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Confluence Analyses of Land Surfaces

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Abstract

A systematic method of deriving a set of regional coordinates is proposed for coordinating water resource activities. It analytically subdivides a continent into those successively smaller-order confluent and multifluent regions in which surface waters are naturally interrelated. Possible applications of the system, together with resulting surface-water coordinates for the State of Wyoming, are presented.

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The United States Geological Survey furnished copies of maps showing major drainage basins and the location of established gaging stations. The drainage areas used for the analyses were obtained from U.S.G.S. Water Supply Papers.

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INTRODUCTION

Definition of Confluence Analyses of Land Surfaces

By confluence analyses of land surfaces[1*] is meant the analytical subdivision of a continent or island into successively smaller confluent and resulting multifluent regions. A confluence is the junction of two or more streams or of one stream and a body of water. A confluent region, then, is a land surface that drains through the mouth of a single stream into another stream or body of water.

A multifluent region is a land surface that drains in multiple ways through the shore line of a stream or body of water. As will be seen later, multifluent regions are remaining areas left from subdividing a land surface into confluent regions.

Purpose

The imminence of a so-called population explosion has made us cognizant of the great value of our water resources. We are also quite aware of the serious consequences that will result if we continue to neglect and mismanage this vital resource. With the population explosion and resulting emphasis on water resource planning comes a need to collect, compile, distribute and somehow store enormous volumes of data. Because of the unique interdisciplinary nature of water resources, duplication of effort in obtaining and handling these data is inevitable unless certain countermeasures are taken. Along with wasteful duplication of effort

*Superscript numerals refer to the list of Selected References.

goes the possibility that much of the data will not be made available to others than those who collected it. Also, the data may be in a form that is not useful to others.

For these and other reasons it is obviously in the best interests of all that efforts in water resource planning be closely coordinated. Coordination of any such effort on a national or global scale certainly requires the adoption of one common, uniform system that incorporates in it the interactions and interdependencies of surface waters.

The primary purpose of this study, then, is to present a systematic way of coordinating water resource activities. To accomplish this, the principles of confluence analyses of land surfaces will be developed by use-testing, beginning with the North American continent and subsequently analyzing all drainage basins of the United States that have their headwaters in the State of Wyoming. It is hoped that the resulting set of surface-water coordinates will be useful for many kinds of considerations of Wyoming's water resource problems. It is also hoped that the system of analysis will be found useful in establishing a logical, uniform set of coordinates for other areas.

Problem

The problem in developing this proposed systematic method of analysis is to find suitable criteria for subdividing land surfaces into successively smaller-order regions. It is necessary to have criteria so that the analyses can be carried out by anyone with essentially identical results. One of the desired results is that all confluent regions of the same order be similar in size. Also the number of subdivisions produced is quite important. There should be enough regions in each order so that there are not too many different orders. Conversely, there should not be too many regions in each order because this would reduce the usefulness of the analyses. In order to be sure that the criteria selected are satisfactory, they must be use-tested over the entire range of sizes and types of drainage basins. Definitions, criteria and subdividing and numbering procedures are given in Chapter III. Testing of the criteria and the subdividing procedures is discussed and illustrated in Chapter IV. Some possible applications are given in Chapter V and conclusions are presented in Chapter VI.

CHAPTER II

PRESENT SYSTEMS

U. S. Geological Survey

The United States Geological Survey, in cooperation with other agencies, observes, collects, compiles and publishes the data for the surface water records of the United States.[2] Using a system that was adopted in 1951, the United States, including Alaska and Hawaii, is divided into twenty regions, most of which are portions of major drainage basins. Stream and reservoir gaging stations are located and identified by successively-larger numbers beginning with the most upstream station and proceeding downstream. The numbers are not consecutive because gaps are left to allow for new stations that may be established. Tributaries are numbered in the same manner, beginning at the most upstream station on the tributary (with a number following the last numbered station upstream from the confluence on the main stem) and proceeding downstream back to the main stem. This many times results in a large gap in the numbering between two adjacent stations on a single stream. The records for each of the twenty regions are published in separate volumes, each accompanied by an index map showing the location of each station covered by the report.

Federal Water Pollution Control Administration

The Federal Water Pollution Control Adminstration[3] has developed the STORET System, which is a standardized, computer-centered method for handling water quality data. The geographic location of sampling points are determined by a stream index and mileage system which organizes data by hydrologic sequence. This system divides the United States into fifteen major drainage basins, each of which is designated as a terminal basin. A terminal basin is one that either flows into an ocean, across the United States border, or into a dead area such as the Great Basin. Terminal major basins are subdivided into terminal minor basins and each are assigned numbers, which account for the first four digits of the identification code. The next three digits differentiate between minor river systems located in the same major and minor terminal basins. The following six digits are used to represent the mileage from the mouth of the river system to the station being identified, to the nearest hundredth of a mile. Work began on developing this sytem in about 1961 and by August 1966 stream coding had been completed for several major drainage basins of the United States.

General

There are, of course, many other governmental agencies and public and private institutions and organizations that collect and/or utilize data pertinent to the water resources field. It is not necessary to identify and discuss all of them here; however, it is important to recognize that many of them do exist and that their activities and needs must be considered in any long-range water resource planning.

CHAPTER III

PRINCIPLES OF ANALYSES

Definitions

Before proceeding with the development of the criteria and the establishment of principles and procedures to be used in the analyses, it is necessary to define the following important terms that will be used throughout the thesis:

1. Confluent Region: A land surface area which is drained through the mouth of a single, identifying trunk stream and which is bounded by an unbroken ridge-line which begins and ends at the mouth of that stream.
2. Multifluent Region: A land surface which is drained in multiple ways through the shore-line of an ocean, lake, sink or stream and which is usually bounded by two or more adjacent confluent regions.
3. Closed Region: A concave, multifluent land surface which is completely enclosed by an encircling ridge-line within which all surface water drains into the region.
4. Trunk Stream: That stream through whose mouth flow all the surface waters of a confluent region.
5. Headwater Region: The uppermost part of a confluent region which can usually be divided into right-hand and left-hand smaller-order confluent regions.

Criteria

As stated earlier, the main problem in developing the principles of analyses is to select criteria that will produce the desired results. The main results desired pertain to the relative sizes of the confluent regions of each order, the number of regions in each order, and the number of orders of regions.

The first criteria that were selected included the criterion that a confluent region be essentially as large or larger than the largest confluent region of the next smaller-order. This was found to be unsatisfactory because many regions seemed to have one unusually large smaller-order region. This and other criteria were use-tested over the entire range of drainage basins selected for study in the scope of this investigation.

The criteria finally chosen for subdividing a continent or island into its largest, first-order, confluent regions are as follows:

1. Each confluent region must drain into the surrounding ocean or other exterior body of water.
2. The smallest first-order confluent region must be essentially as large or larger than the next-to-largest of the second-order confluent subdivisions of any of the first-order regions.

Similarly, the criteria for subdividing areas into all smaller-order confluent regions are as follows:

1. Each confluent region must drain into an ocean or other body of water or into the next larger-order trunk stream.
2. Each confluent region must extend to the external boundary of the next larger-order region.

3. The smallest confluent region must be essentially as large or larger than the next-to-largest of the next smaller-order confluent subdivisions of the particular drainage region being subdivided.

Subdividing Procedures

The subdividing of a continent into different regions must conform to the criteria finally selected as set forth in the preceeding section. As can be seen from the criteria, the analyses must be done on a trial and error basis. For instance, the first-order confluent regions are tentatively selected and then all second-order confluent regions are examined to see that the size criterion has been satisfied. This is a continuing cyclic process and should be continued one step beyond the desired stopping place. One aspect of the criteria that should be emphasized concerns subdividing second- or smaller-order confluent regions. When doing so, only the elements of the particular region being subdivided need to be examined as to meeting the criteria. It is not necessary to examine all next smaller-order regions of the continent. Doing so would make the analyses infeasible because of the great differences in the areas of the first-order confluent regions.

One of the special cases to be dealt with in the analyses are the headwater regions of the confluent areas. During the process of the analyses it was noticed that almost all trunk streams have a definite fork in the upper reaches of the basin. Because of this it was decided to subdivide the headwater regions into left- and right-hand confluent regions. Other special cases, for example closed multifluent regions such as the Great Basin, are discussed in detail in Chapter IV.

Numbering Procedures

Every confluent and multifluent region can be identified by name or by number. Names are usually determined by the names of the trunk streams or by the names of lakes, reservoirs or other prominent geographical features of the area.

The numbering system is a very important part of this analysis and a great deal of consideration was given to this phase of the study. The objective was to find a method of numbering in which every letter and number has special meaning and yet still retain a simple and concise system. The following are general rules for numbering subdivisions of land surfaces:

1. All confluent regions are designated by even-numbers and all multifluent regions are designated by odd-numbers. This even and odd numbering sequence is carried throughout the system becuase of the natural occurrence of alternating confluent and multifluent regions.
2. The first-order regions of a continent are numbered by ordinally counting clockwise around the continent starting with 00 for the largest confluent region, 01 for the adjacent multifluent region, 02 for the next confluent region, and so forth around to the last multifluent region which is adjacent to the beginning confluent region.
3. Confluent regions are divided into left- and right-hand sides (looking downstream) and the numbers of the components of these sides are prefixed by the letters L and R, respectively.
4. The components of confluent regions are numbered by ordinally

counting upstream along the trunk stream (each side separately) starting with R1 or L1 for the first smaller-order multifluent region, R2 or L2 for the adjacent confluent region, and so forth continuing upstream, finally ending with RH or LH for the confluent headwater region.

5. The components of coastal multifluent regions are numbered by ordinally counting clockwise along the coast starting with 01 for the first smaller-order multifluent region, 02 for the adjacent confluent region, and so forth.
6. The components of closed multifluent regions that drain inward to a lake or sea are numbered by ordinally counting clockwise around the shore starting with 00 for the largest confluent region, 01 for the adjacent multifluent region, and so forth.
7. The components of inland multifluent regions along streams are numbered by ordinally counting upstream along the trunk stream into which it drains starting with 01 for the first smaller-order multifluent region, 02 for the adjacent confluent region, and so forth.

The numbering system is graphically explained in Chapter IV as the confluence analysis principles are use-tested and illustrated.

The extension of the numbering system to the location and identification of specific points such as stream gaging stations is discussed and illustrated in Chapter V.

CHAPTER IV

TESTING THE PRINCIPLES OF ANALYSES

The North American Continent

Using the criteria and procedures already established, the North American continent was subdivided into eight first-order confluent regions and eight resulting first-order multifluent regions, as shown in Figure 1. All second-order confluent regions of North America were then examined to find the two largest regions, which are the Missouri River basin (530,000 sq. mi.) and the Ohio River basin (203,000 sq. mi.). The size of the Ohio River basin then becomes, in accordance with the criteria on page 7, the limiting size criterion for the first-order confluent regions of North America.

This same procedure can be used to subdivide any continent or island into its first-order regions. The numbering of these regions begins with 00 for the largest confluent region (the Mississippi River Basin) and continues clockwise around the continent. This gives each confluent region an even number (00 through 14) and each alternate multifluent region an odd number (01 through 15).

Table I gives identifying numbers, names and approximate areas of each first-order confluent region of North America. The areas given here and throughout this analysis are approximate only and should not be used for purposes requiring exact figures. Any precise measurement of a contributing drainage area requires the use of detailed maps and such accuracy was not considered necessary for this study.

