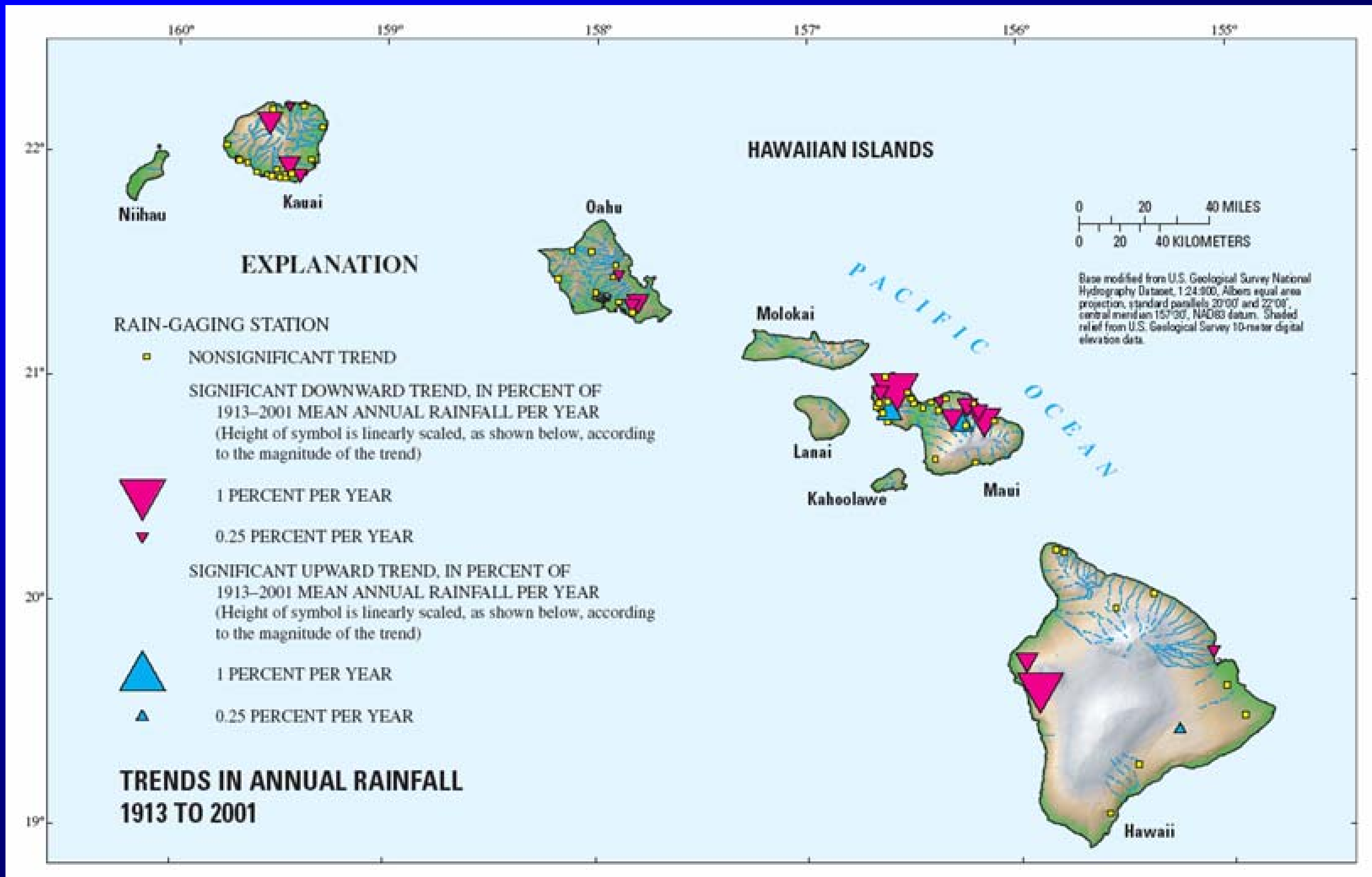
Rain- Overland Flow, Makaha Strm



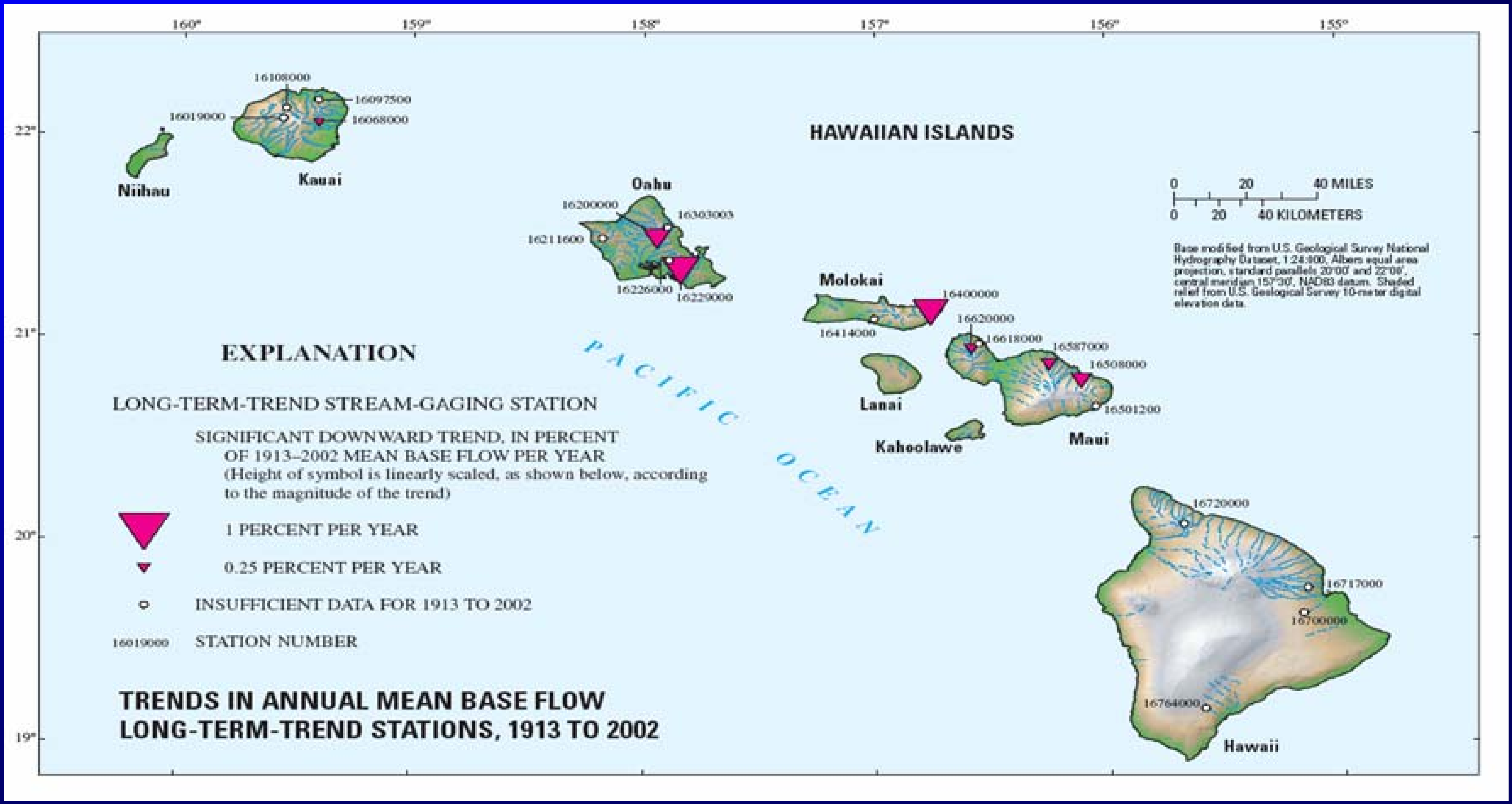
Rain-Overland Flow, Hanalei Strm

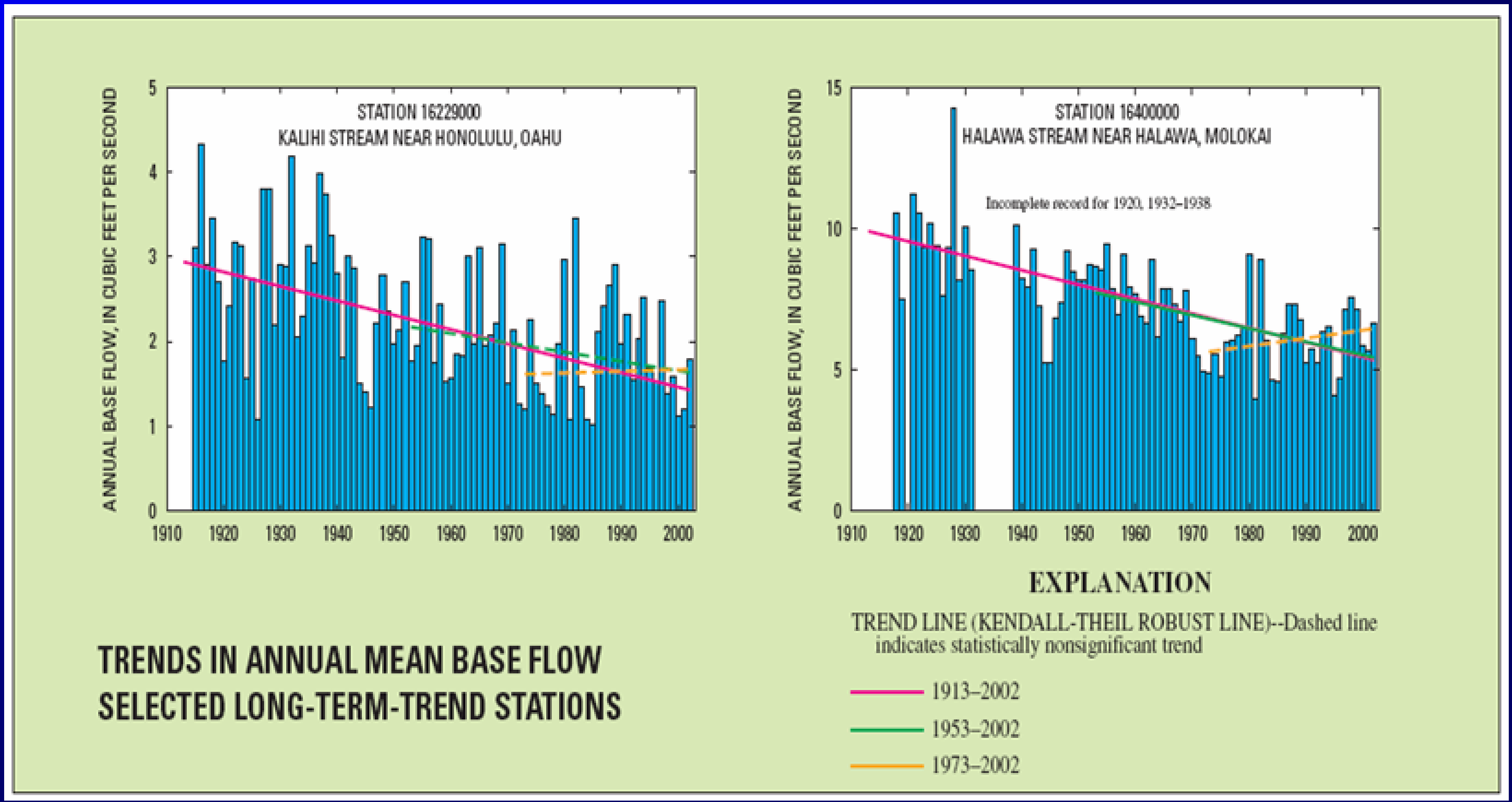


Long-Term Trends of Stream Flow in Hawaii

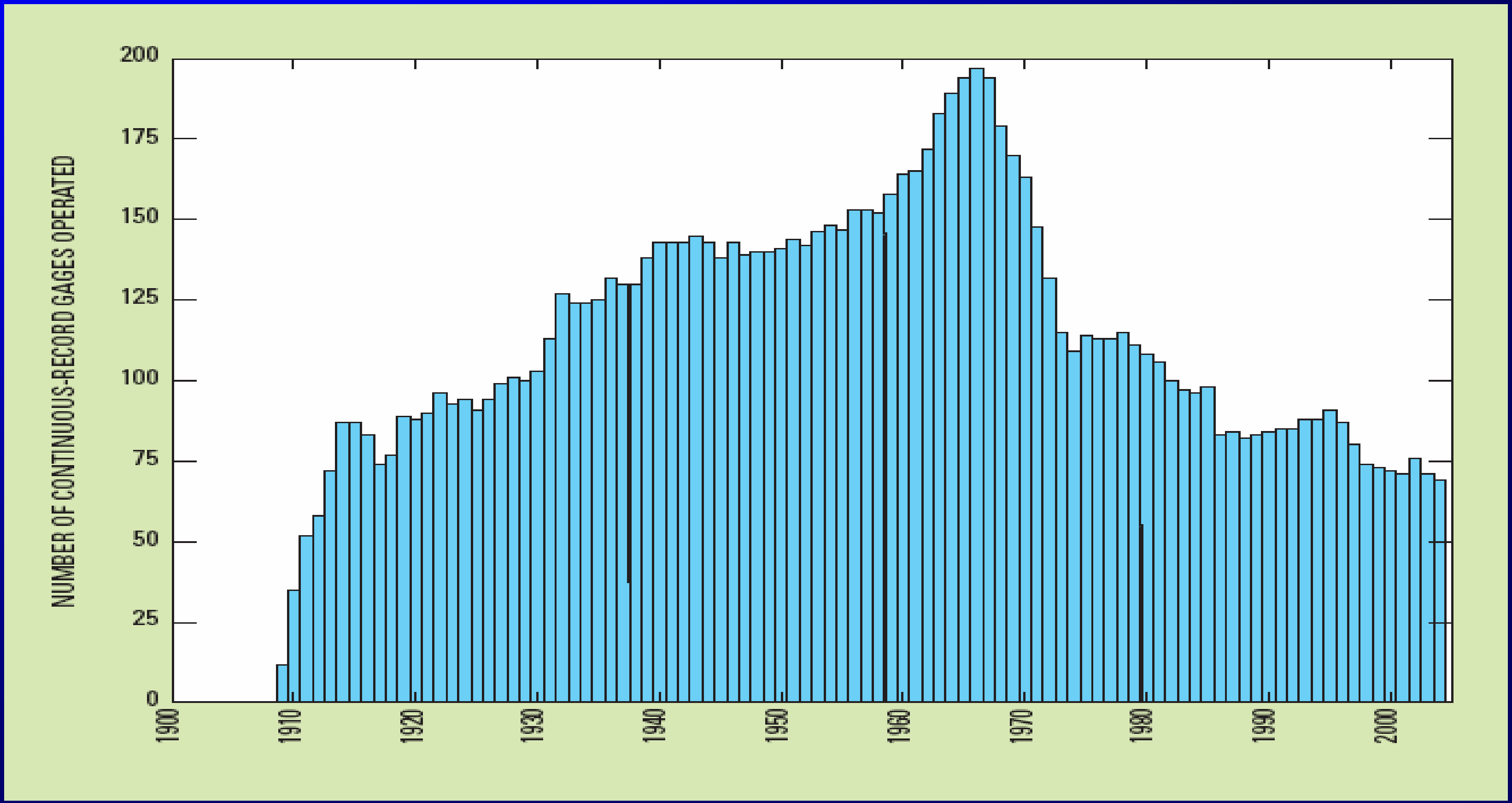

160°
159°
158°
157°
156°
155°
22°
21°
20°
19°
Niihau
Kauai
Oahu
HAWAIIAN ISLANDS
Molokai
Lanai
Kahoolawe
Maui
Hawaii
PACIFIC OCEAN
0 20 40 MILES
0 20 40 KILOMETERS
EXPLANATION
RAIN-GAGING STATION
NONSIGNIFICANT TREND
SIGNIFICANT DOWNWARD TREND, IN PERCENT OF 1913–2001 MEAN ANNUAL RAINFALL PER YEAR
(Height of symbol is linearly scaled, as shown below, according to the magnitude of the trend)
1 PERCENT PER YEAR
0.25 PERCENT PER YEAR
SIGNIFICANT UPWARD TREND, IN PERCENT OF 1913–2001 MEAN ANNUAL RAINFALL PER YEAR
