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WORLD ATLAS
OF
COMMERCIAL GEOLOGY

PART II
WATER POWER OF THE WORLD

WASHINGTON, D. C.
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CONTENTS.

Maps of the world showing heights above sea level and distribution of rainfall are given on pages 4 and 5. Plates 1 to 8 follow the text.

WORLD ATLAS OF COMMERCIAL GEOLOGY.

PART II. WATER POWER OF THE WORLD.

By Herman Stabler, B. E. Jones, O. C. Merrill, and N. C. Grover.

INTRODUCTION.

The development of the mineral resources of the world depends on the local availability of cheap mechanical or electrical energy. In many regions such energy must be obtained from water flowing in surface streams; in others it must be generated from fuels. The value of a mineral in the ground is intimately related to the source of the energy needed to recover it for commercial use. A knowledge of the water-power resources of the world is therefore essential to a proper study and utilization of the mineral resources. Furthermore, water power and mineral fuels will compete with each other in determining the selection of sites for manufacturing industries and in their development.

Part II of the World Atlas of Commercial Geology sets forth in general terms the water-power resources of the world and the extent of their present development. When used in conjunction with the other parts of the atlas it will throw considerable light on the possible interrelations of water power and the mineral deposits and industries throughout the world. The tedious search of literature in several languages, the correlation of the data (some of them meager), and the estimation of resources for Part II have been the work of a score of men, most of them engineers. In addition to the engineers whose names appear above, on whom the brunt of the work fell, R. W. Davenport, J. F. Deeds, D. J. Guy, A. H. Horton, B. H. Lane, B. J. Peterson, C. H. Pierce, R. R. Randall, Philip Seabury Smith, F. J. Sopp, V. V. Tchikoff, N. W. Tubbs, and G. M. Wood rendered material aid in preparing the volume.

Developed water power.—All available information has been used in preparing the accompanying estimates of developed water power and of the capacity of the water wheels now installed in water-power plants. These estimates are presented in terms of horsepower and should be reduced one-fourth for expression in kilowatts. As water-power development is always in progress reliable statistical information concerning it is never strictly up to date, so that the recent development must be estimated. On the whole, however, the figures show comparatively the progress of the utilization of water power throughout the world.

North America, although it contains less than 15 per cent of the water-power resources of the globe, has developed more water power than all the rest of the world. About 41 per cent of the developed water power of the world is in the United States. European countries, particularly Germany, the territory comprised in the former empire of Austria-Hungary, Norway, Sweden, France, Italy, and Switzerland, have developed a relatively large percentage of their water power, and the percentage is greater in Germany than in any other country in Europe.

Potential water power. — Few countries have made systematic studies of their potential water power. The estimates made for the United States and Canada are unsatisfactory, for they express orders of magnitude of the potential water power rather than known amounts, and those for most of the other countries discussed in this atlas are even less reliable, though detailed data have been compiled in a few countries. For Asia, Africa, South America, and Central America, where great expanses of territory are practically unexplored and water power is a subject of little interest, it is necessary to rely on studies of rainfall and topography and to check the results of these studies, wherever possible, by such meager detailed information as can be gathered. The maps on pages 4 and 5 show heights above sea level and distribution of rainfall in these regions.

The estimates of power here given represent continuous horsepower available at the ordinary low stages of streams. Obviously no estimates could be made of the cost of development, but factors have been introduced to correct the estimates in so far as the theoretical power may lie beyond the limits of engineering feasibility.

Nearly half the potential water power in the world is in Africa, for that continent is essentially a great plateau on which the streams become large before they fall to the sea, and they fall rather abruptly. Northern and southern Africa, because their rainfall is low and poorly distributed, have only small water-power resources, but tropical Africa, particularly the Kongo basin, has a heavy rainfall, which, in connection with the characteristic topography of the continent, produces great potential water power.