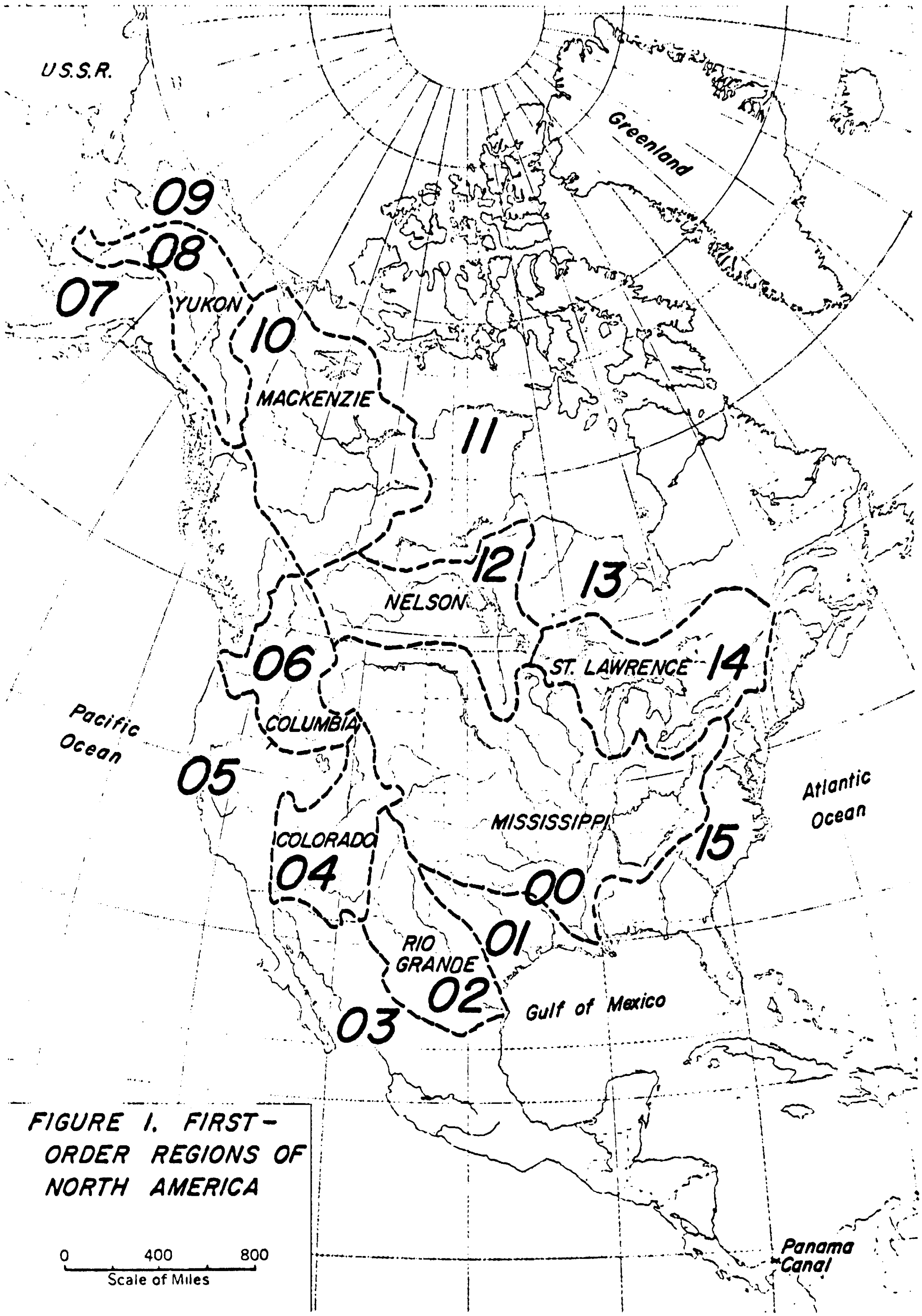


FIGURE 1. FIRST-ORDER REGIONS OF NORTH AMERICA

TABLE I

FIRST-ORDER CONFLUENT REGIONS OF NORTH AMERICA

Identifying Number	Identifying Name	Approximate Area (sq. mi.)
00	Mississippi	1,250,000
02	Rio Grande	280,000
04	Colorado	240,000
06	Columbia	260,000
08	Yukon	300,000
10	Mackenzie	700,000
12	Nelson	420,000
14	St. Lawrence	380,000

The Mississippi River Basin

The subdivision of the first-order Mississippi River basin is shown in Figure 2. The Mississippi River basin has an area of approximately 1,250,000 sq. mi. which accounts for over 40 percent of the total land area of the United States. Its largest second-order region is the Missouri River basin which, with an area of 530,000 sq. mi., is larger than all but two of the first-order regions of North America.

The main problem encountered here was the vast size of the Missouri River basin as compared to the other regions. The size criterion used was that the second-largest third-order basin, which is the Yellowstone River basin (68,000 sq. mi.), is essentially smaller than the Red River basin (70,000 sq. mi.). However, as can be seen, this is merely a matter of choice since the two basins are so similar in size. This is one place where judgment is used in determining whether or not to include a basin in a certain order. The decision depends on how many regions have already been included and on how the further analyses will be affected.

Figure 3 shows the subdivision of the Missouri River basin into its third-order elements. One decision to be made here was whether or not to include the smaller basins, such as the Cheyenne River basin (24,000 sq. mi.), the James River basin (22,000 sq. mi.) and the Milk River basin (22,000 sq. mi.), with the obvious larger ones, the Platte River basin (86,000 sq. mi.), the Yellowstone River basin (68,000 sq. mi.) and the Kansas River basin (60,000 sq. mi.). To include the smaller ones would give about the right number of regions and would divide the whole basin up fairly equally. However, it was finally decided not to

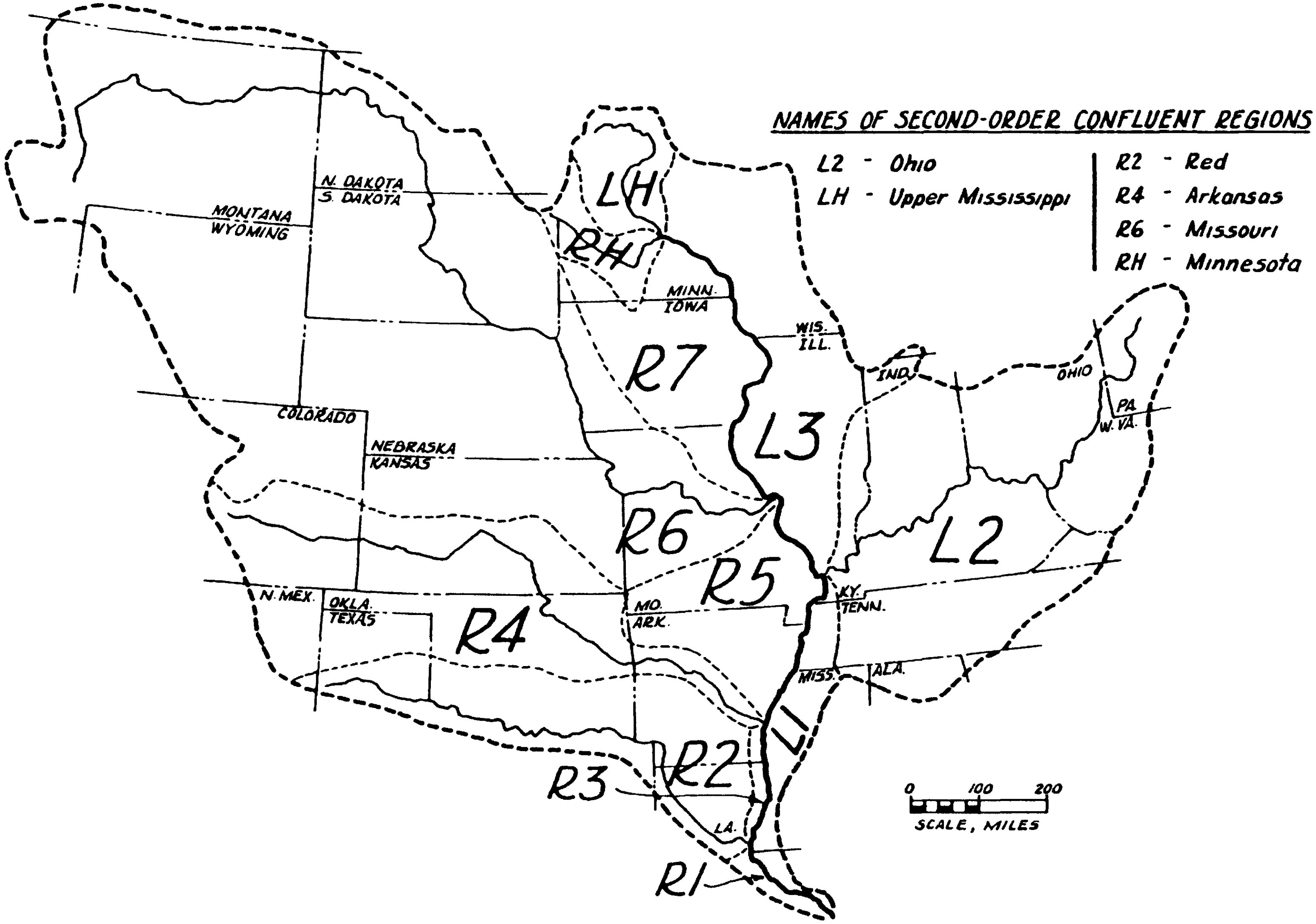
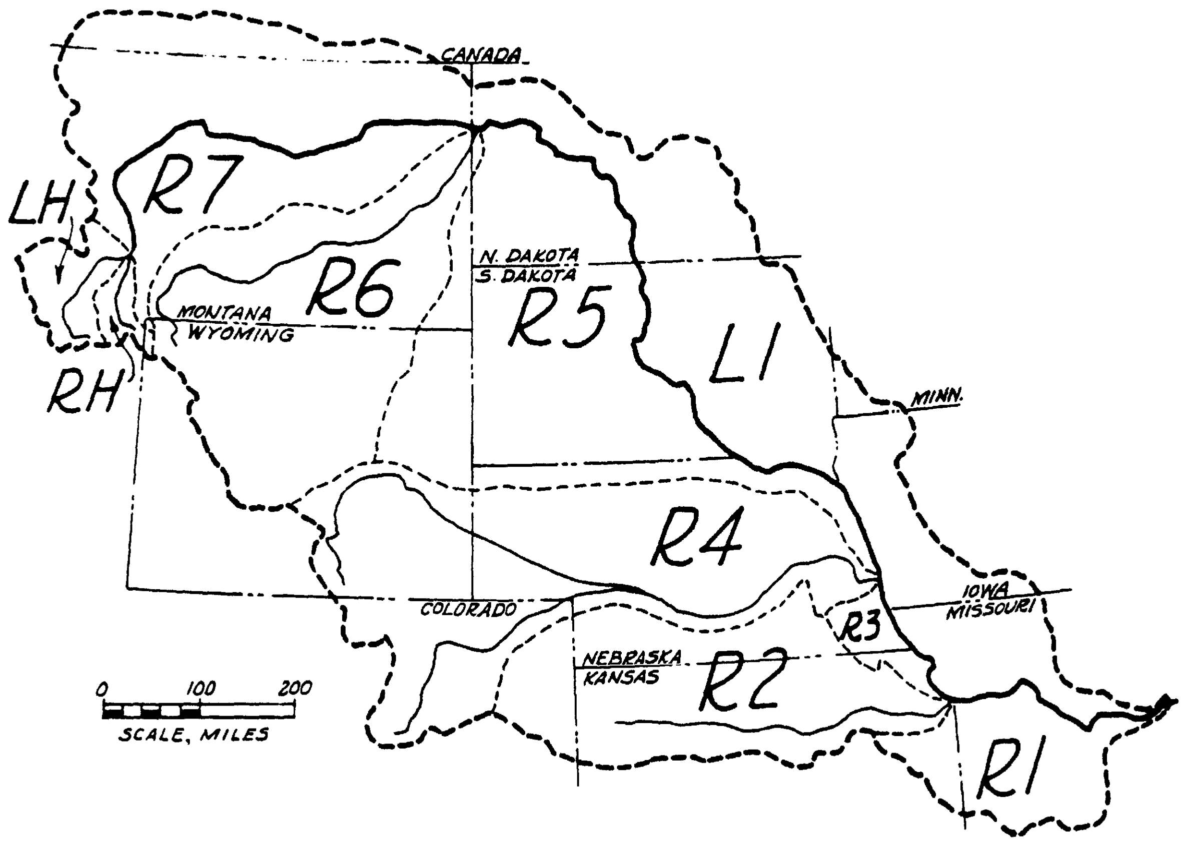


FIGURE 2. FIRST-ORDER MISSISSIPPI RIVER BASIN (North America Basin 00)



NAMES OF THIRD-ORDER CONFLUENT REGIONS

LH - Jefferson

R2 - Kansas
R4 - Platte
R6 - Yellowstone
RH - Madison

FIGURE 3. SECOND-ORDER MISSOURI RIVER BASIN
(North America Basin 00R6)

include them because of their similarity in size to four fourth-order tributary regions, which are the North Platte River basin (36,000 sq. mi.), the South Platte River basin (24,000 sq. mi.), the Republican River basin (25,000 sq. mi.) and the Bighorn River basin (23,000 sq. mi.). Obviously, before this judgment was made, it was necessary to first tentatively subdivide all of the third-order regions into their fourth-order elements.

This detailed explanation of some problems encountered in analyzing the Mississippi River and Missouri River basins is included to give the reader a brief idea of the procedures followed in the analyses. However, in the interests of clarity, such details for the routine portions of the remaining analyses will be omitted. To aid those interested in following through the other analyses, tables are included which give the areas of the regions included in the scope of this study.

Since one purpose of this study is to present a set of surface-water coordinates for use in coordinating Wyoming's water resource activities, the remainder of this study will be devoted to analysis of only those regions which at some order of subdivision fall within the boundaries of the State of Wyoming.

Figures 4, 5, 6, and 7 show the third-order Platte River basin, the fourth-order North Platte River basin, the fifth-order Laramie River basin, and the sixth-order Little Laramie River basin, respectively. The subdivision of the Little Laramie River into its seventh-order regions in Figure 7 is about as far as that basin can usefully be subdivided. The Platte River basin is quite unusual in that roughly 70 percent of its area is above a very definite fork in the trunk stream which gives the North Platte and South Platte headwater regions.