(Height of symbol is linearly scaled, as shown below, according to the magnitude of the trend)
1 PERCENT PER YEAR
0.25 PERCENT PER YEAR
TRENDS IN ANNUAL RAINFALL
1913 TO 2001

Trends in Streamflow Characteristics in HI



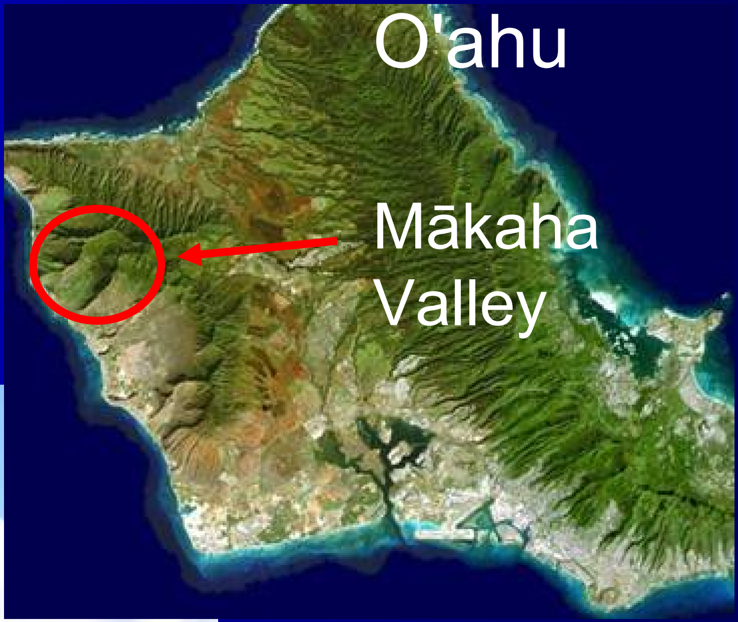

STATION 16229000
KALIHI STREAM NEAR HONOLULU, OAHU
ANNUAL BASE FLOW, IN CUBIC FEET PER SECOND
STATION 16400000
HALAWA STREAM NEAR HALAWA, MOLOKAI
Incomplete record for 1920, 1932–1938
TRENDS IN ANNUAL MEAN BASE FLOW
SELECTED LONG-TERM-TREND STATIONS
EXPLANATION
TREND LINE (KENDALL-THEIL ROBUST LINE)--Dashed line indicates statistically nonsignificant trend
1913–2002
1953–2002
1973–2002

USGS stream-gaging stations in HI



Case study: Makaha valley hydrology

Evaluation of the Effects of Alien Plant Species, Groundwater Extraction, and Long-term Weather Patterns on Mākaha Valley's Stream Flow