Because of its vast area and the high altitude of its central part, Asia would have enormous water-power resources if the rainfall were greater, but throughout northern, western, and central Asia the precipitation is low. Furthermore, the seasonal distribution of the rainfall in southern and eastern Asia is so irregular that the stage of the rivers fluctuates greatly and the continuous horsepower represented by the estimates is only a small part of the power that would be available if all slope and all discharge could be utilized. Asia therefore, though 50 per cent greater in area than Africa, ranks second in water-power resources.

North America, South America, and Europe have water-power resources that rank in the order in which they are named, which is also the order of their areas. The water-power resources of Europe are perhaps better known as a whole than those of other continents, though the information relating to them is incomplete, especially that relating to Russia and the Balkan States.

So small a part of the world's water-power resources has been developed that different scales are used for the resources and for the developed power on the accompanying numbered maps (Pls. 1–8). Furthermore, as the practice of installing water-power wheels to utilize a flow that is materially greater than the ordinary low flow is well established, the estimates of the resources should be at least doubled to represent possible future installed capacity for comparison with the estimates of developed water power. Thus, though the potential water power of the world is estimated at nearly 440 million horsepower when the streams are at ordinary low-water stage and the present installed capacity at a little more than 23 million horsepower, or more than 5 per cent of the estimated potential power, probably only 2 or 3 per cent of the total potential power has been developed. The extreme ultimate develop-

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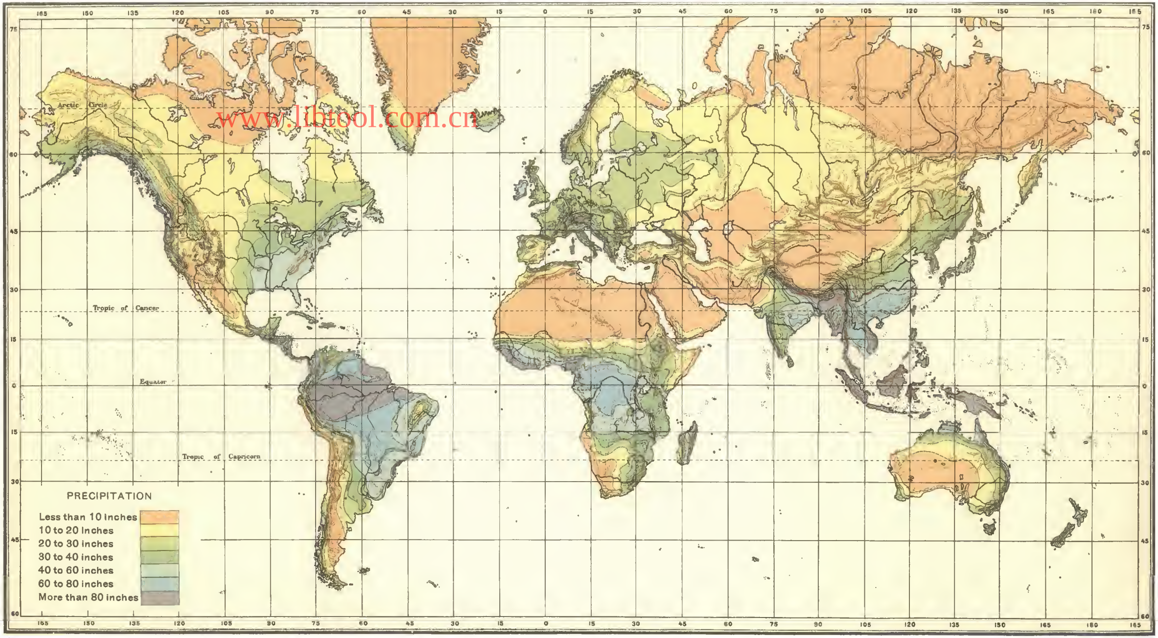
ALTITUDE OF LAND.

Adapted from "Physical maps of the continents," by J. Paul Goode, Chicago, 1913-1915. The Mercator projection used for this map greatly exaggerates the areas toward the poles. Reprinted from "Geography of the world's agriculture," published by Office of Farm Management, U. S. Department of Agriculture.