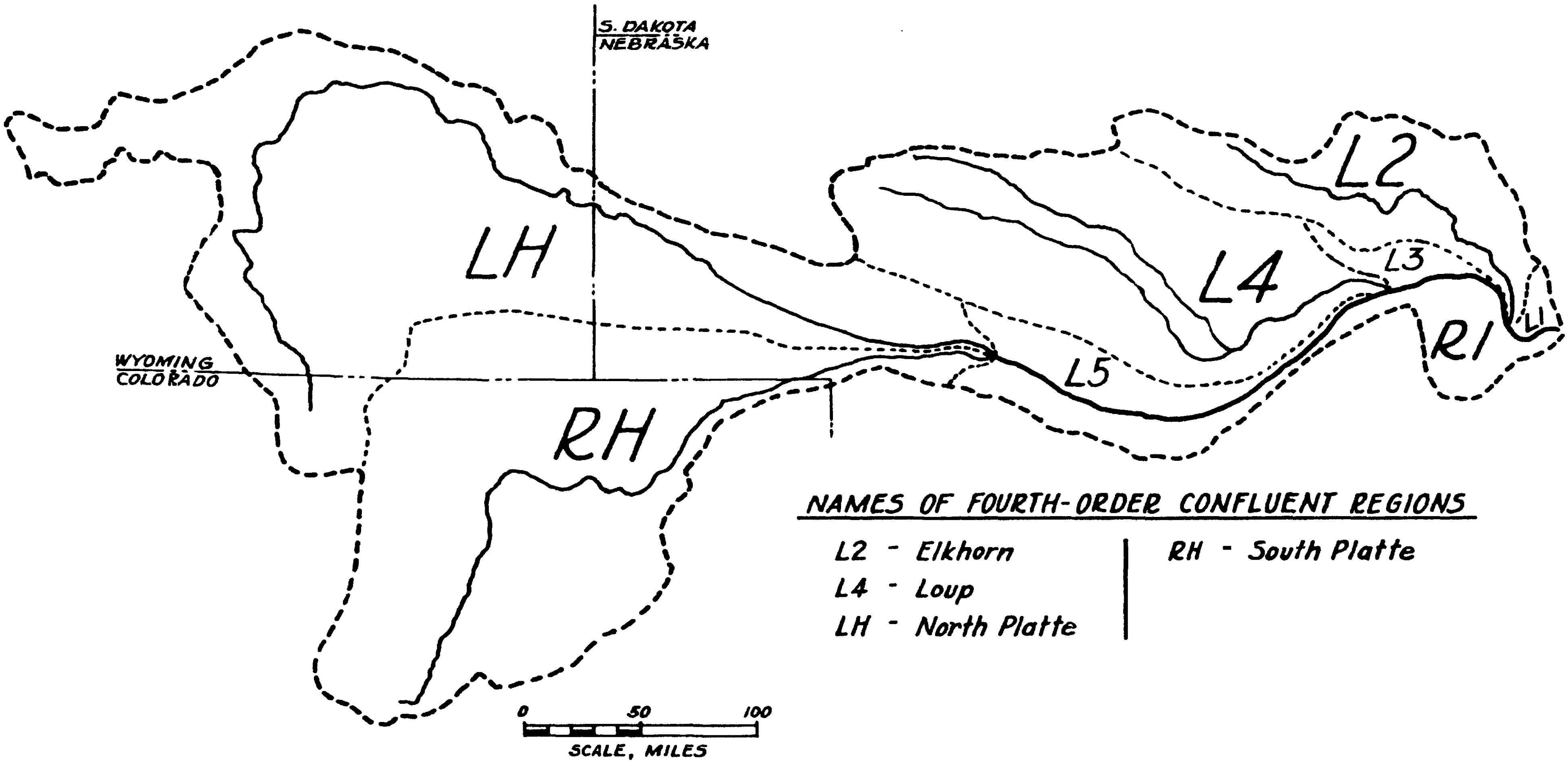


FIGURE 4 THIRD-ORDER PLATTE RIVER BASIN (North America Basin 00R6R4)

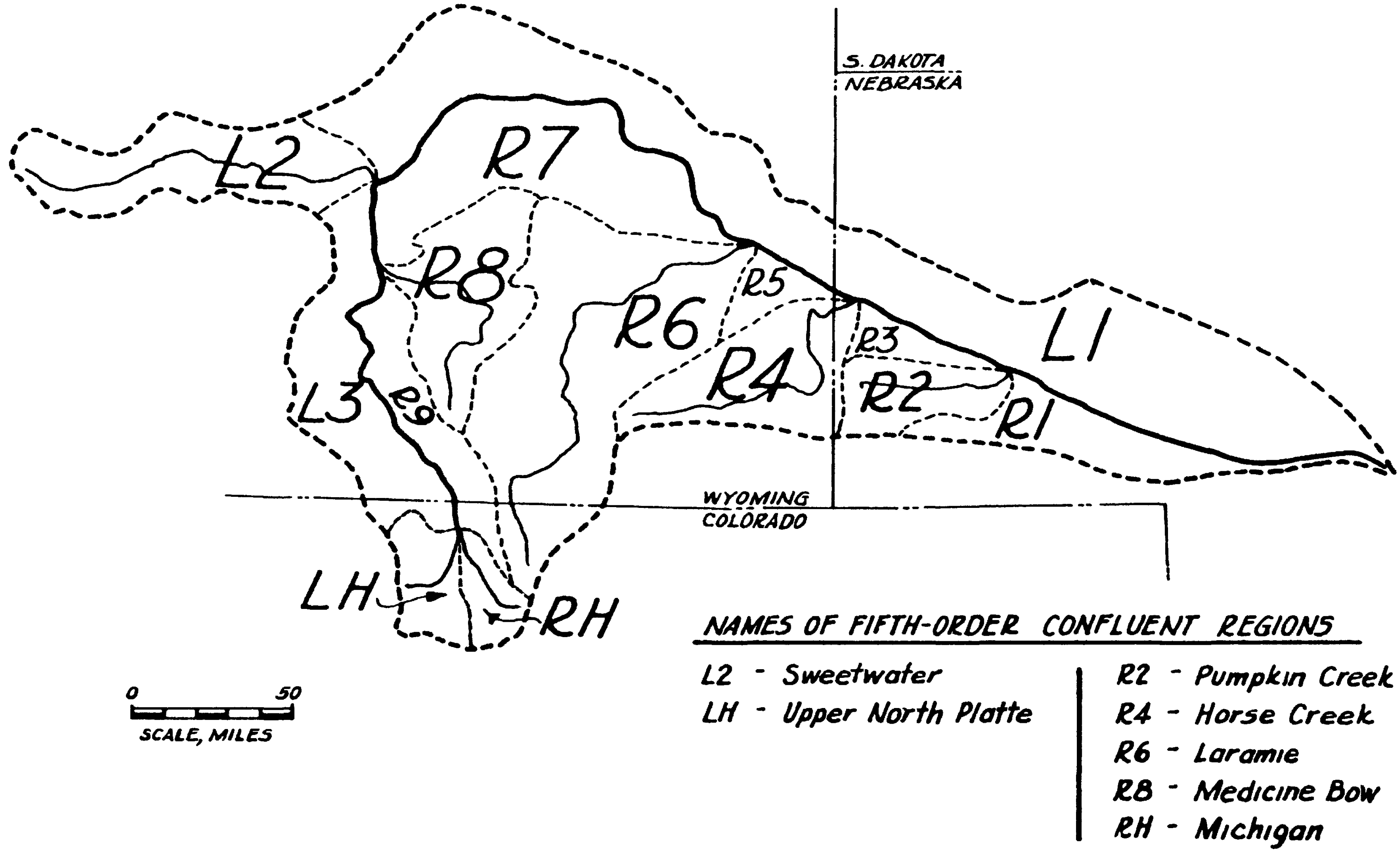


FIGURE 5. FOURTH-ORDER NORTH PLATTE RIVER BASIN (N.A. 00 R6 R4 LH)

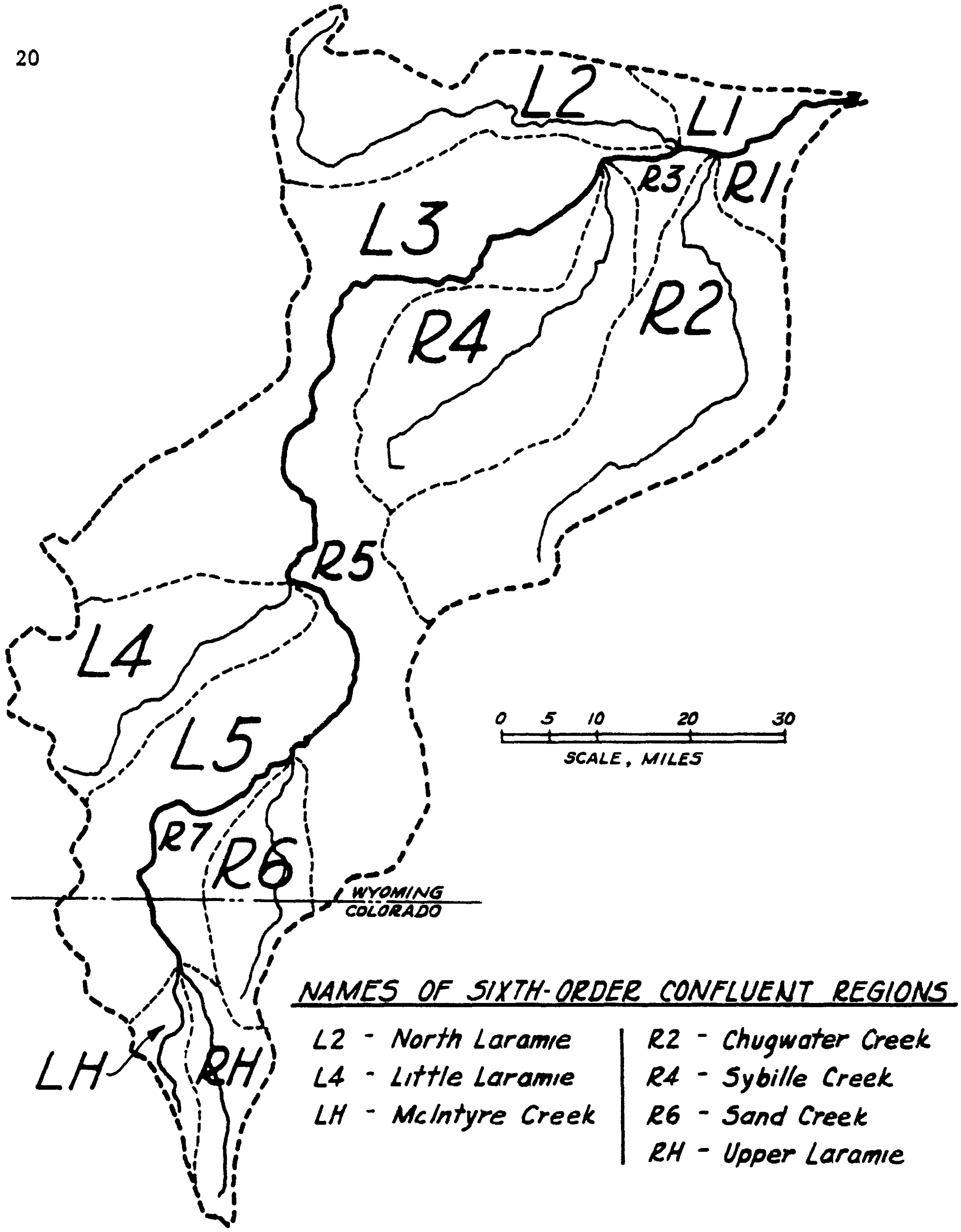


FIGURE 6. FIFTH-ORDER LARAMIE RIVER BASIN
(North America Basin 00R6R4LHR6)