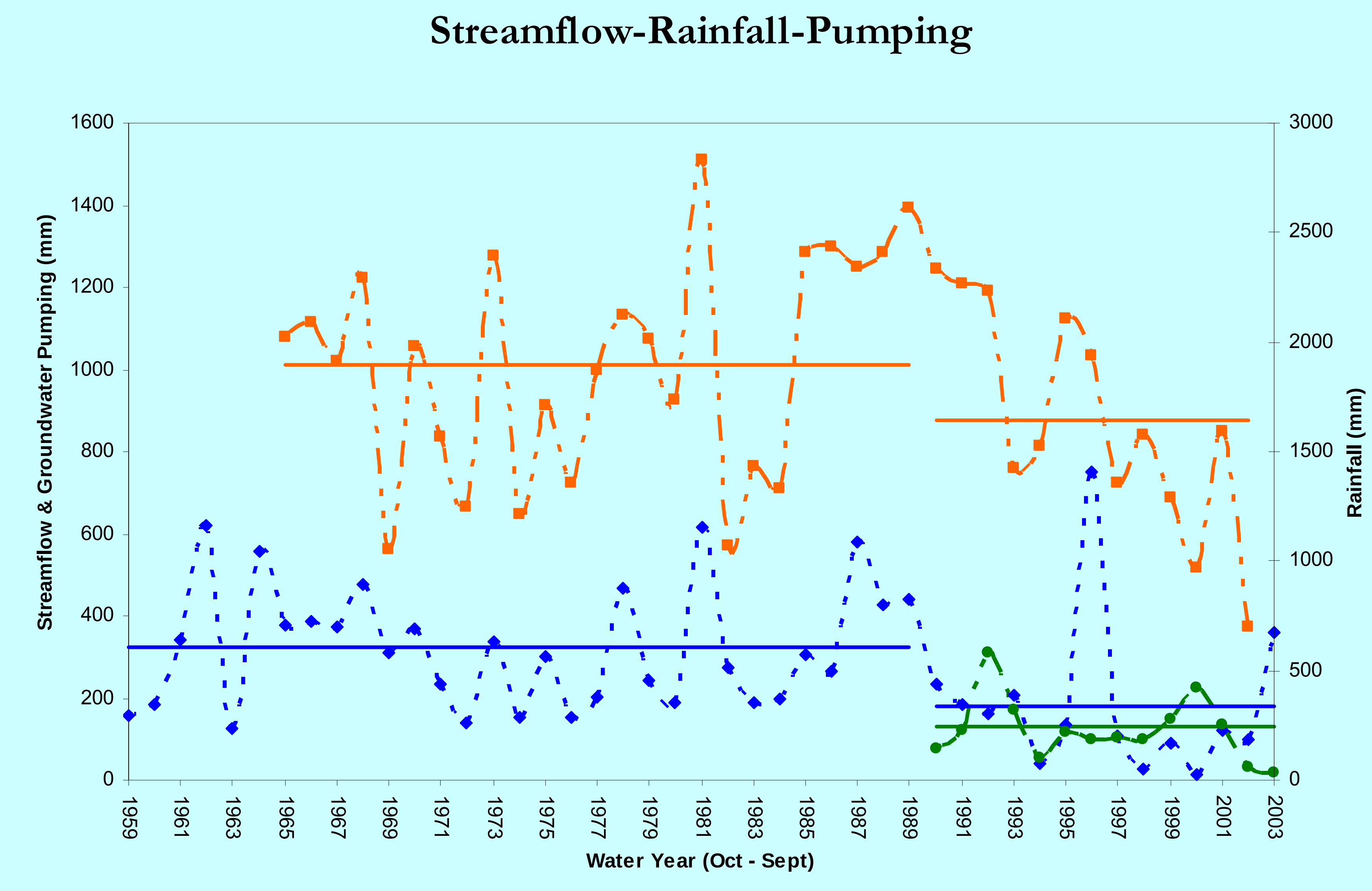
Case study: Makaha valley hydrology

Objectives

- Produce detailed vegetation maps (Miura)
- Assess spatial-temporal variation of hydrologic cycle
- Calibrate and validate a watershed model
- Evaluate effect(s) of changing vegetation, weather patterns, and groundwater pumping