MEAN ANNUAL PRECIPITATION.

Adapted from "Oxford wall maps of the continents," by A. J. Herbertson, 1908-1911, except the United States, which is based on data supplied by U. S. Weather Bureau. The Mercator projection used for this map greatly exaggerates the areas toward the poles. Reprinted from "Geography of the world's agriculture," published by Office of Farm Management, U. S. Department of Agriculture.

ment with the greatest possible conservation of stream flow by storage may reach even as high as 5 to 10 billion horsepower, but such a figure is purely speculative. The reasonable estimate of the potential water power here given amounts to nearly four times the world's present total used power from all sources.

The maps (Pls. 1–8) show graphically the distribution of power in the several continents and are in most of their features self-explanatory. For convenience of description numbers corresponding to those used in the Survey's records have here been assigned to the drainage areas shown on the maps and described in the text.

NORTH AMERICA.

The western part of North America is a high plateau bordered on the west by the ranges of the Pacific Mountain system and on the east by those of the Rocky Mountain system, which extends from Alaska to Panama. In general the eastern part of the continent is low and slopes uniformly down to sea level, except the Appalachian Highlands, a narrow mountainous strip near the Atlantic coast that extends from St. Lawrence River nearly to the Gulf of Mexico. This strip and a low plateau in southeastern Canada afford most of the potential power in the eastern part of the continent. The central part is an area of plains, and although the rivers are large the slopes are in general flat and uniform and afford few power sites.

The rainfall of the western part of the continent varies with both altitude and latitude. The rainfall of the coast region north of San Francisco is heavy, reaching 90 inches annually in northern Washington and 150 to 200 inches at places in British Columbia and Alaska. From San Francisco southward to the end of the Lower California peninsula the rainfall is extremely light. Still farther south it increases again until it reaches 60 inches in southern Mexico and Central America. The annual rainfall is 10 to 20 inches in the region east of the Rocky Mountains as far as Manitoba, South Dakota, and western Kansas, but it is 40 to 60 inches over most of the area east of the Mississippi in the United States and 20 to 30 inches over the corresponding area in Canada.

The potential water power in these regions is closely related to altitude and rainfall. On the western slope of the mountains along the north Pacific coast heavy rainfall and steep gradients create great potential power, but on the eastern slope of the same mountains the rainfall and consequently the potential power are less. In the great central part of the continent the potential power is small, but in the mountain range along the Atlantic coast another concentration of potential power is made possible by the uniform and comparatively heavy rainfall. In Mexico and Central America the high mountains and large fall of the rivers afford great potential power, though in northern Mexico the power in limited by the scanty rainfall. In outlining the general conditions the continent has here been divided into 19 drainage areas, described below.

1. *Middle Atlantic.*—The middle Atlantic area includes the basins of all the streams that flow into the Atlantic Ocean between the St. Lawrence River basin on the north and the James River basin on the south. Abundant precipitation and many small falls afford opportunities for a large number of good power sites. The area contains the most densely populated parts of the Western Hemisphere, and the large demand for power has resulted in the utilization of many sites where it can be easily developed.

The principal rivers in this area are the St. John, in Maine and New Brunswick; the Penobscot, Kennebec, Androscoggin, Merrimack, and Connecticut, in the New England States; and the Hudson, Delaware, Susquehanna, and Potomac, in the Middle Atlantic States. In New Brunswick, Nova Scotia, and Prince Edward Island the potential power is estimated at 400,000 horsepower, of which 54,000 horsepower, or 13 per cent, has been developed. The largest plant, one having a capacity of 4,000 horsepower, is on Aroostook River. Most of the other plants develop 1,000 horsepower or less. The Province of Nova Scotia is constructing a 12,000-horsepower plant, which when completed will supply power to the city of Halifax. The largest potential power site in this area in Canada is at Grand Falls, on St. John River, where it is proposed to develop 80,000 horsepower. At another site on this river 30,000 horsepower may be developed.