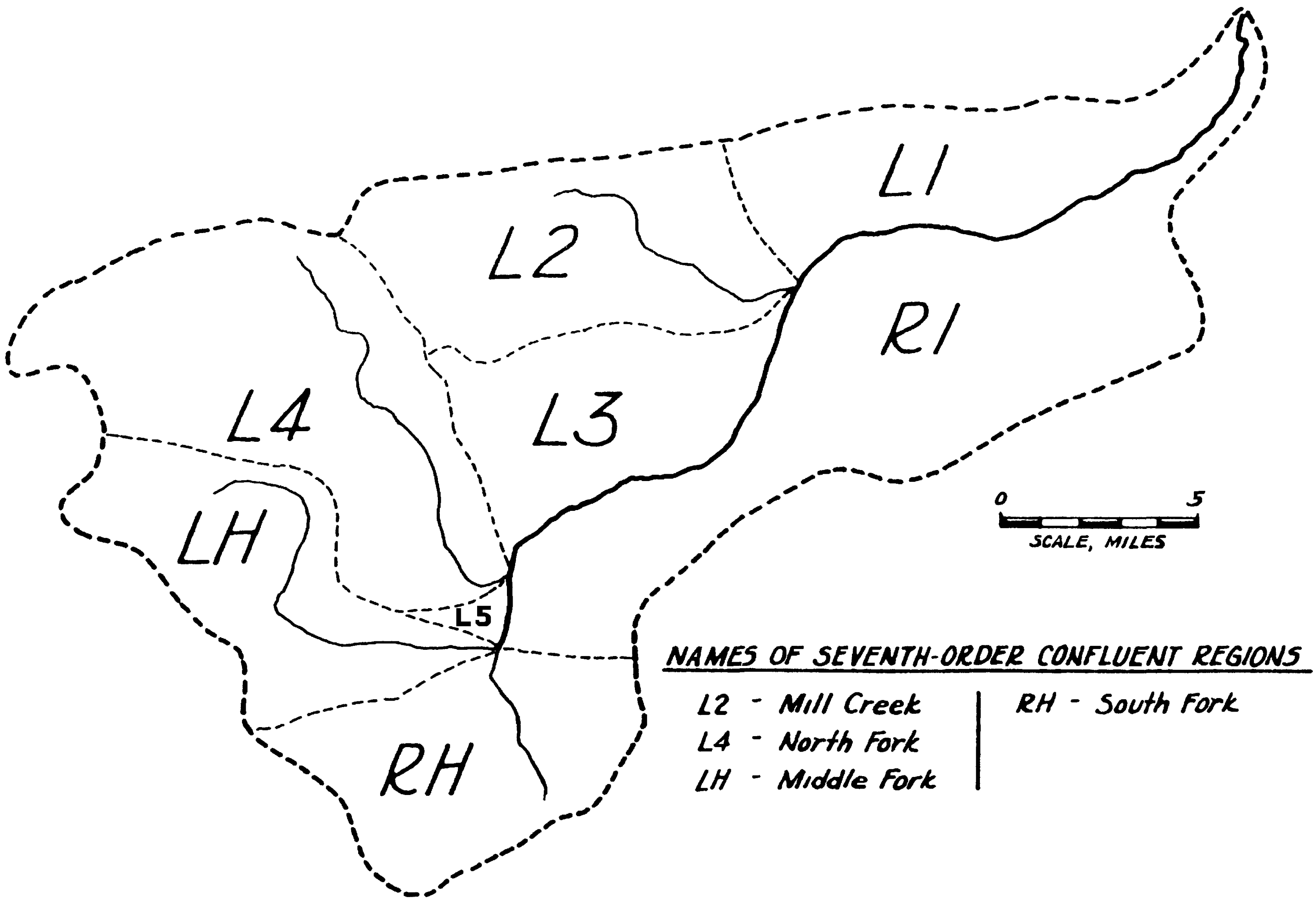
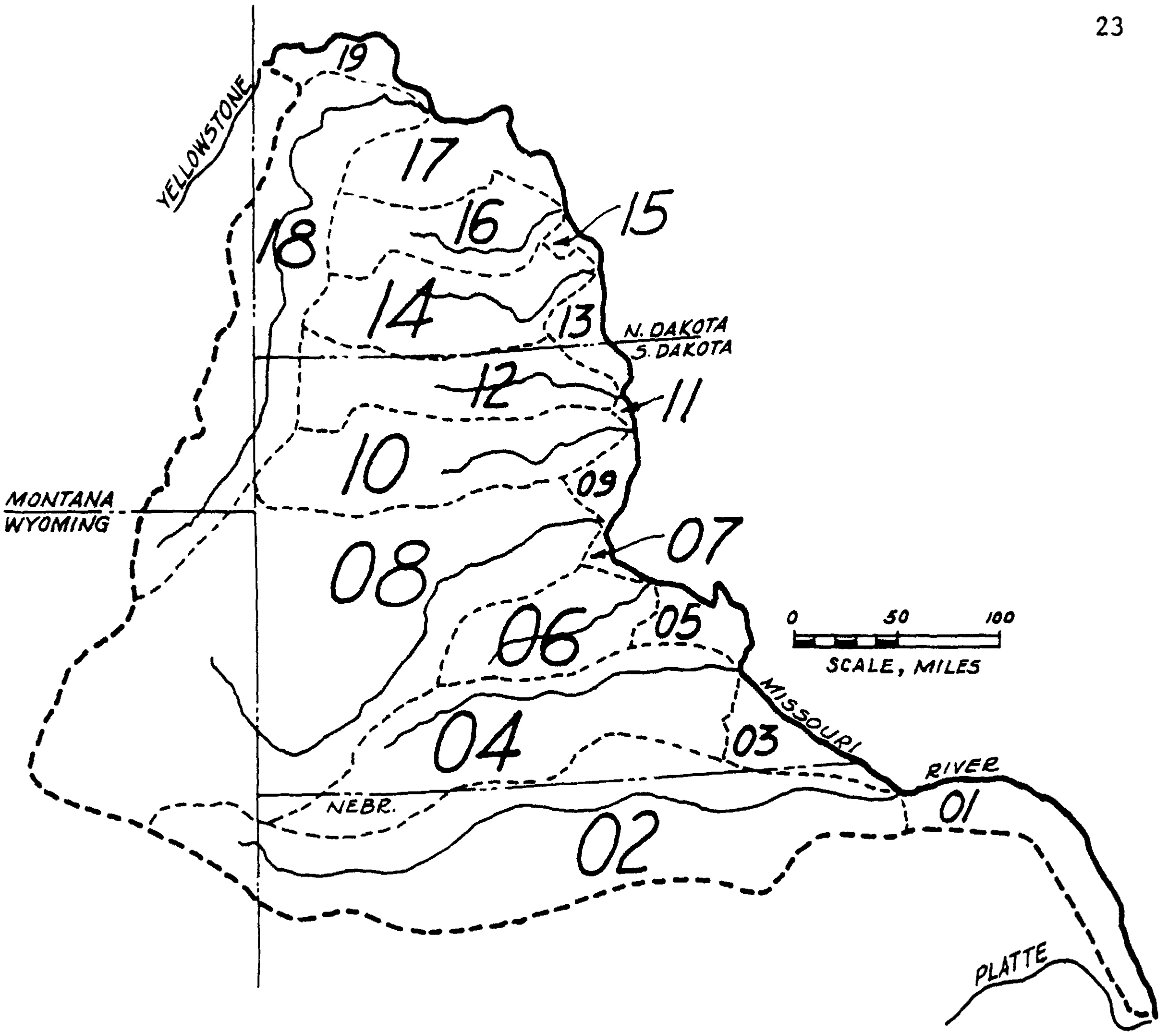


FIGURE 7. SIXTH-ORDER LITTLE LARAMIE RIVER BASIN (N. A. 00 R6 R4 LH R6 L4)

The large multifluent area between the Platte River and the Yellowstone River confluent regions is referred to as the Platte-Yellowstone multifluent region. The special method of analyzing and numbering this region is shown in Figure 8. One problem encountered here was the lack of sufficiently large fifth-order confluent regions which resulted in having quite a few fourth-order regions. However, as can be seen, the distribution of the areas was fairly good except for the large Cheyenne River confluent region. Figure 9 shows the analysis of the fourth-order Cheyenne River confluent region. The fifth-order Belle Fourche River basin (L4 of Figure 9) is one of many illustrations of the frequent occurrence of one unusually large drainage basin within a larger-order region. As indicated in Table II, the Belle Fourche River basin (7,400 sq. mi.) is larger than five of the nine fourth-order confluent regions of the Platte-Yellowstone multifluent region.

Figure 10 shows the subdivision of the Yellowstone River basin into its fourth-order regions. Two of these fourth-order regions, the Bighorn River basin and the Powder River basin, account for nearly all of the Yellowstone River basin that lies in Wyoming. Therefore, the next step was to analyze the Bighorn River and Powder River basins, as shown in Figures 11 and 12, respectively.

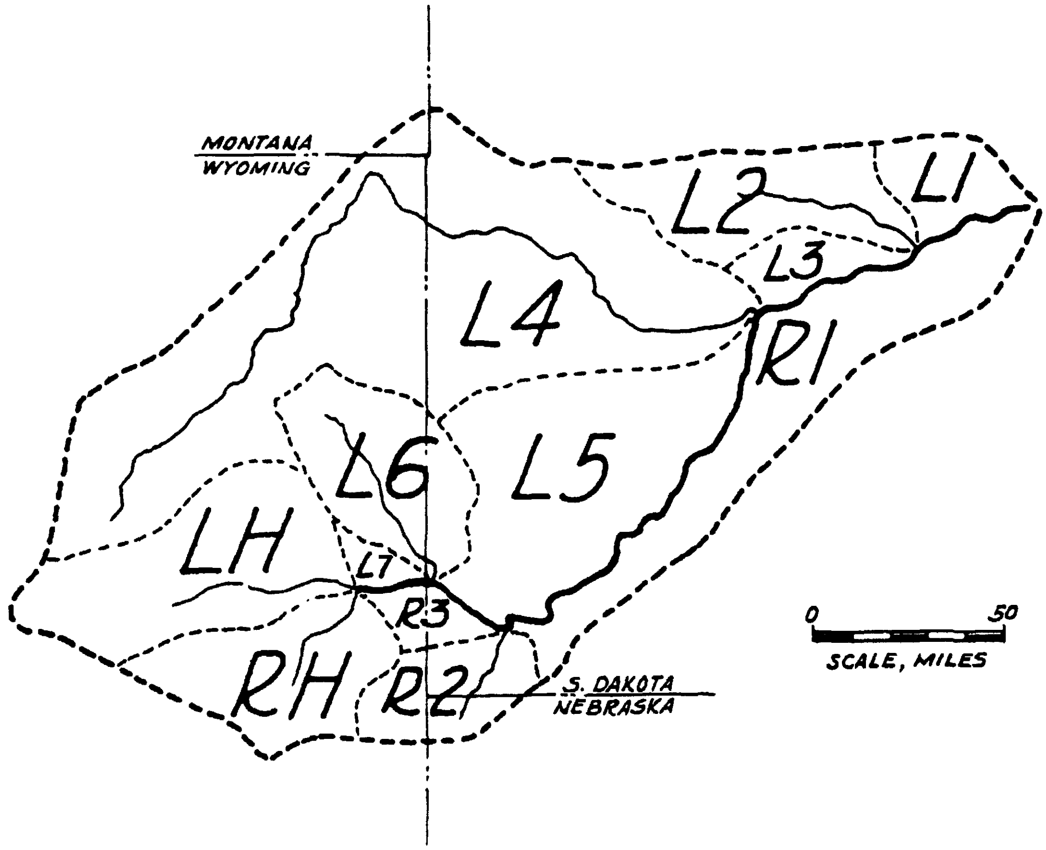
This is as far as the analysis of the Mississippi River basin was carried because, as will be shown later in Chapter V, this results in a fairly thorough subdivision of the basin as it pertains to the State of Wyoming. Table II gives the identifying names and numbers and the areas of all regions of the Mississippi River basin that were included in the analyses.



NAMES OF FOURTH-ORDER CONFLUENT REGIONS

02 - Niobrara
04 - White
06 - Bad
08 - Cheyenne
10 - Moreau
12 - Grand
14 - Cannonball
16 - Heart
18 - Little Missouri

FIGURE 8. THIRD-ORDER PLATTE-YELLOWSTONE REGION
(North America Basin 00R6R5)



NAMES OF FIFTH-ORDER CONFLUENT REGIONS

L2 - Cherry Creek	R2 - Hat Creek
L4 - Belle Fourche	RH - Lance Creek
L6 - Beaver Creek	
LH - South Fork	

FIGURE 9. FOURTH-ORDER CHEYENNE RIVER BASIN
(North America Basin 00 R6 R5 08)