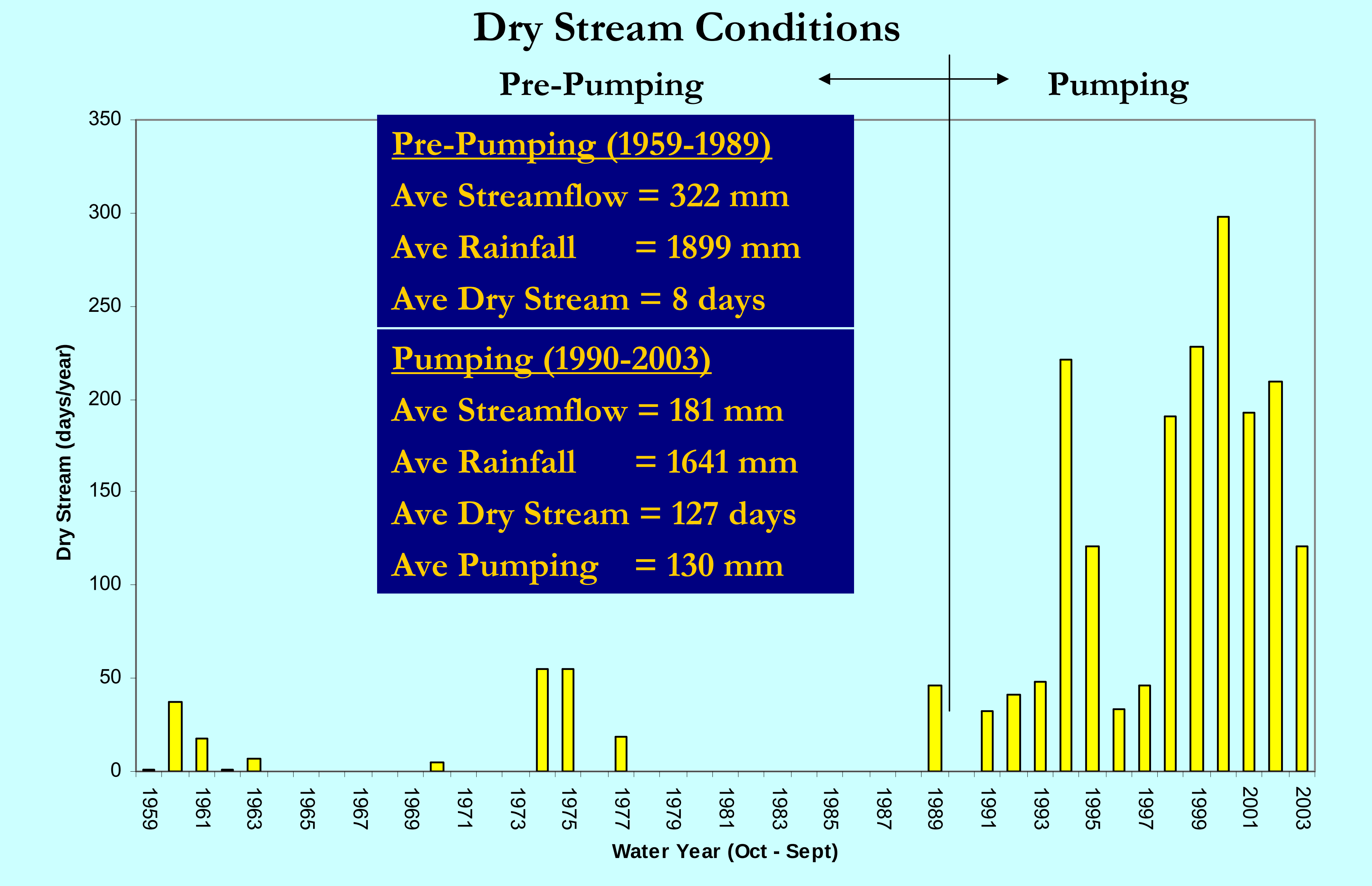
Case study: Makaha valley hydrology

Long term observed data



Case study: Makaha valley hydrology

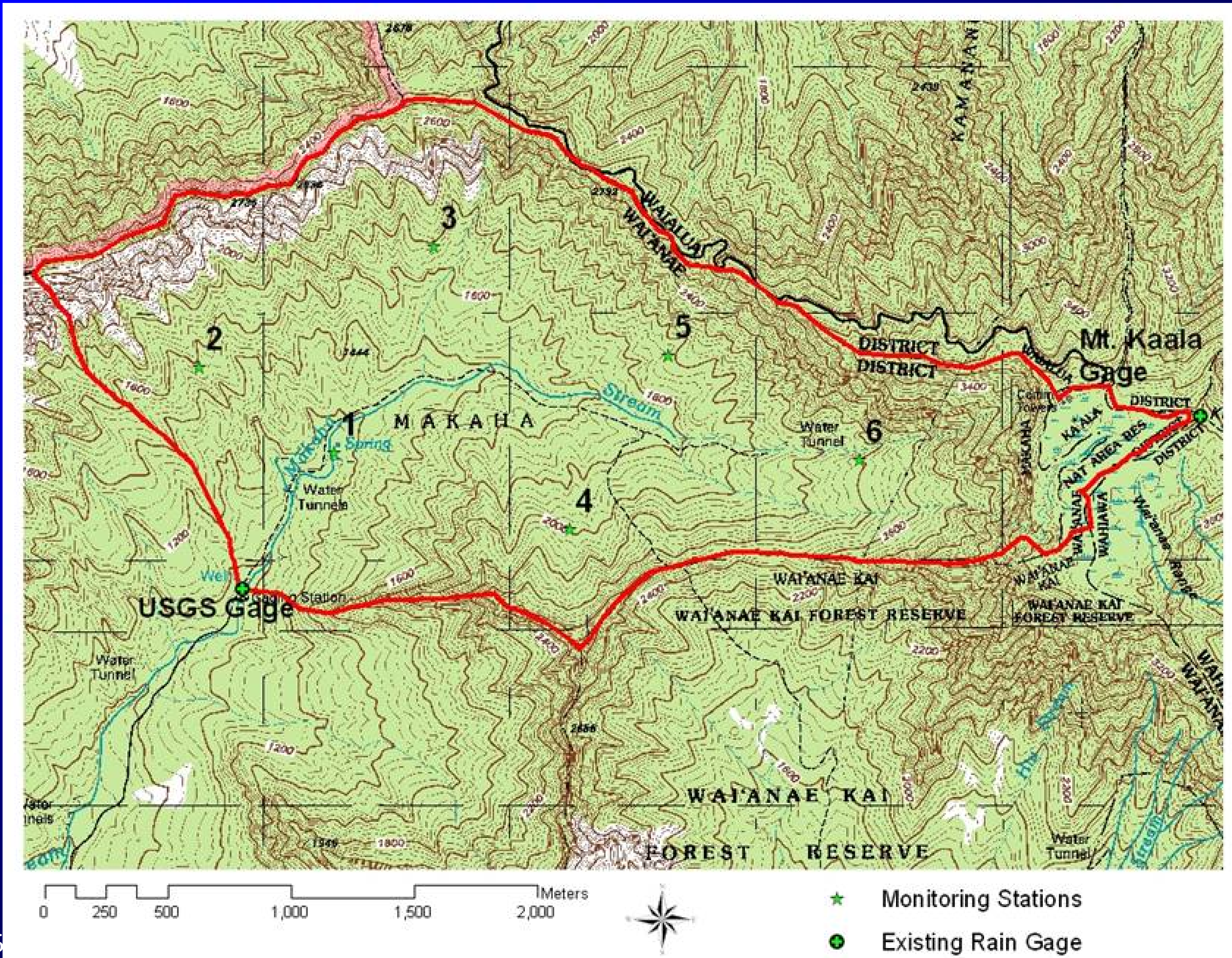
Long term observed data

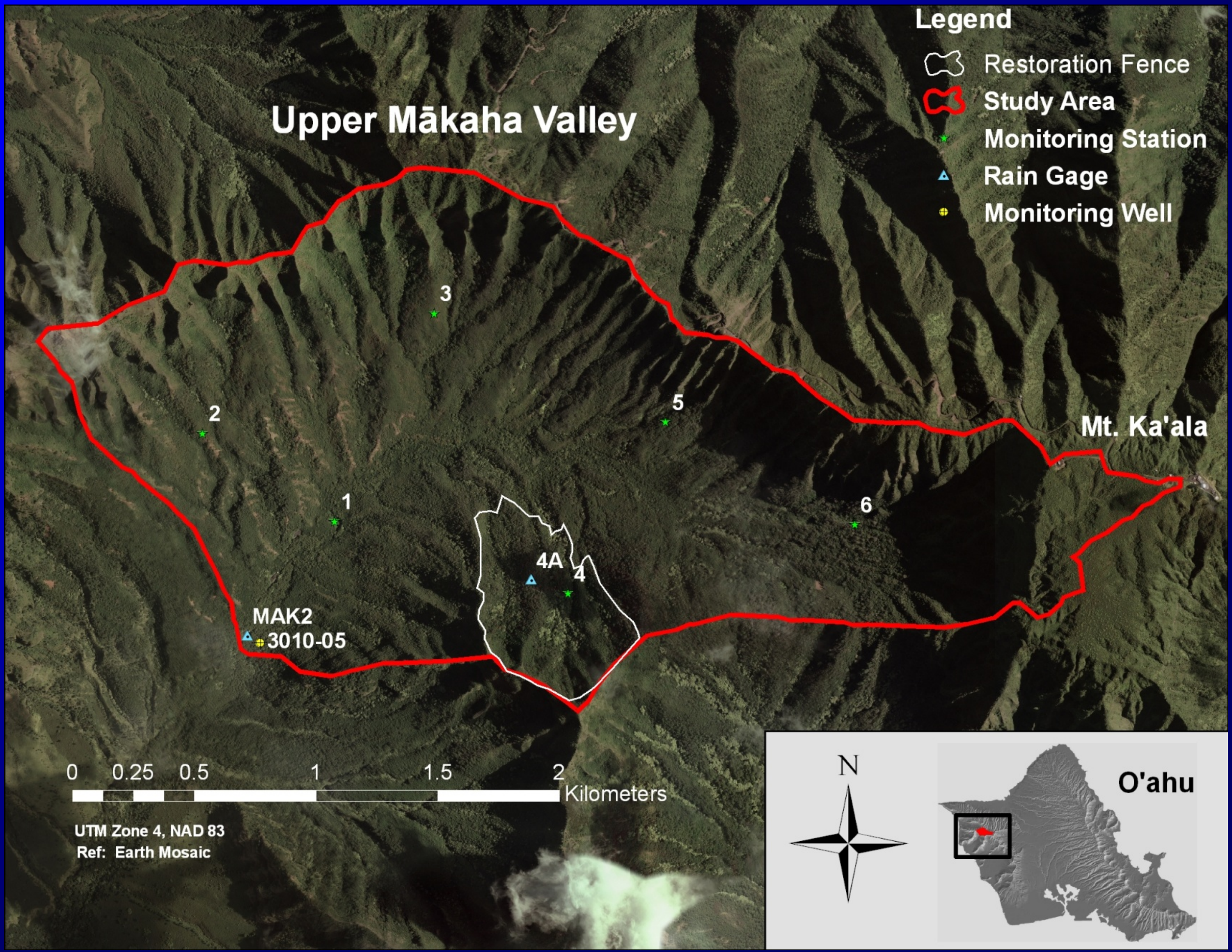


Hypotheses for Streamflow Reduction

1. Caused by reduction in rainfall.
2. Caused by increases in evapotranspiration due to:
    1. atmospheric demand.
    2. changes in vegetation.
3. Caused by pumping of groundwater.
4. Caused by a combination of two or more of the above.