In New England water power has been extensively used since colonial days, and the installed capacity is greater than the estimated potential power at low water. The power can be greatly increased by storage, however, and some sites that have not yet been utilized because of their unfavorable location or because of the high cost of developing them may become available when the demand for power increases sufficiently. The total potential power 95 per cent of the time on eight of the principal rivers in Maine is estimated at 370,000 horsepower, which might be increased by storage to 550,000 horsepower. The power available on these streams 60 per cent of the time at existing plants is 390,000 horsepower, or more than the total potential power 95 per cent of the time.

Three water-power plants on West Branch of Penobscot River, in Maine, have a total capacity of 50,000 horsepower, which is used in pulp and paper mills. The plants installed in the Androscoggin River basin, in Maine, have a capacity of 121,000 horsepower, of which 51,000 horsepower is developed at Rumford Falls and 22,000 horsepower at Lewiston. On Androscoggin River, in New Hampshire, the developed water power available 60 per cent of the time amounts to 47,000 horsepower. Most of this power is developed at plants near Berlin. On Merrimack River in New Hampshire 22,000 horsepower is developed at Manchester for use in cotton mills. On Merrimack River in Massachusetts 26,000 horsepower is developed at Lawrence and 24,000 horsepower at Lowell, mostly in comparatively small plants, and the power is used for manufacturing. Four plants on Deerfield River have an installed capacity of 58,000 horsepower, and 66,000 horsepower is developed on Connecticut River at Turners Falls, near Montague City. On Connecticut River at Holyoke a large number of small plants supply power for manufacturing, their total capacity amounting to 48,000 horsepower. On Connecticut River in New Hampshire, near Vernon, Vt., there is a public-utility plant having a capacity of 30,000 horsepower. In Connecticut there is a plant of 15,000 horsepower on Housatonic River at Falls Village. Other power streams in New England are Presumpscot River, in Maine; Pemigewasset and Winnepesaukee rivers, in New Hampshire; Winooski River, in Vermont; Chicopee River, in Massachusetts; and Shetucket River, in Connecticut. The principal users of power in New England, besides public utilities, are pulp, paper, cotton, and woolen mills.

In the Atlantic drainage area of the Middle Atlantic States the principal power plants are on Hudson, Delaware, and Susquehanna rivers. There are large unutilized sites on Potomac River just above Washington, D. C., and on Susquehanna River near Conowingo, Md. The rainfall in most parts of this region is 40 to 50 inches a year. Parallel to the coast, from 25 to 50 miles inland, in the zone where the Coastal Plain borders the Piedmont Plateau, there is what is called the "fall line," where there are moderate falls on all the rivers that enter the Atlantic south of New York. This fall line also extends into the drainage area of the Gulf of Mexico, but it is there farther from the coast and not so pronounced. The fall line touches the heads of tidal estuaries as far south as James River, and in this stretch the falls occur nearly at tide level.

In the Middle Atlantic States there are many large manufacturing and public-utility plants, and much of the potential power at low water has been developed. This power may be greatly increased, however, by constructing reservoirs for storing flood waters, although the conditions for storage are not so good here as in New England. The principal plants installed develop 38,000 horsepower on Hudson River at Spier Falls, N. Y.; 30,000 horsepower on Mohawk River at Cohoes, N. Y.; 28,000 horsepower on West Canada Creek, a tributary of Mohawk River, at Trenton Falls, N. Y.; 118,000 horsepower on Susquehanna River at McCalls Ferry, near Holtwood, Pa.; and 20,000 horsepower on Susquehanna River at Yorkhaven, Pa.; and there are many smaller plants in New York and Pennsylvania. The plants specifically mentioned are all public-utility plants, but they supply power also to manufacturing industries. Most of the power developed at McCalls Ferry, Pa., is transmitted to Baltimore, Md. On Hudson River near Glens Falls, N. Y., more than 40,000 horsepower is developed at four plants for use in the manufacture of paper, and a total of about 200,000 horsepower is devoted to this use in the State, but not all of it is in this drainage area. There are fairly large plants on Lehigh and Schuylkill rivers in Pennsylvania and on Shenandoah River in Virginia.