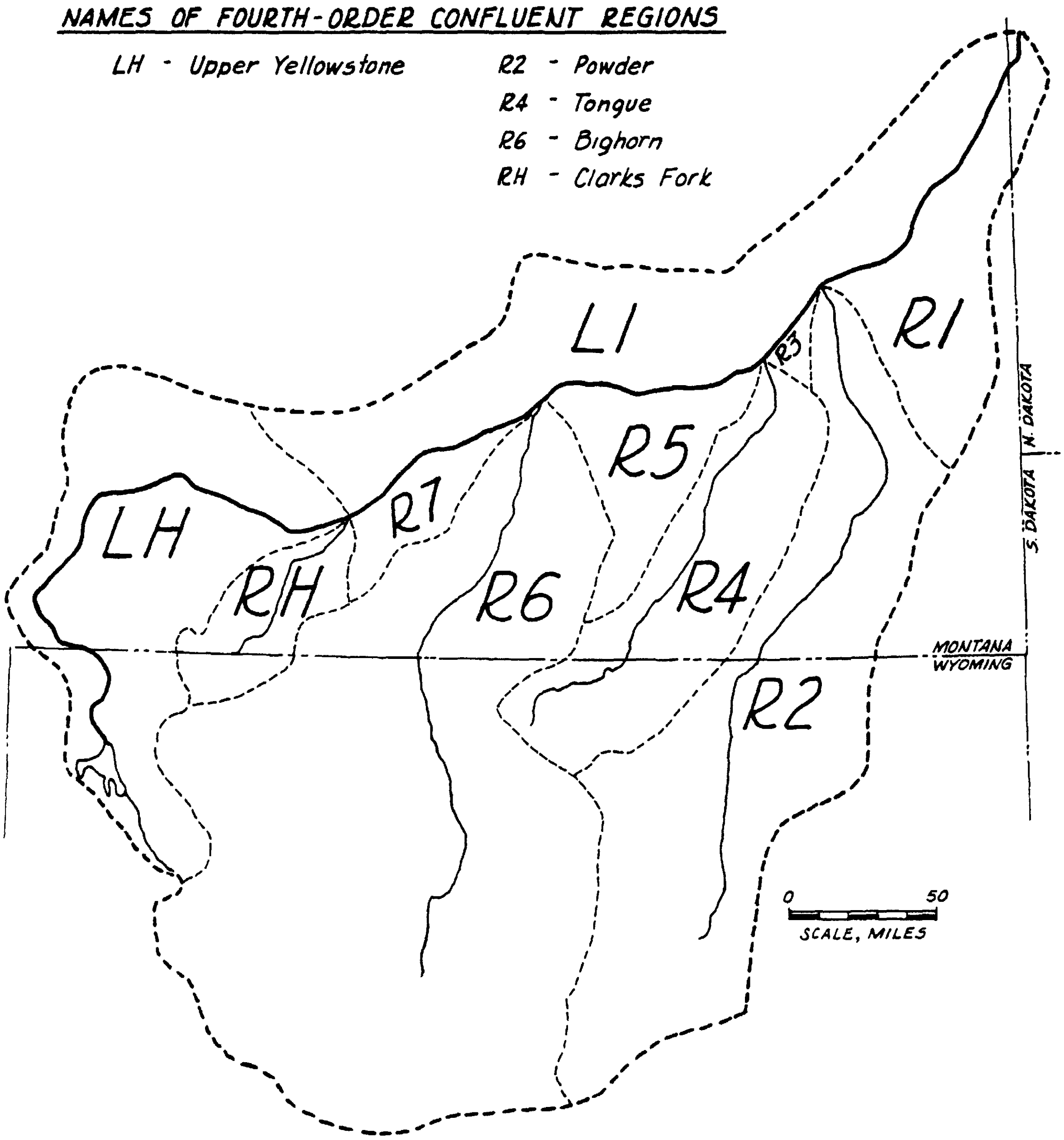
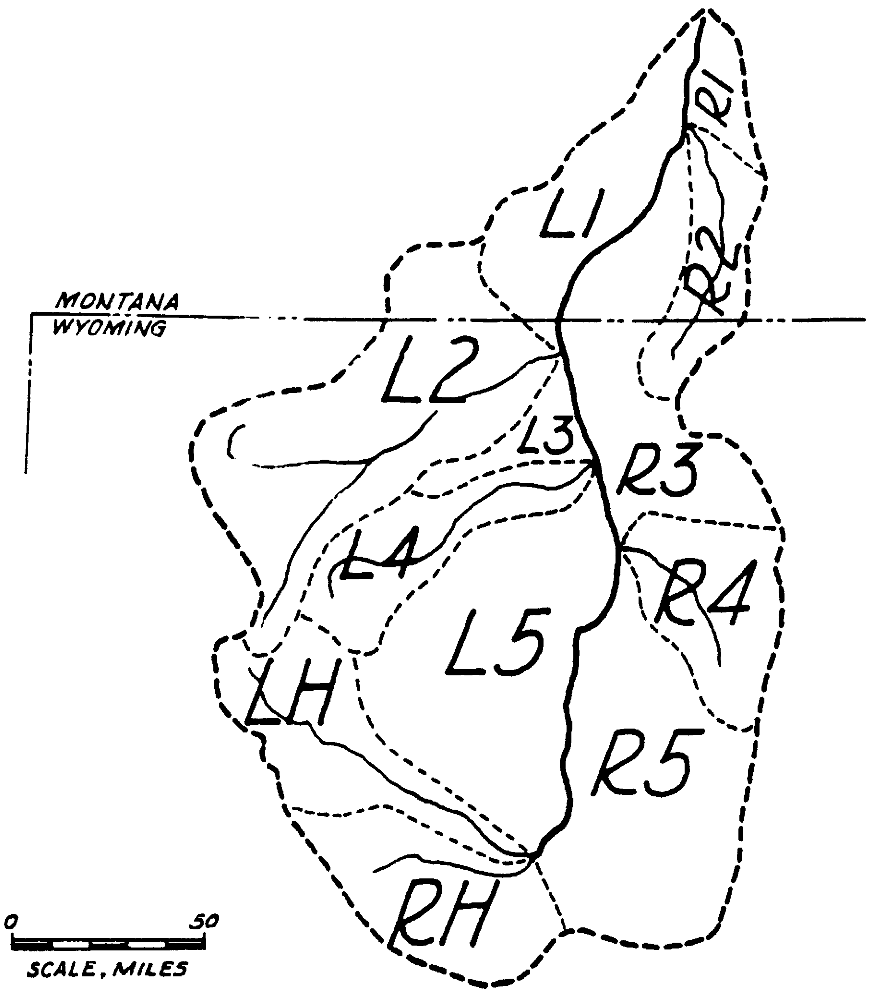


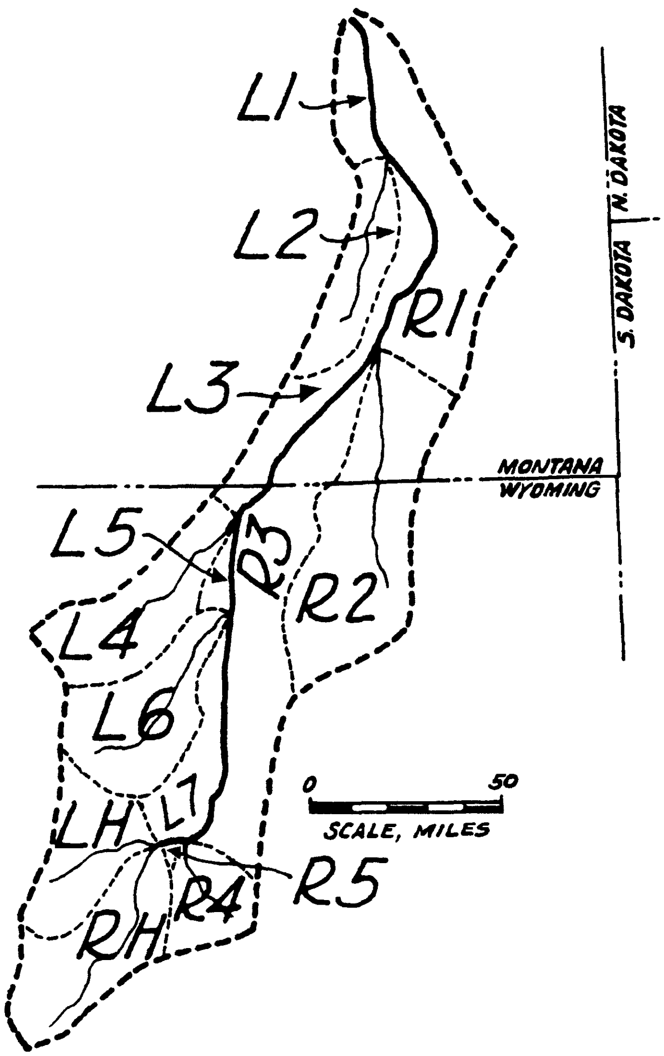
FIGURE 10. THIRD-ORDER YELLOWSTONE RIVER BASIN
(North America Basin 00R6R6)



NAMES OF FIFTH-ORDER CONFLUENT REGIONS

L2 - Shoshone	R2 - Little Bighorn
L4 - Greybull	R4 - Nowood Creek
LH - Upper Wind	RH - Little Wind

FIGURE 11. FOURTH-ORDER BIGHORN RIVER BASIN
(North America Basin 00 R6 R6 R6)



NAMES OF FIFTH-ORDER CONFLUENT REGIONS

L2 - Mizpah Creek	R2 - Little Powder
L4 - Clear Creek	R4 - Salt Creek
L6 - Crazy Woman Creek	RH - South Fork
LH - Middle Fork	

FIGURE 12. FOURTH-ORDER POWDER RIVER BASIN
(North America Basin 00R6R6R2)

TABLE II

THE MISSISSIPPI RIVER BASIN

Identifying Number	Identifying Name	Approximate Area (sq. mi.)
00	Mississippi	1,250,000
00 R2	Red	70,000
R4	Arkansas	160,000
R6	Missouri	530,000
L2	Ohio	203,000
LH	Upper Mississippi	19,000
RH	Minnesota	16,000
00 R6 R2	Kansas	60,000
R4	Platte	86,000
R6	Yellowstone	68,000
LH	Jefferson	9,700
RH	Madison	2,500
00 R6 R4 L2	Elkhorn	7,000
L4	Loup	15,000
LH	North Platte	36,000
RH	South Platte	24,000
00 R6 R4 LH R2	Pumpkin Creek	1,100
R4	Horse Creek	1,600
R6	Laramie	4,600
R8	Medicine Bow	2,400
L2	Sweetwater	3,000
LH	Upper North Platte	700
RH	Michigan	500
00 R6 R4 LH R6 R2	Chugwater Creek	760
R4	Sybille Creek	510
R6	Sand Creek	200
L2	North Laramie	500
L4	Little Laramie	400
LH	McIntyre Creek	75
RH	Upper Laramie	130
00 R6 R4 LH R6 L4 L2	Mill Creek	45
L4	North Fork	65
LH	Middle Fork	35
RH	South Fork	35

TABLE II (cont.)

MISSISSIPPI RIVER BASIN

Identifying Number	Identifying Name	Approximate Area (sq. mi.)
00 R6 R5 02	Niobrara	12,000
04	White	10,000
06	Bad	3,200
08	Cheyenne	24,500
10	Moreau	5,200
12	Grand	5,600
14	Cannonball	4,200
16	Heart	3,400
18	Little Missouri	900
00 R6 R5 08 R2	Hat Creek	1,100
L2	Cherry Creek	1,800
L4	Belle Fourche	7,400
L6	Beaver Creek	1,600
LH	South Fork	2,900
RH	Lance Creek	2,100
00 R6 R6 R2	Powder	13,000
R4	Tongue	5,500
R6	Bighorn	23,000
LH	Upper Yellowstone	8,000
RH	Clarks Fork	3,000
00 R6 R6 R6 R2	Little Bighorn	1,300
R4	Nowood Creek	2,200
L2	Shoshone	3,000
L4	Greybull	1,200
LH	Upper Wind	2,300
RH	Little Wind	1,900
00 R6 R6 R2 R2	Little Powder	2,100
R4	Salt Creek	840
L2	Mizah Creek	800
L4	Clear Creek	1,100
L6	Crazy Woman Creek	1,000
LH	Middle Fork	1,000
RH	South Fork	1,200

The Colorado River Basin

The Colorado River basin (240,000 sq. mi.) is the smallest of the five-order regions of North America. The subdivision of the Colorado River basin is shown in Figure 13. The second-order Green River basin is the only portion of the Colorado River basin that falls in the State of Wyoming. Therefore, for the purpose of this study, the next step is to analyze the Green River basis. Figure 14 shows the subdivision of the Green River basin into its third-order regions. The procedures for subdividing the Colorado River and the Green River basins are the same as were used in analyzing the Mississippi River basin.

Table III gives the identifying names and numbers and the approximate areas of all regions of the Colorado River basin that were included in the analysis.

The Colorado-Columbia Multifluent Region

This very large multifluent region begins at the mouth of the Colorado River where it empties into the Gulf of California and includes all of the Baja California area of Mexico, the State of California and Western Oregon to the mouth of the Columbia River. It also includes the Great Basin which is a 200,000 sq. mi. closed multifluent region. There are only three confluent regions of appreciable size in the entire area, the San Joaquin River (18,000 sq. mi.), the Sacramento River (28,000 sq. mi.) and the Klamath River (12,000 sq. mi.). These three basins become the second-order confluent regions as shown in Figure 15.

Since the northeast corner of the Great Basin does touch on the southwest corner of Wyoming, it was decided to next analyze this closed multifluent region. The confluence analysis principles are not directly

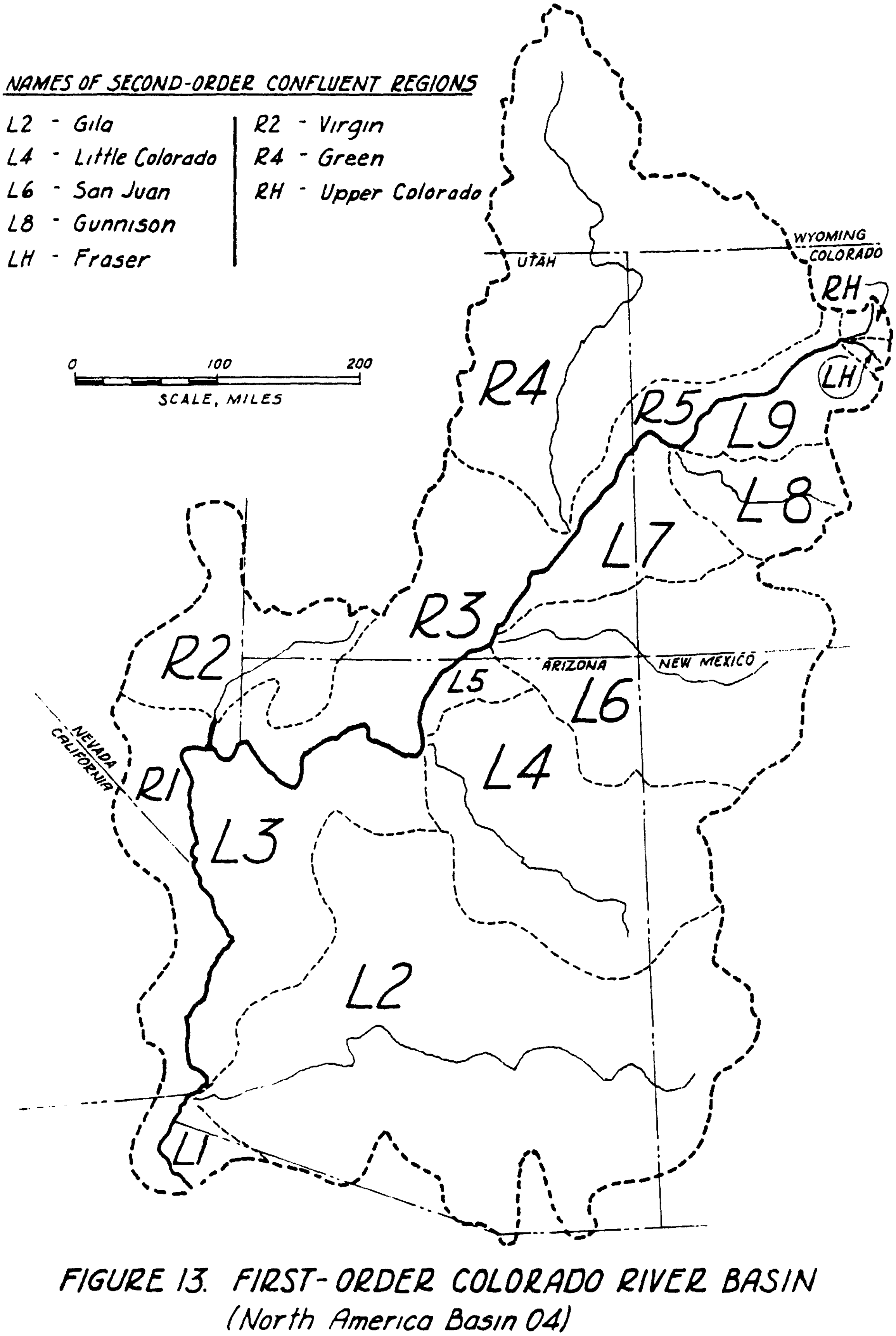


FIGURE 13. FIRST-ORDER COLORADO RIVER BASIN
(North America Basin 04)