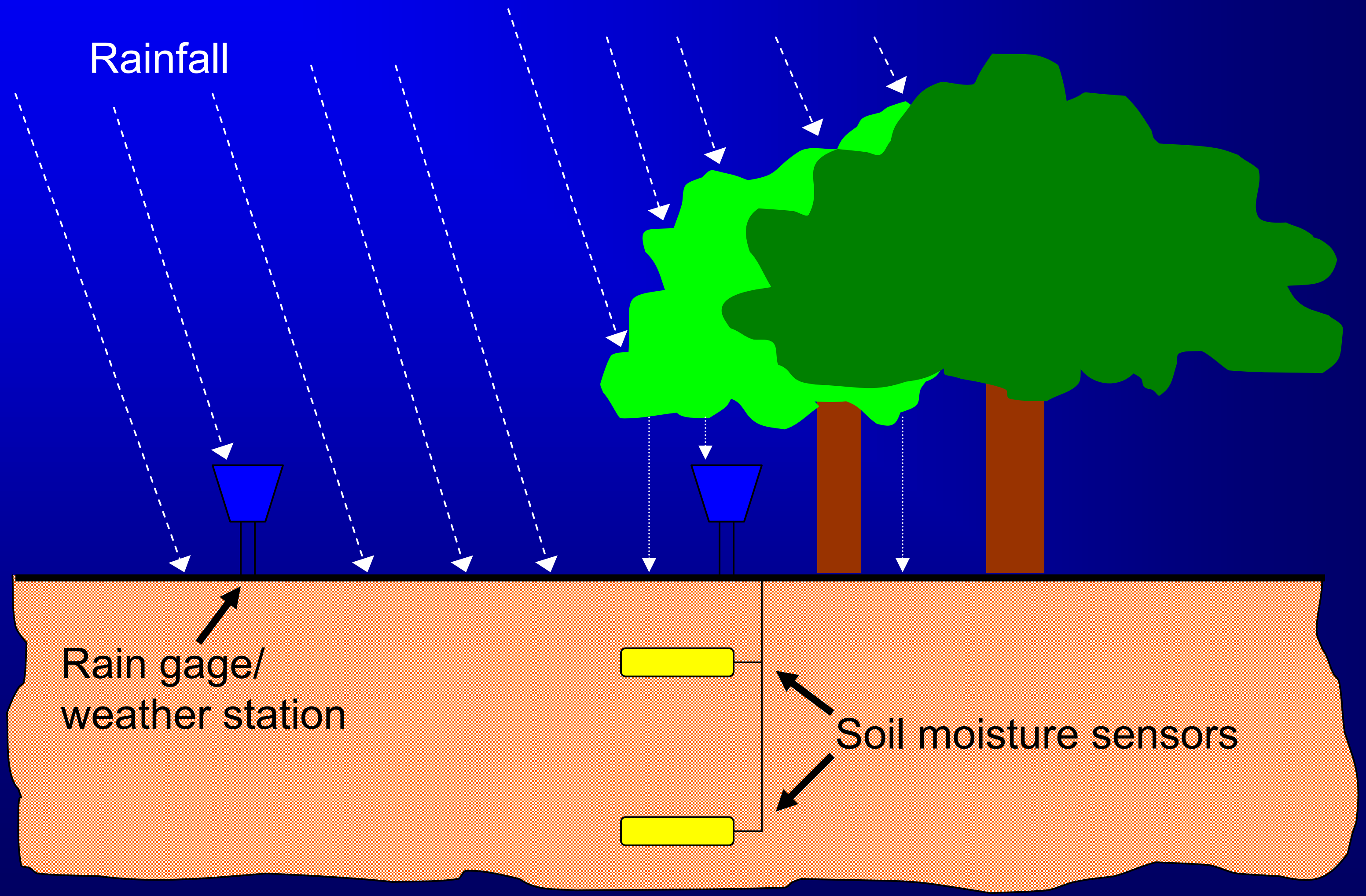
Case study: Makaha valley hydrology

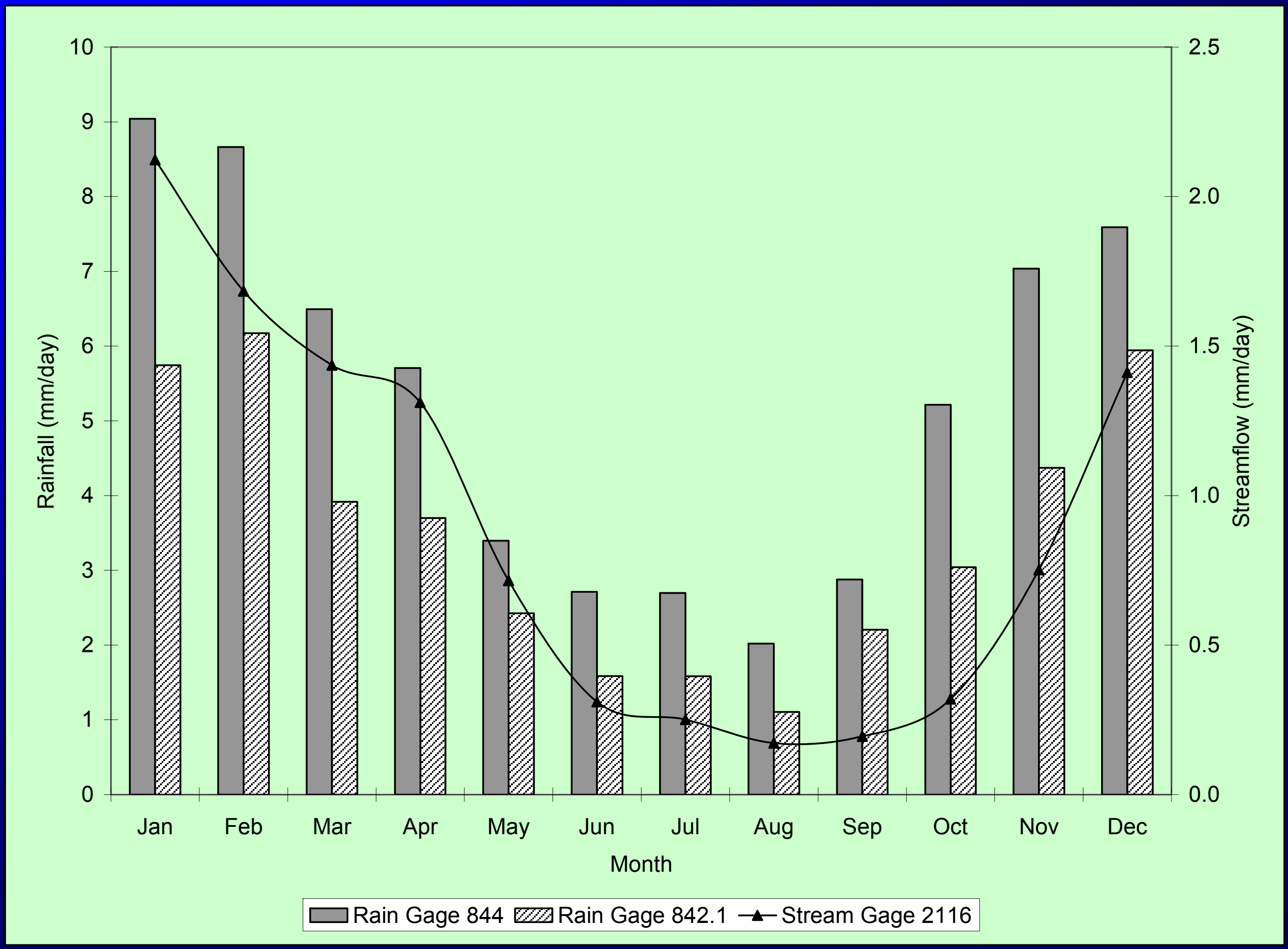



Upper Mākaha Valley
Legend
Restoration Fence
Study Area
Monitoring Station
Rain Gage
Monitoring Well
3
2
5
1
6
Mt. Ka'ala
4A
4
MAK2
3010-05
0 0.25 0.5 1 1.5 2
Kilometers
UTM Zone 4, NAD 83
Ref: Earth Mosaic
N
O'ahu

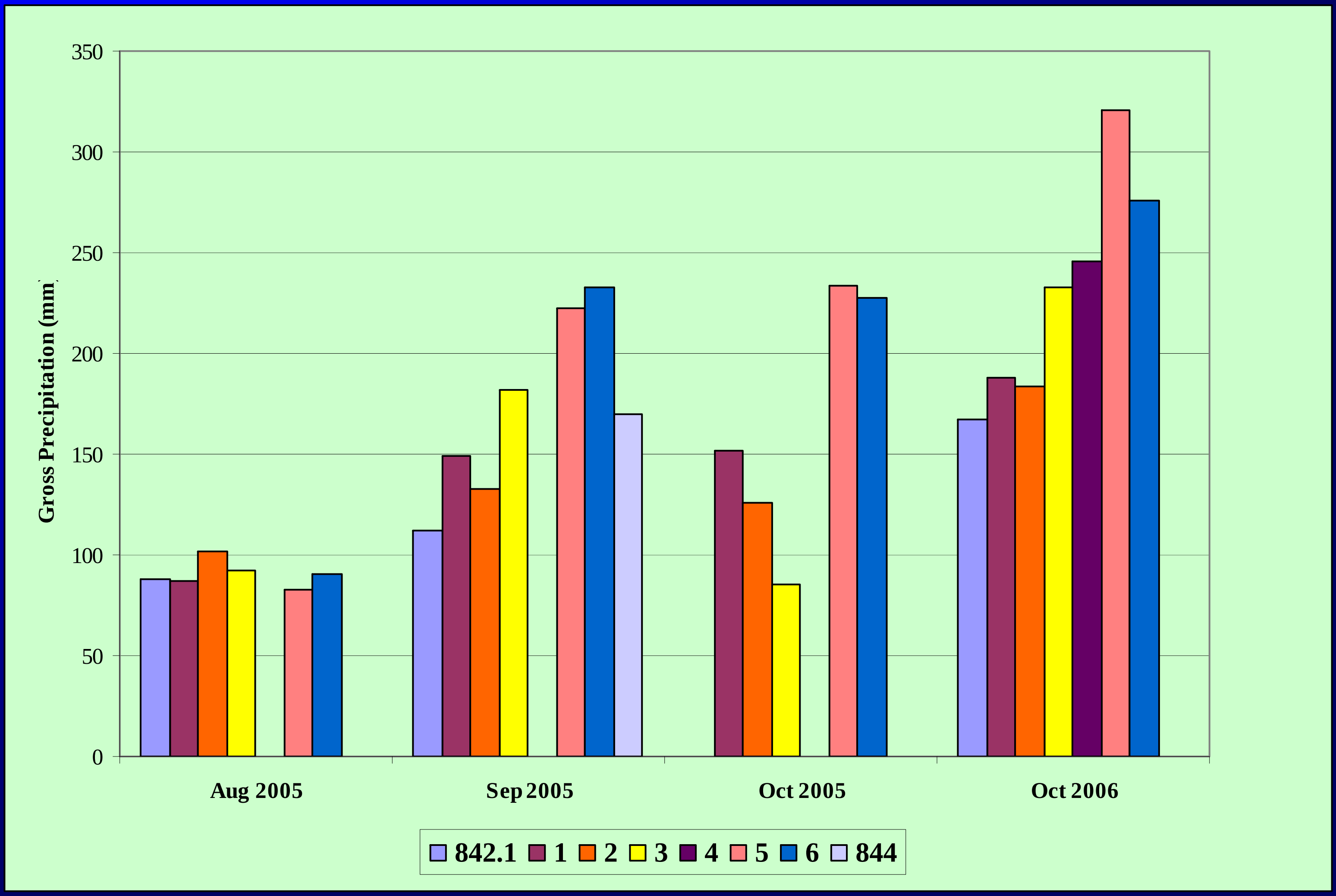
Case study: Makaha valley hydrology

Station Configuration

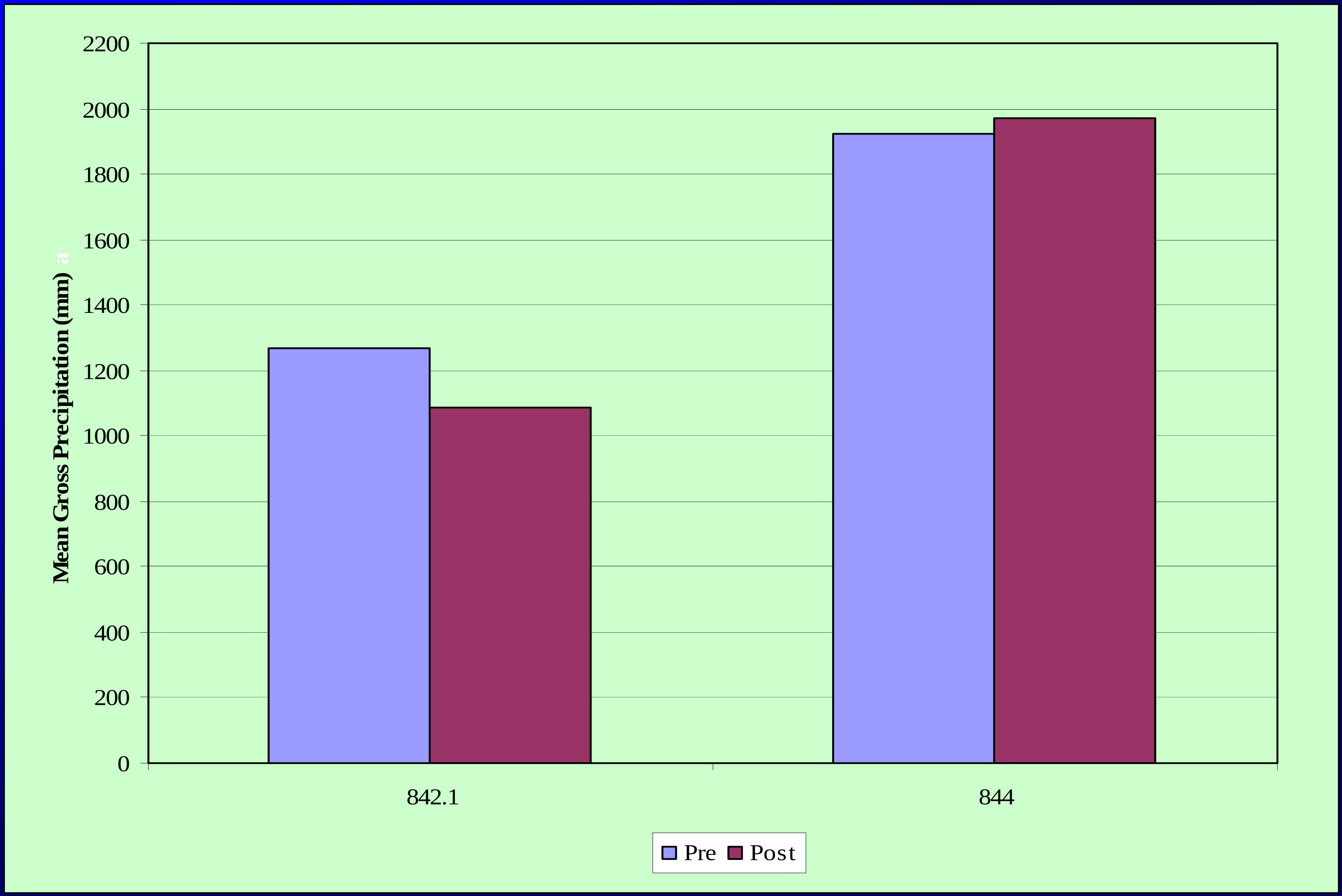



10
9
8
7
6
5
4
3
2
1
0
Rainfall (mm/day)
2.5
2.0
1.5
1.0
0.5
0.0
Streamflow (mm/day)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Rain Gage 844
Rain Gage 842.1
Stream Gage 2116