2. *South Atlantic and eastern Gulf of Mexico.*—The south Atlantic and eastern Gulf area includes the basins of all streams that flow into the Atlantic Ocean or the Gulf of Mexico between the middle Atlantic area and Mississippi River. The principal rivers are the James, in Virginia; the Roanoke, in Virginia and North Carolina; the Cape Fear, Peedee, and Santee, in North Carolina and South Carolina; the Savannah, between South Carolina and Georgia; the Altamaha, in Georgia; the Chattahoochee, between Georgia and Alabama; the Alabama and Tombigbee, in Alabama; and the Pearl, in Mississippi. In this area the fall line occurs at altitudes of 100 to 200 feet above sea level.

The annual rainfall in this area is 50 to 60 inches along the coast, 40 to 50 inches between the coast and the mountains, and 60 or in places even 70 inches in the mountains and in a narrow strip that extends along the Gulf of Mexico from Tallahassee, Fla., to the mouth of the Mississippi. This heavy precipitation, combined with a fall of more than 1,000 feet between the mountains and the ocean, produces many potential power sites, some of the largest of which have been utilized. The potential power on James River, in Virginia, has been developed at many places down as far as Richmond, where 16,000 horsepower is utilized. There is a plant of 3,350 horsepower on Roanoke River at Roanoke, Va.; two plants having a total capacity of 13,000 horsepower on Dan River, a tributary of the Roanoke; and several plants, the largest of which has a capacity of 4,500 horsepower, on Rappahannock River. Most of these plants supply public utilities, but the power from Dan River is used in cotton mills.

In North Carolina there are plants at Badin (81,000 horsepower) and Blewitt (44,000 horsepower), on Yadkin River, and at Bridgewater (36,000 horsepower) and Lookout Shoals (30,000 horsepower), on Catawba River, and other large plants on Cape Fear and Neuse rivers. The plant at Badin is used in the production of aluminum, and the others in North Carolina and South Carolina furnish power to cotton mills and public utilities.

In South Carolina, on Catawba River, there are plants at Fishing Creek, Great Falls, and Rock Creek that have a total capacity of 130,000 horsepower. On Wateree River (the continuation of the Catawba below the mouth of Wateree Creek) there is the largest water-power plant in South Carolina, one having a rated capacity of 90,000 horsepower. Wateree River is in turn a tributary of the Santee. On Broad River there is a plant at Ninety Nine Island which has a capacity of 31,000 horsepower and two others farther down which have a total capacity of 26,000 horsepower. Other power streams in this area are Tugaloo River, a tributary of the Savannah, and Saluda River, which unites with the Broad to form the Congaree, a tributary of the Santee.

In Georgia, at Tallulah Falls, on Tallulah River, a headwater tributary of the Savannah, a plant of 90,000 horsepower has been built. On Savannah River near Augusta there is a plant of about 18,000 horsepower. At Lloyd Shoals, on the Ocmulgee, a tributary of the Altamaha, there is a plant of 25,000 horsepower, and at Goat Rock, on the Chattahoochee, there is one of 19,000 horsepower. There are other smaller plants on Oconee, Chestatee, and Towaliga rivers and Muckalee Creek. Among the proposed plants in the Savannah River basin are one of 75,000 horsepower on Tugaloo River and one of 55,000 horsepower on the Savannah at Calhoun Falls.

In Florida is there a plant of 5,600 horsepower on Withlacoochee River at Camp Station and a smaller plant on Hillsboro River.

In Alabama there is a 100,000-horsepower plant on Coosa River at Lock 12, and another plant of about the same capacity is to be constructed on this river near Gadsden. There are other plants which have capacities of 5,000 horsepower or less on Tallapoosa and Chattahoochee rivers.