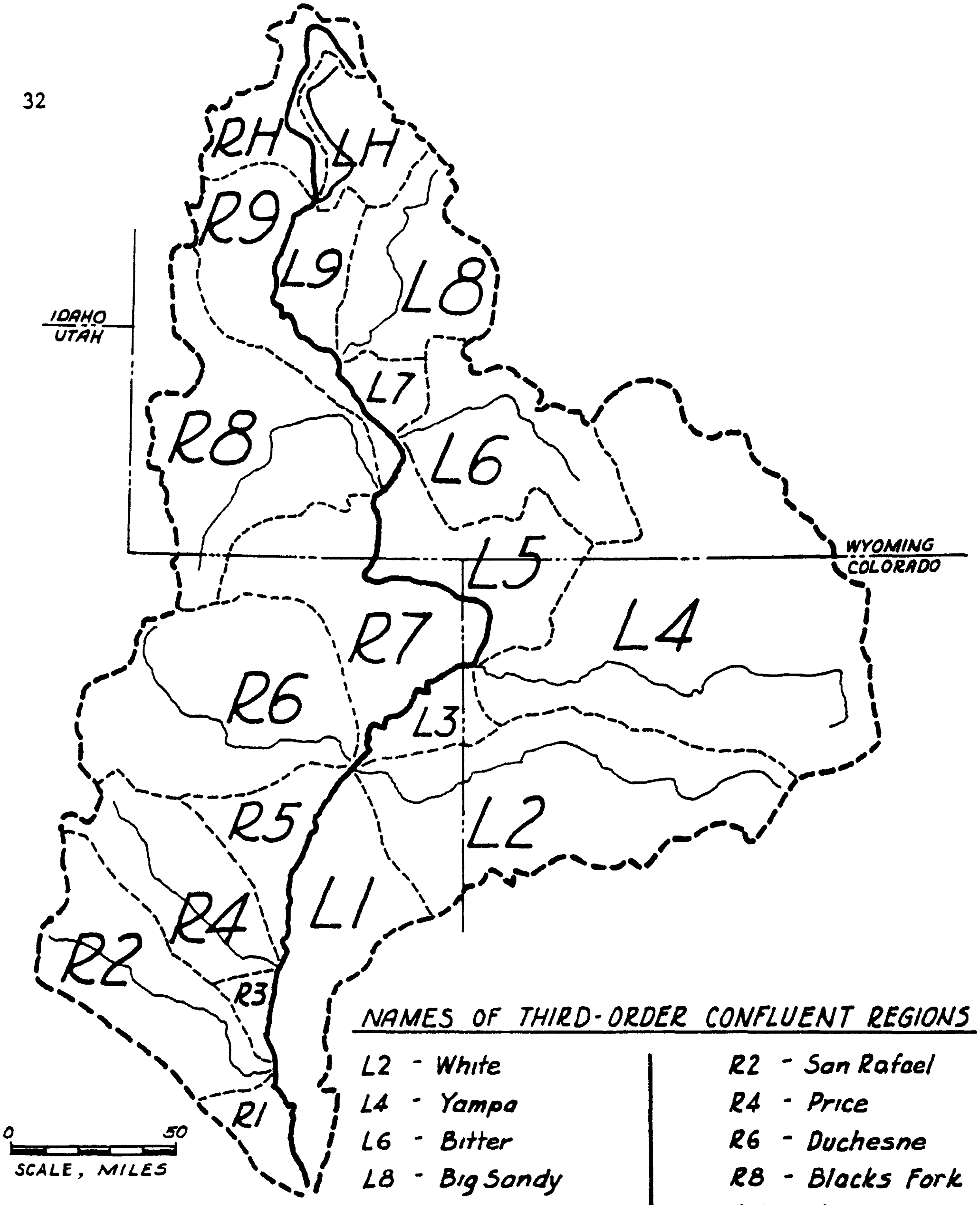


FIGURE 14. SECOND-ORDER GREEN RIVER BASIN
(North America Basin 04 R4)

TABLE III

THE COLORADO RIVER BASIN

Identifying Number	Identifying Name	Approximate Area (sq. mi.)
04	Colorado	240,000
04 R2	Virgin	10,000
R4	Green	44,000
L2	Gila	56,000
L4	Little Colorado	27,000
L6	San Juan	25,000
L8	Gunnison	8,000
LH	Fraser	300
RH	Upper Colorado	450
04 R4 R2	San Rafael	2,200
R4	Price	2,000
R6	Duchesne	4,000
R8	Blacks Fork	4,000
L2	White	5,000
L4	Yampa	8,000
L6	Bitter	3,000
L8	Big Sandy	1,800
LH	New Fork	1,200
RH	Upper Green	1,300

applicable to closed, multifluent regions like the Great Basin that are composed of similar but much smaller closed basins intermixed with arid desert regions such as the Mojave Desert. Therefore it was decided to name these smaller-order closed basins by the name of the most prominent stream, lake or sea in the region and then to analyze each of the areas independently. The third-order subdivisions of the Great Basin and the names that were selected for them are shown in Figure 16. As for numbering these third-order regions, it was decided to use a two-letter system rather than numbers. For example, the Great Salt Lake basin was given the identification code of North America Basin 05 01 SL where the letters SL are derived from the name "Salt Lake".

The Great Salt Lake basin (35,000 sq. mi.) is unique in that it is a closed, multifluent region with smaller-order confluent regions flowing inward to the lake. This type of region is subdivided using the same procedure used in subdividing a continent or island. The main difference is that the first-order regions of a continent drain outward to the surrounding oceans while here the drainage is inward to the Great Salt Lake. In Figure 17 the Great Salt Lake basin is subdivided into its fourth-order confluent and resulting multifluent regions. The numbering begins with 00 for the largest confluent region and continues clockwise around the lake with 01 for the next multifluent region, and so forth.

Since only a few areas were actually involved in the analysis of the Colorado-Columbia multifluent region and these are given above, a table of areas is not included for this section.

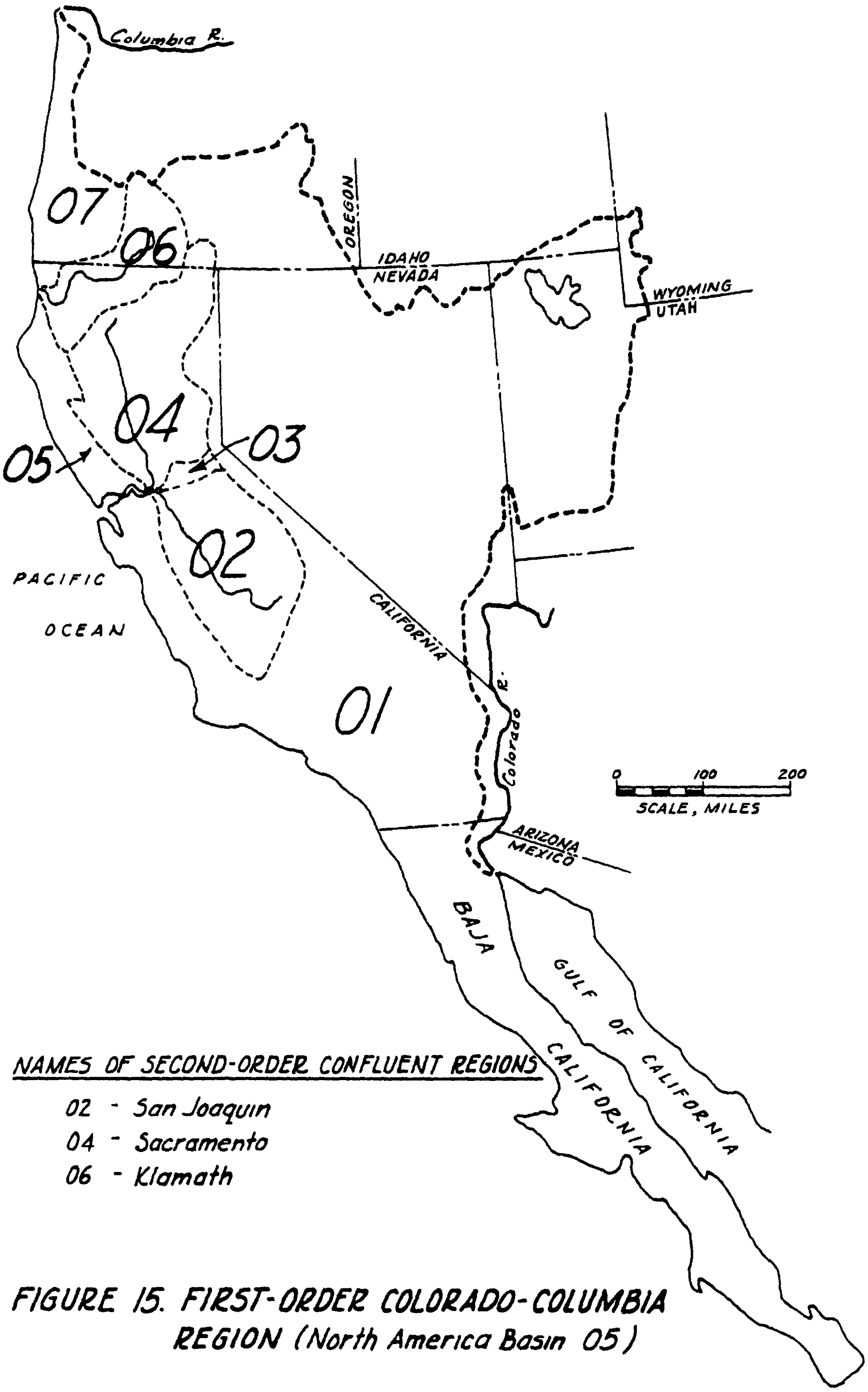


FIGURE 15. FIRST-ORDER COLORADO-COLUMBIA REGION (North America Basin 05)