Rainfall Spatial Distribution



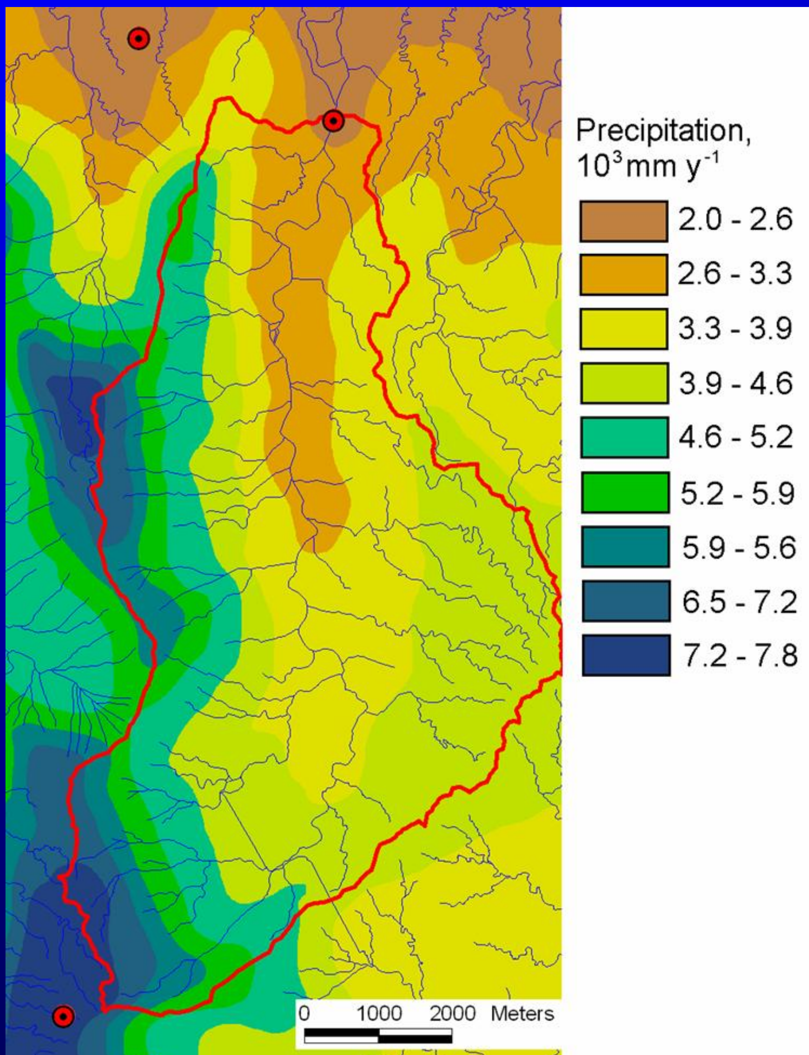
Pre-Post Pumping Rainfall



Effect of rainfall spatial distribution on surface water and sediment

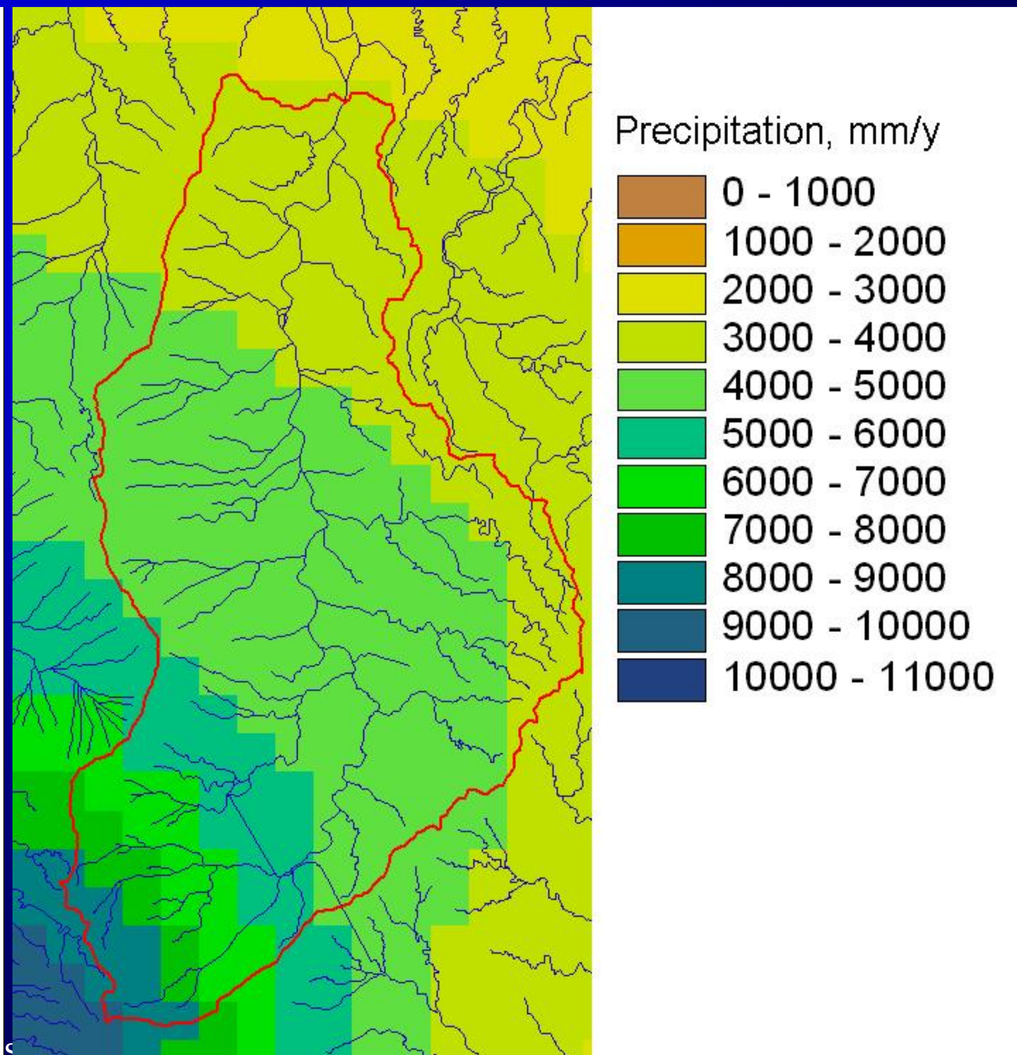
Scenario 1

PRIZM model



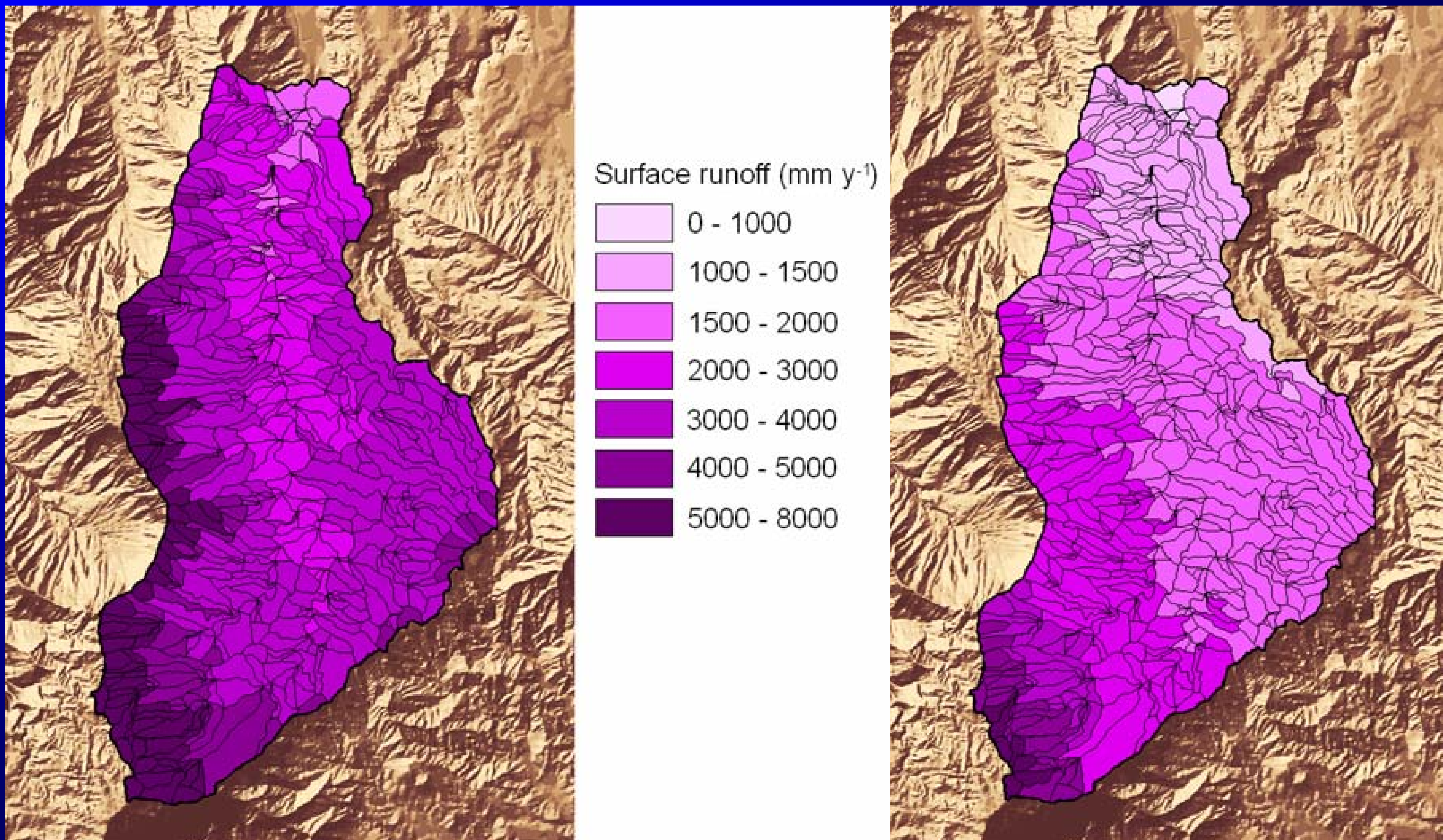
Scenario 2

Giambelluca, 1986