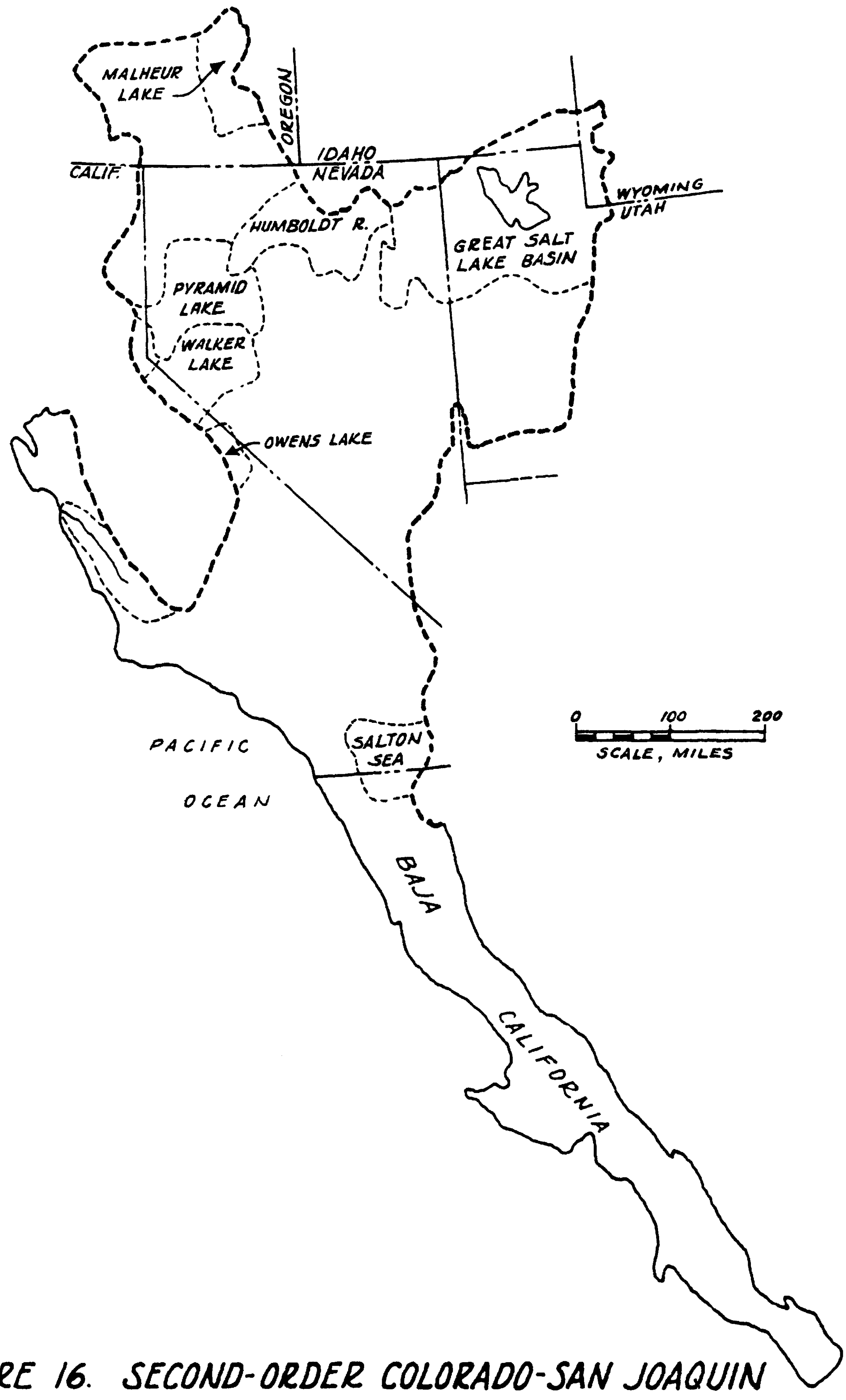
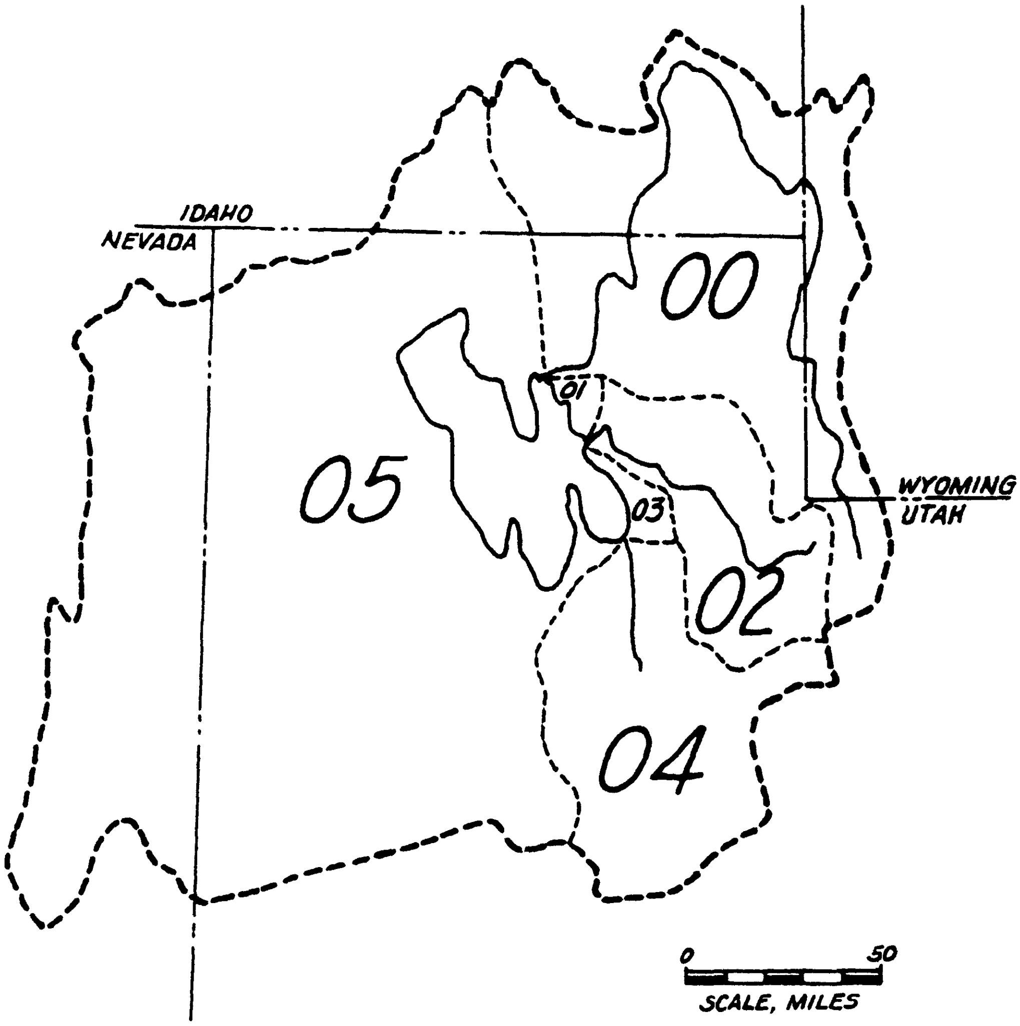


FIGURE 16. SECOND-ORDER COLORADO-SAN JOAQUIN REGION (North America Basin 05 01)



NAMES OF FOURTH-ORDER CONFLUENT REGIONS

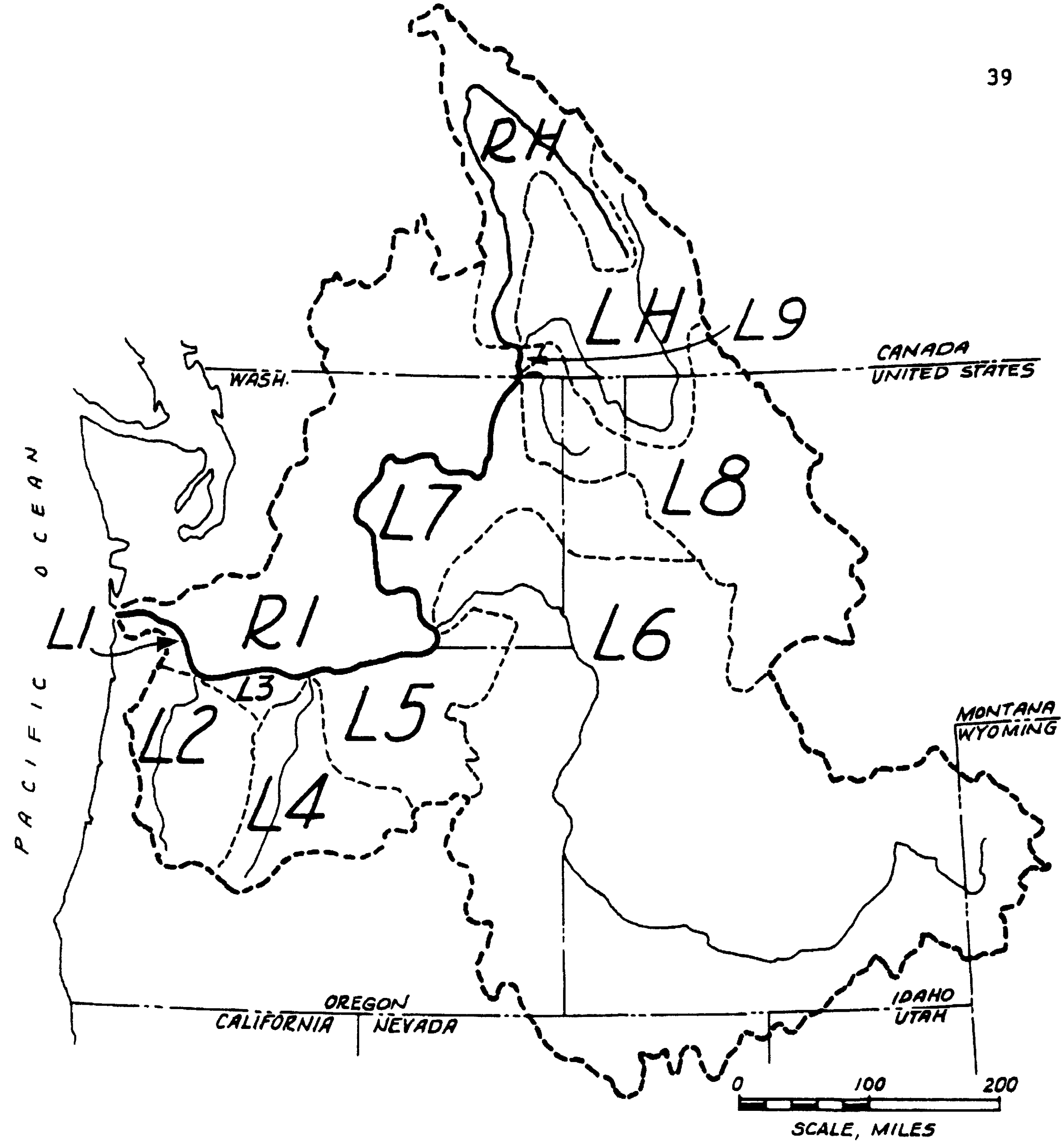
00 - Bear
02 - Weber
04 - Jordan

FIGURE 17. THIRD-ORDER GREAT SALT LAKE BASIN
(North America Basin 05 01 SL)

The Columbia River Basin

The analyses of the first-order Columbia River basin in Figure 18 and the second-order Snake River basin in Figure 19 completes the analyses of all drainage basins which at some point fall in the State of Wyoming. The Snake River basin is another example of the tendency to have one unusually large confluent region which was the reason for choosing the criterion that a region be as large or larger than the second-largest next smaller-order confluent region. The procedures used in analyzing the Columbia River and Snake River basins are similar to those discussed earlier.

Table IV gives the identifying names and numbers and the approximate areas of all regions of the Columbia River basin that were included in the analyses.

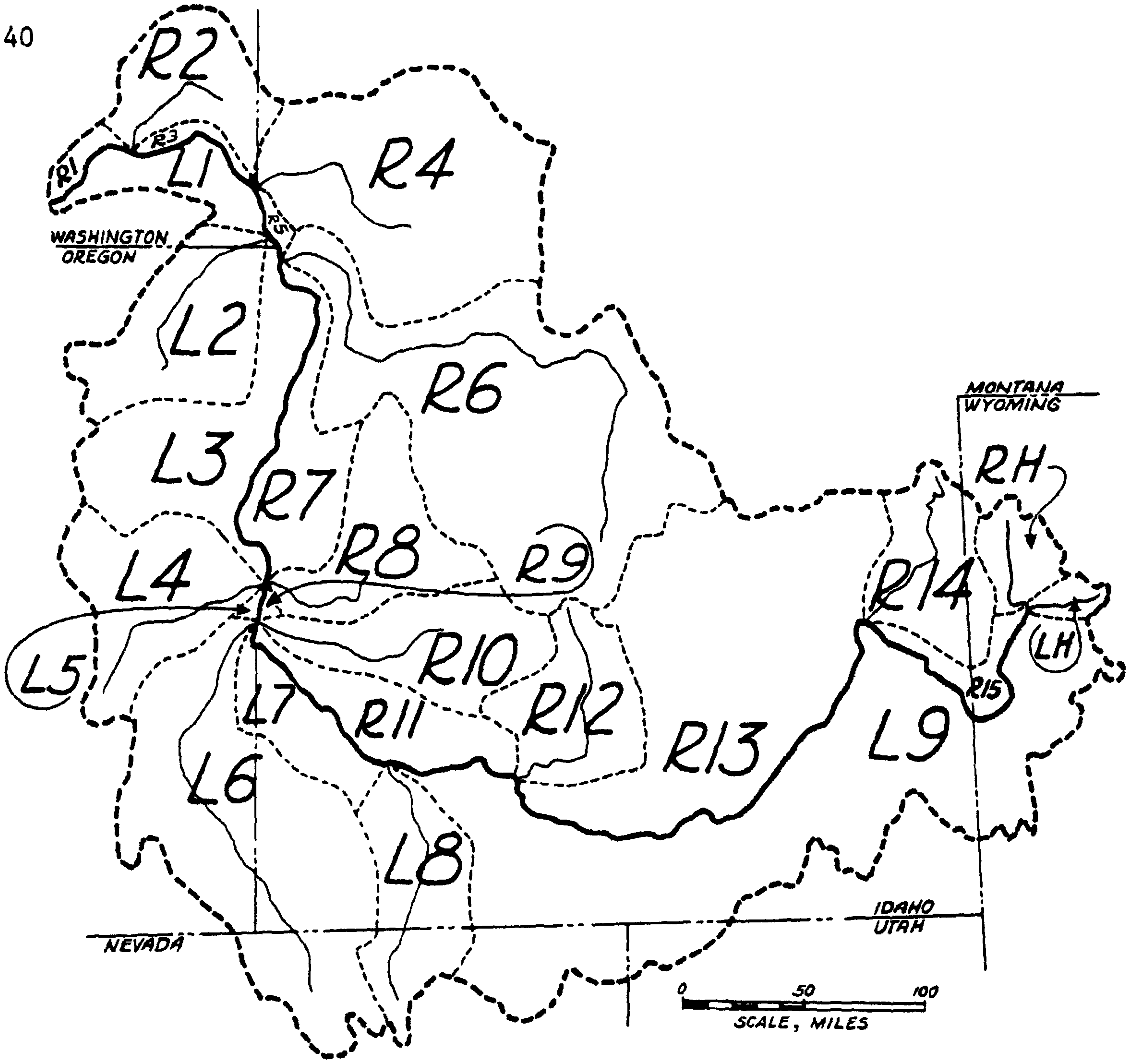


NAMES OF SECOND-ORDER CONFLUENT REGIONS

L2 - Willamette
L4 - Deschutes
L6 - Snake
L8 - Pend Oreille
LH - Kootenay

RH - Upper Columbia

FIGURE 18. FIRST-ORDER COLUMBIA RIVER BASIN
(North America Basin 06)