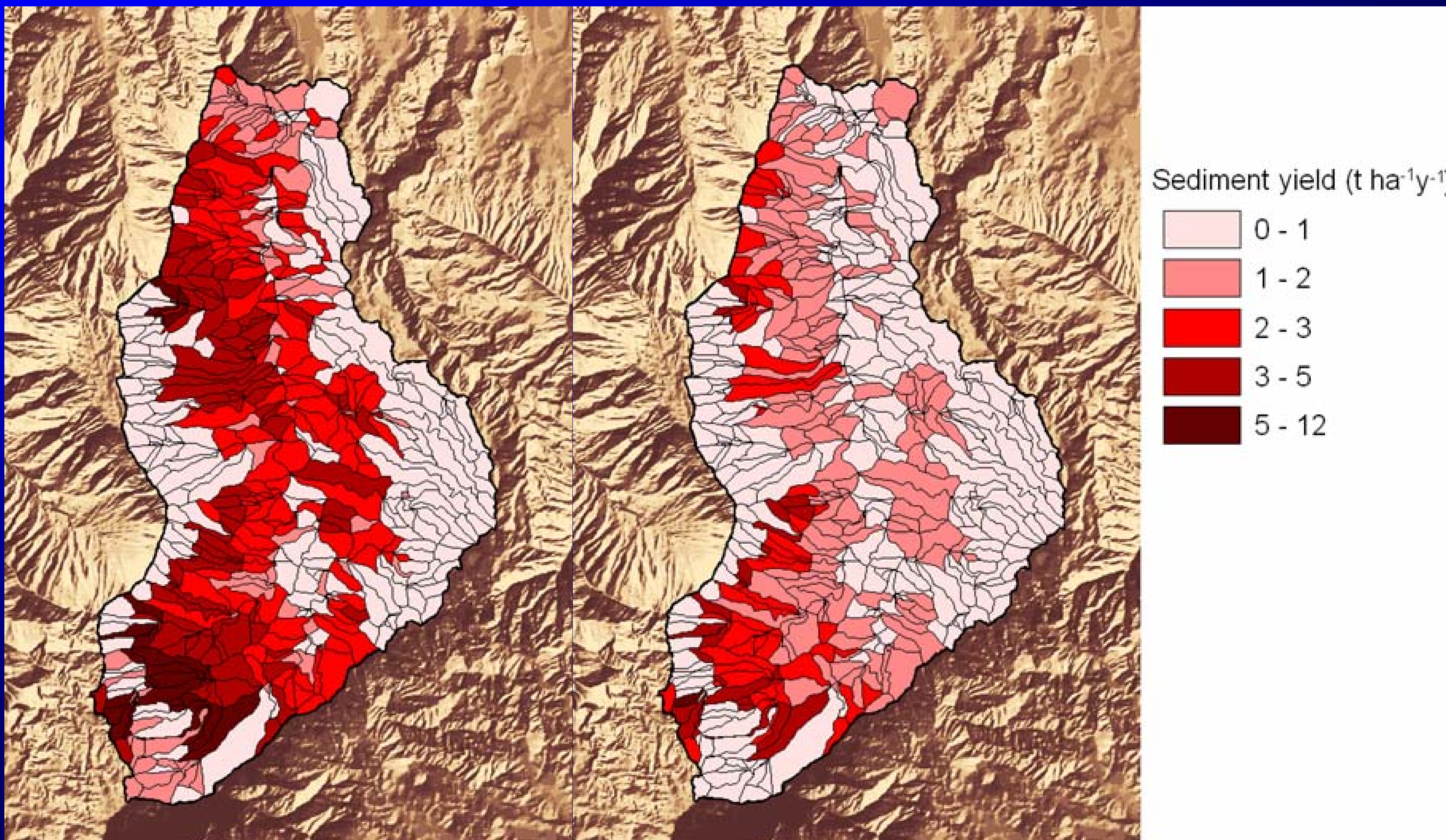
Resulting spatial distribution of runoff

Scenario 1 | Scenario 2



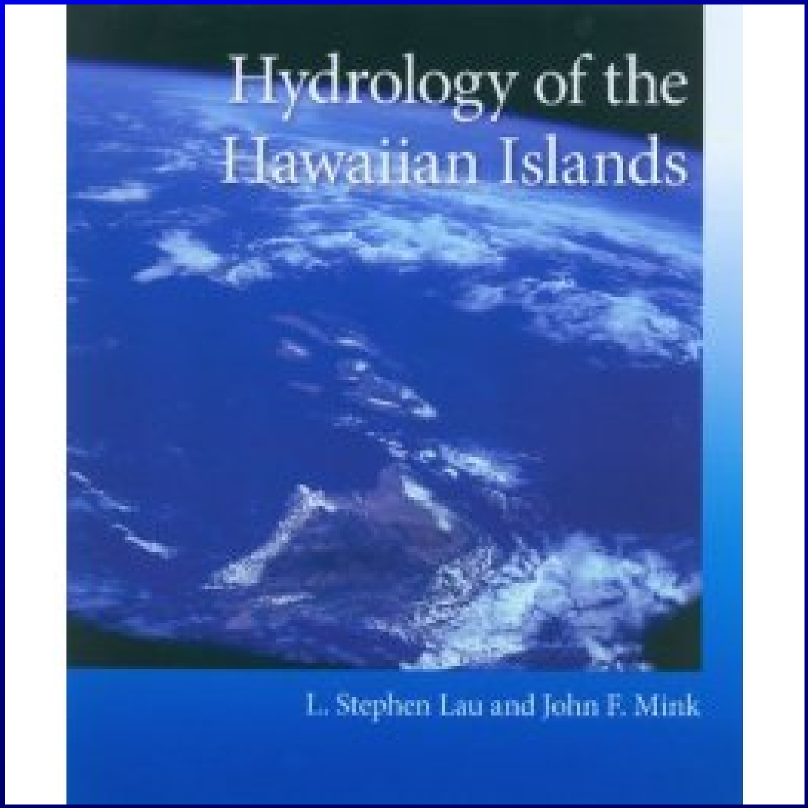
Resulting spatial distribution of sediment yield

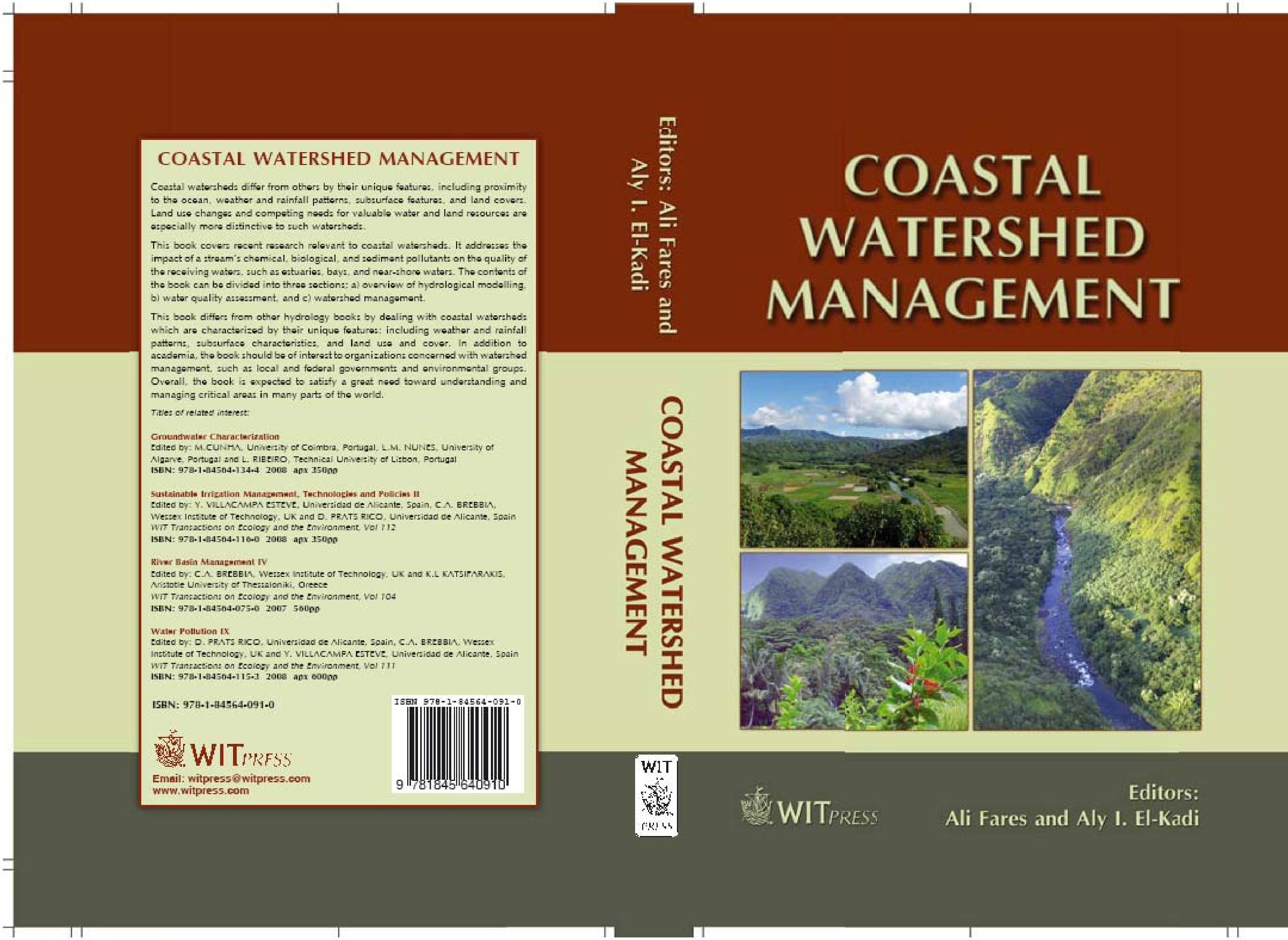
Scenario 1 Scenario 2



Multidisciplinary Approach!