NAMES OF THIRD-ORDER CONFLUENT REGIONS

L2 - Grande Ronde	R2 - Palouse
L4 - Malheur	R4 - Clearwater
L6 - Owyhee	R6 - Salmon
L8 - Bruneau	R8 - Payette
LH - Buffalo Fork	R10 - Boise
	R12 - Big Wood
	R14 - Henrys Fork
	RH - Upper Snake

FIGURE 19. SECOND-ORDER SNAKE RIVER BASIN
(North America Basin 06 L6)

TABLE IV

THE COLUMBIA RIVER BASIN

Identifying Number	Identifying Name	Approximate Area (sq. mi.)
06	Columbia	260,000
06 L2	Willamette	11,000
L4	Deschutes	11,000
L6	Snake	110,000
L8	Pend Oreille	26,000
LH	Kootenay	23,000
RH	Upper Columbia	19,000
06 L6 R2	Palouse	3,300
R4	Clearwater	9,600
R6	Salmon	14,000
R8	Payette	3,300
R10	Boise	4,000
R12	Big Wood	3,000
R14	Henrys Fork	3,000
L2	Grande Ronde	4,000
L4	Malheur	4,700
L6	Owyhee	11,000
L8	Bruneau	3,300
LH	Buffalo Fork	400
RH	Upper Snake	850

CHAPTER V

APPLICATIONS

The State of Wyoming

As stated previously, one purpose of this study is to present a set of surface-water coordinates which hopefully will be found to be useful for coordinating Wyoming's water resource activities. Figure 20 shows the subdivision of the State of Wyoming into the different orders of confluent and multifluent regions that resulted from the preceeding analyses. The heavy dashed lines are the boundary lines of the first-order Mississippi River, Colorado River, Colorado-Columbia and Columbia River regions. Coincidently, these are also the boundaries of the second-order Missouri River, Green River, Colorado-San Joaquin and Snake River regions. The boundary lines for the third-order regions are shown by lighter dashes and the fourth- and fifth-order regions are shown by dash-dot and dotted lines, respectively. Any of the regions shown can easily be identified by referring to the proper figures given in Chapter IV. For example, starting in the upper left-hand corner of the State with "Missouri RH", Figure 3 on page 16 shows this to be the Madison River. Moving clockwise around the State the next two regions are "Yellowstone LH and RH" which can be identified from Figure 10 on page 25 as the Upper Yellowstone River and the Clarks Fork. Continuing clockwise, next is "Bighorn L2" which is listed in Figure 11 on page 26 as the Shoshone River.

In the lower-center of the State is an area completely enclosed by the Missouri River and Green River basins which is commonly called the

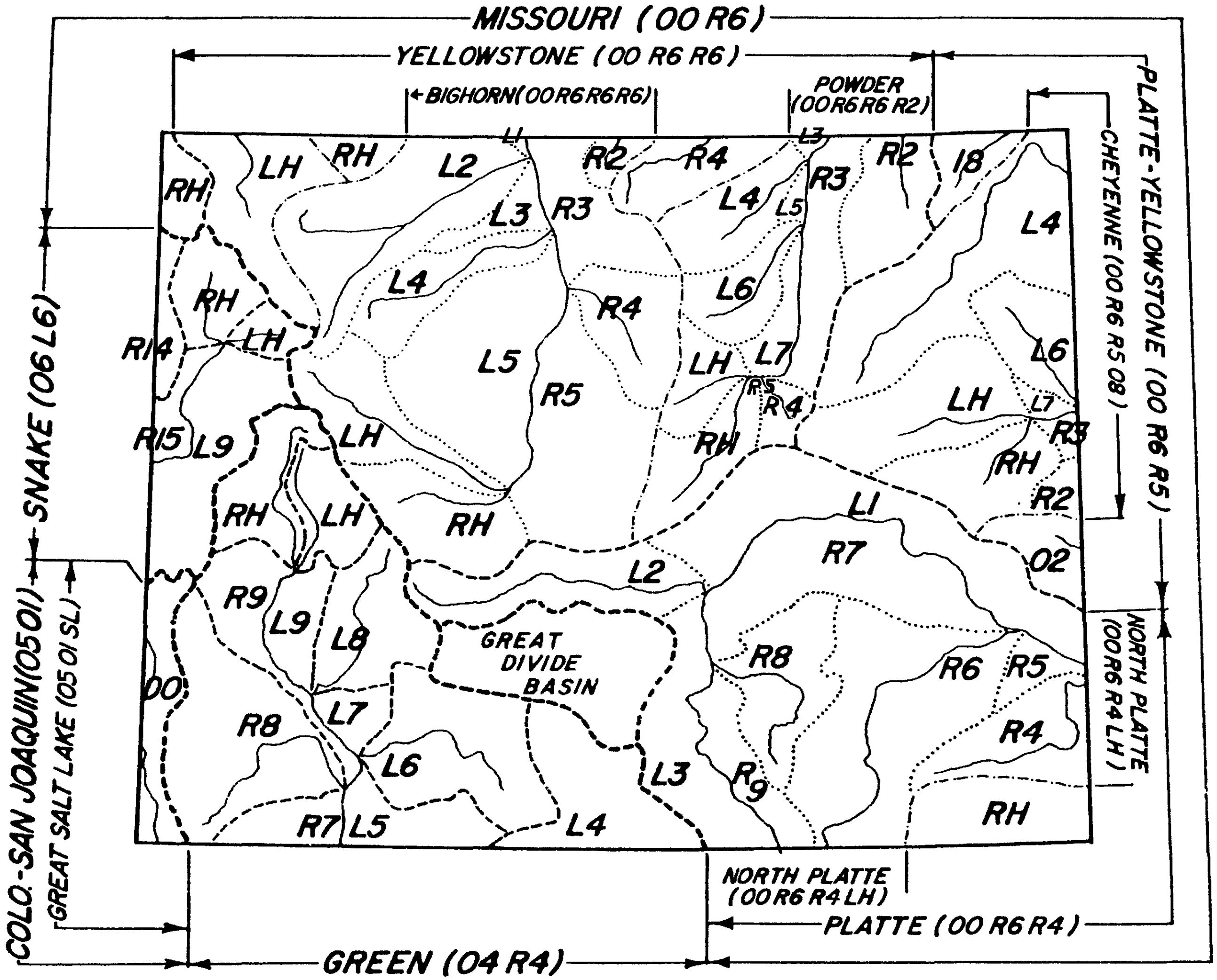
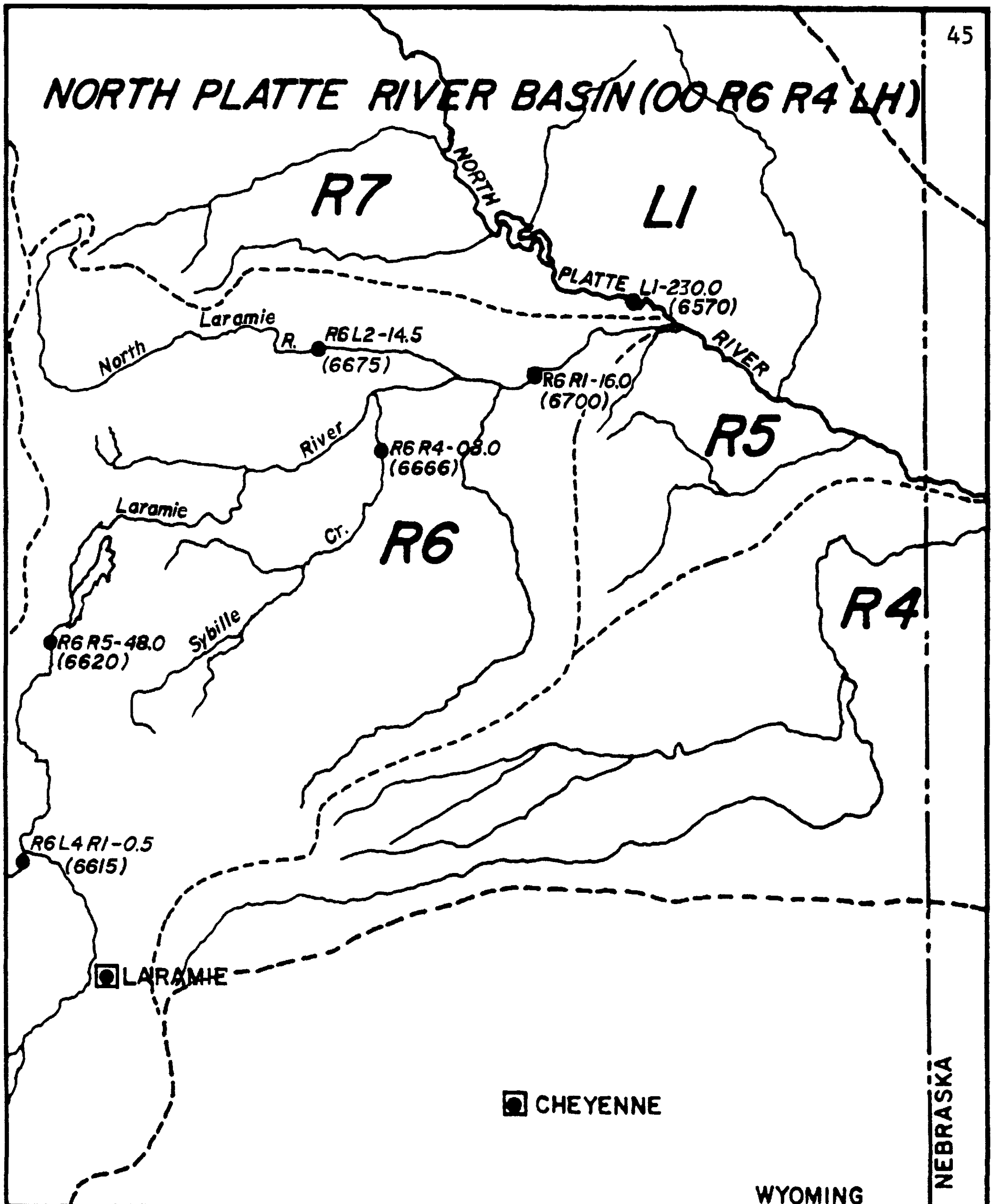


FIGURE 20. The Analyses Applied to the State of Wyoming

Great Divide Basin. This large (4,000 sq. mi.) concave, closed multifluent region drains inwardly and does not contribute (through surface flow) to any of the adjacent basins. As was stated earlier about the similar but much larger Great Basin of the Colorado-Columbia multifluent region, it is beyond the scope of this study to analyze such an area. The important considerations are to locate and identify these closed, non-contributing regions and to not include them in the analyses of adjacent regions.

Identification of Stream Gaging Stations

Figure 21 illustrates a way the system might be used to locate and identify points such as stream gaging stations on land surfaces. The numbering system already developed might well be extended merely by adding the distance in miles that a station is located upstream from the mouth of the last-identified confluent region. For example, the station "North Platte R6 R1-16.0" is on the Laramie River 16.0 miles upstream from the mouth and is located on the right bank of the river. If the station had been located on the left bank of the river it would have been identified as "North Platte R6 L1-16.0". Since some of the regions, such as the North Laramie River, have not been further subdivided it is not possible to show the complete number that would show on which bank of the stream the station is located. All we can show by "North Platte R6 L2-14.5" is that the station is 14.5 miles upstream from the mouth of the North Laramie River. The same problem exists with station "North Platte L1-230.0" where further analysis of the L1 multifluent region is necessary to locate the station more exactly.



NOTE: The numbers in parentheses are U.S.G.S. gaging station numbers.

0 10 20

SCALE, MILES

FIGURE 21. Identification of Stream Gaging Stations in North Platte Basin

Other Possible Applications

Many additional uses of the proposed system are possible since the interactions and interdependencies of surface waters were utilized in developing the principles of confluence analysis. A few such examples are as follows:

1. Water pollution--Establishment and location of interrelated stations for water quality networks.
2. Water rights--Tabulating and indexing locations of applications and permits.
3. Water supply augmentation--Coordination and evaluation of related weather modification efforts.
4. Water and snow management--Coordination and control of runoff management activities.
5. Water conservation--Coordination and evaluation of interrelated conservation measures.
6. Land drainage--Analysis of drainage methods and practices.
7. Watershed management--Control of experimental erosion and run-off studies.
8. Flood control--Study of drainage areas and waters contributing to floods.
9. Sedimentation control--Study of land areas contributing to sedimentation.
10. Climatological data--Storage, retrieval and dissemination of data as related to water resource activities.

CHAPTER VI

CONCLUSIONS

Clearly there is a genuine need for the adoption of a uniform system of coordinating water resource activities. The time and expense involved in developing modernized systems that are designed for todays' high-speed electronic computers and in converting to these systems must be considered. However, a more important consideration is how long can we afford to wait before we assume these very necessary tasks.

Confluence analyses of land surfaces is a feasible method of deriving a set of coordinates based upon the interrelationships among surface waters by analytically subdividing a continent into successively smaller-order confluent and multifluent regions. The criteria for subdividing and numbering such regions were extensively use-tested over a wide range of types and sizes of drainage basins and were found to be successful in producing the desired numbers and sizes of regions.

It is hoped that consideration will be given to this need for a systematic method of coordinating water resource activities, and that the ideas and principles developed in this study will be useful in the fulfillment of that need.

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SELECTED REFERENCES

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3. Federal Water Pollution Control Administration, Storet System For Data Handling In Water Pollution Control. Washington, D. C.: U. S. Government Printing Office, December, 1964.