Additional Readings




COASTAL WATERSHED MANAGEMENT
Coastal watersheds differ from others by their unique features, including proximity to the ocean, weather and rainfall patterns, subsurface features, and land covers. Land use changes and competing needs for valuable water and land resources are especially more distinctive to such watersheds.
This book covers recent research relevant to coastal watersheds. It addresses the impact of a stream's chemical, biological, and sediment pollutants on the quality of the receiving waters, such as estuaries, bays, and near-shore waters. The contents of the book can be divided into three sections: a) overview of hydrological modelling, b) water quality assessment, and c) watershed management.
This book differs from other hydrology books by dealing with coastal watersheds which are characterized by their unique features: including weather and rainfall patterns, subsurface characteristics, and land use and cover. In addition to academia, the book should be of interest to organizations concerned with watershed management, such as local and federal governments and environmental groups. Overall, the book is expected to satisfy a great need toward understanding and managing critical areas in many parts of the world.
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Groundwater Characterization
Edited by: M.CUNHA, University of Coimbra, Portugal, L.M. NUNES, University of Algarve, Portugal and L. RIBEIRO, Technical University of Lisbon, Portugal
ISBN: 978-1-84564-134-4 2008 apx 350pp
Sustainable Irrigation Management, Technologies and Policies II
Edited by: Y. VILLACAMPA ESTEVE, Universidad de Alicante, Spain, C.A. BREBBIA, Wessex Institute of Technology, UK and D. PRATS RICO, Universidad de Alicante, Spain
WIT Transactions on Ecology and the Environment, Vol 112
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WIT Transactions on Ecology and the Environment, Vol 111
ISBN: 978-1-84564-115-3 2008 apx 600pp
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COASTAL WATERSHED MANAGEMENT
WIT PRESS
COASTAL WATERSHED MANAGEMENT
WIT PRESS
Editors:
Ali Fares and Aly I. El-Kadi

Mahalo!


Weather Monitoring Station #1
Mākaha Valley Watershed Study
University of Hawai'i, Mānoa
Honolulu Board of Water Supply

Urbanization effects

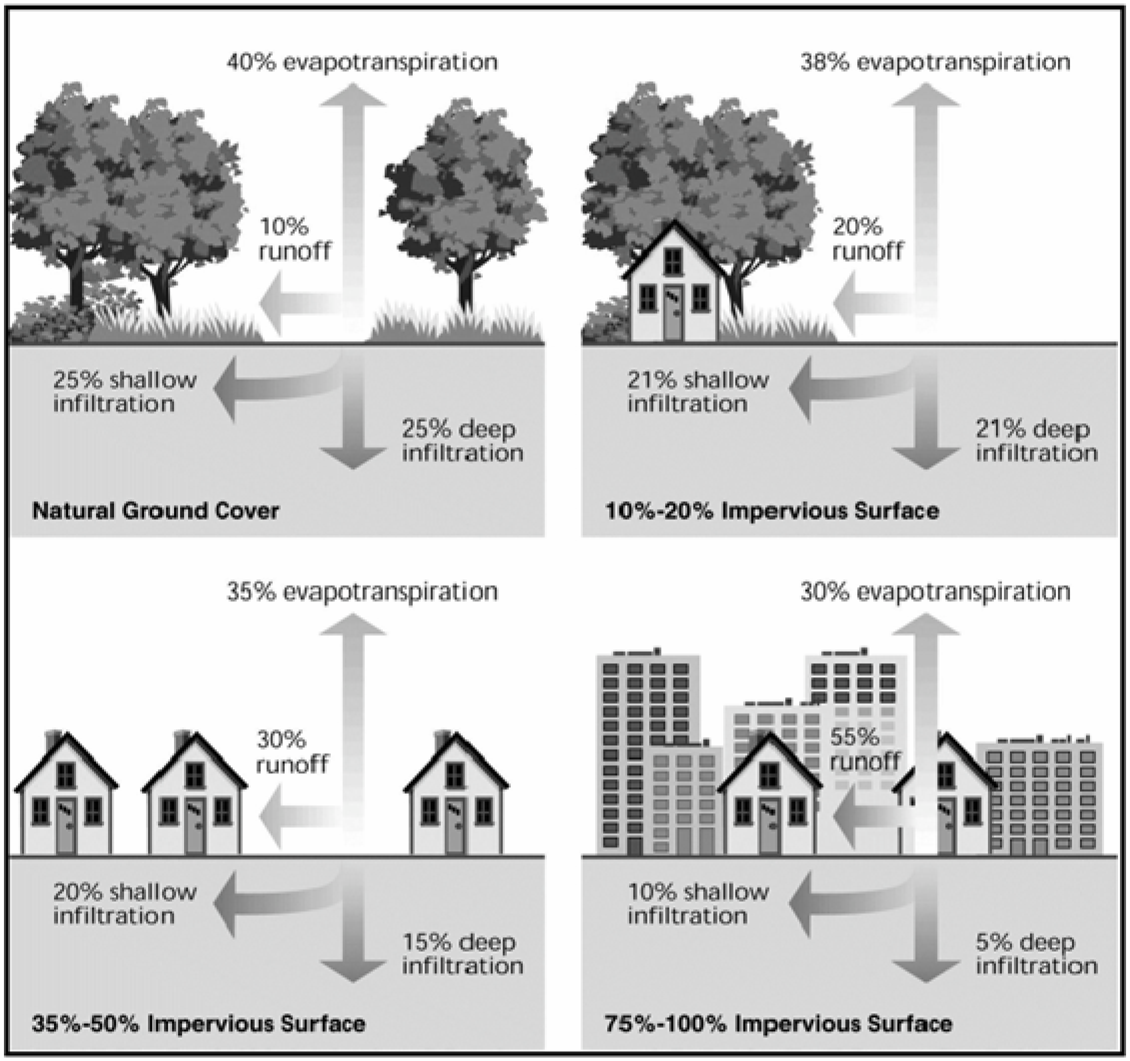
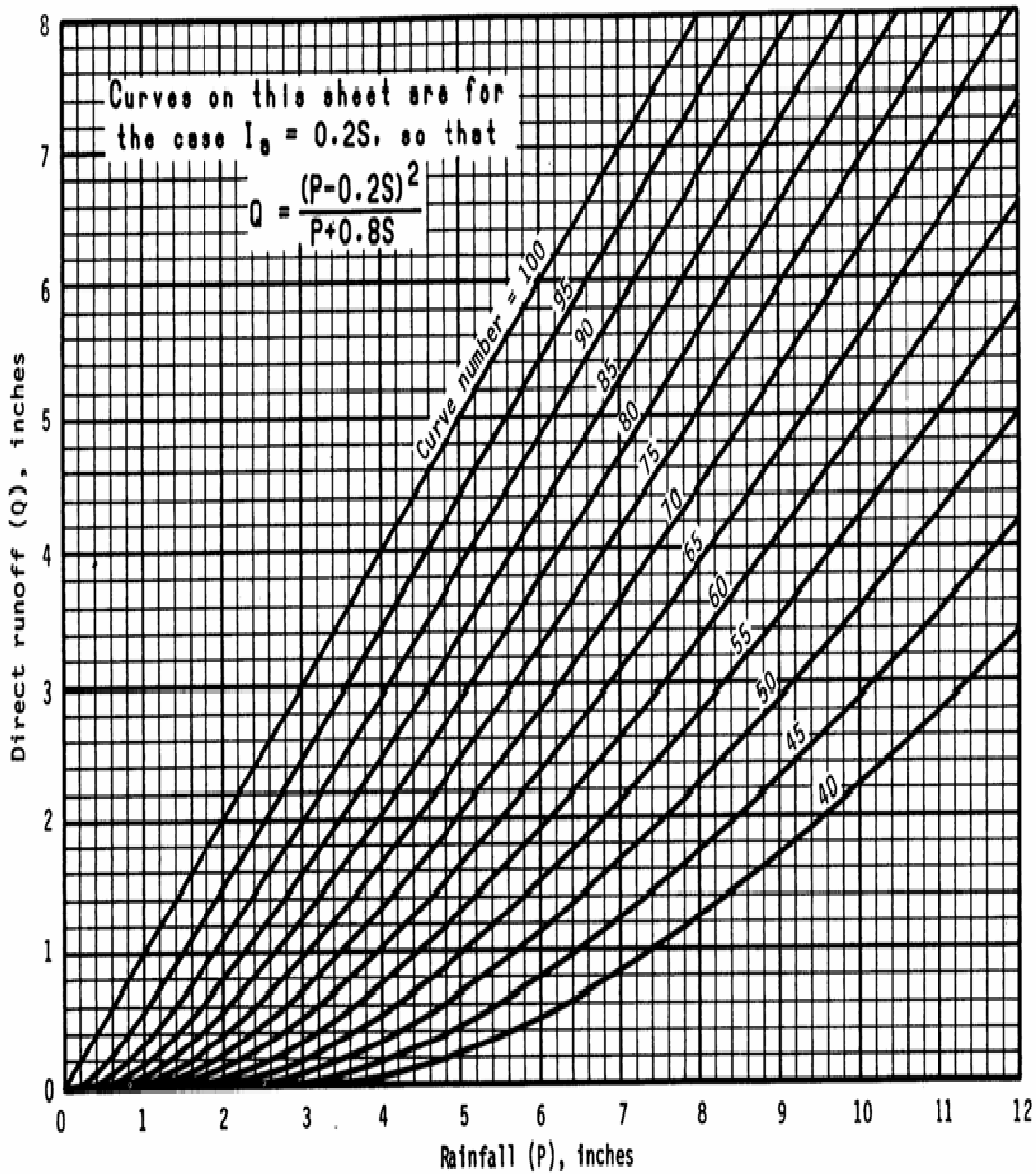


Figure 1.2: Relationship Between Impervious Cover and Surface Runoff

Source: Federal Interagency SRWG, 2000



–Solution of runoff equation.

Rainfall-Runoff: CN Method

- Q = runoff, P = rain, S = potential maximum retention after runoff begins (in) and
- Ia = initial abstraction = 0.2*S

$$\mathbf{Q} = \frac{(\mathbf{P} - 0.2 * \mathbf{S})^2}{(\mathbf{P} + 0.8 * \mathbf{S})}$$

$$\mathbf{S} = \frac{\mathbf{1000}}{\mathbf{CN}} - \mathbf{10}$$

What's a Watershed?

- WATERSHED, or CATCHMENT, is a topographic area that is drained by a stream, that is, the total land area above **some point** on a stream or river that drains past that point.
- The watershed is often used as a **planning or management unit**. Natural environment unit.


0 1000 2000 Meters

Oahu’s Watersheds