In general the south Atlantic area is served by twelve large power companies that have plants in this and adjacent drainage areas. The systems are interconnected and have an installed capacity of more than 1,200,000 horsepower—800,000 hydroelectric and 400,000 steam. The power load is 8.2 per cent residential, 7.6 per cent railway, and 84.2 per cent industrial, mainly in cotton mills, although mines, iron and steel mills, and miscellaneous manufacturing plants also use considerable power. The minimum potential water power of the drainage area is about 2,000,000 horsepower, the maximum is twice as much, and the developed water power is nearly 1,500,000 horsepower.

3. *Ohio River.*—The Ohio River area includes the entire drainage basin of Ohio River. On the headwaters of the Ohio the annual rainfall is 50 to 60 inches, and on the lower courses it is 40 to 50 inches. A small area along the Cumberland Mountains in eastern Tennessee has a mean rainfall of 60 to 70 inches. The total fall in the tributary streams is somewhat less than that in corresponding streams on the Atlantic side of the Appalachian Highlands, and both the potential and the developed power, although considerable, are less. The country is mainly agricultural, but there are manufacturing cities along the Ohio and many large towns and cities within the area, so that a market is available for cheap power.

The Ohio is formed by the junction of the Allegheny and the Monongahela, which drain mountainous regions of Pennsylvania and West Virginia. Below their junction at Pittsburgh, Pa., the main tributaries are the Kanawha, Big Sandy, Kentucky, Cumberland, and Tennessee from the south and the Beaver, Muskingum, Scioto, Miami, and Wabash from the north. Kanawha and Tennessee rivers combine a moderate amount of fall with a large and well-sustained flow, so that most of the potential power sites in the basin are on these rivers and their tributaries. The streams entering from the north rise in the low divide between Ohio River and the Great Lakes, and although their mean annual run-off is high they have flat slopes and are of relatively little value for power.

On Allegheny and Monongahela rivers a number of small plants, each having a capacity of less than 1,000 horsepower, have been constructed. On New River, a tributary of the Kanawha in Virginia, there are two plants having a combined capacity of 35,000 horsepower. On Kanawha River there are plants at Glen Ferris and Kanawha Falls, in West Virginia, which have a combined capacity of 12,000 horsepower and supply power for a carbide company. In Kentucky the power plants are few and small. At Rock Island, 75 miles southeast of Nashville, Tenn., on Caney Fork, a tributary of Cumberland River, there is a plant of 12,000 horsepower, and on the headwaters of the Cumberland in Kentucky there are a few potential power sites.

Tennessee River and its tributaries form the greatest sources of power in the basin of Ohio River. The headwaters of the Tennessee are in Virginia, North Carolina, Georgia, and eastern Tennessee, and from eastern Tennessee the river flows southwestward, making a loop through northern Alabama, and then turns northward to flow across Tennessee and Kentucky to the Ohio. Practically all the potential power sites in Tennessee are in this drainage basin. The largest power plants are at Parksville and Caney Creek, on Ocoee River, and at Hales Bar, on Tennessee River below Chattanooga. The plants on Ocoee River have a capacity of 45,000 horsepower, and the one at Hales Bar has a capacity of 54,000 horsepower. At Muscle Shoals, on Tennessee River, in Alabama, the United States Government started to construct a power plant designed to have an initial capacity of 120,000 horsepower. The continuous output to be made available here is about 72,000 horsepower, and except in very dry years it will amount to 100,000 horsepower. Work on this plant was started during the war to develop power for producing nitrogen from the air. A series of plants to be built on Little Tennessee River by the Aluminum Company of America will have an aggregate capacity of 400,000 horsepower and will utilize a large part of the potential power of that stream. Work has been begun on two of these plants, one of which will have an ultimate capacity of 96,000 horsepower and the other probably nearly as much. At 22 undeveloped power sites on Tennessee River and its tributaries in Tennessee the estimated potential power is more than 700,000 horsepower without storage and nearly 900,000 horsepower with storage. This does not include the 400,000 horsepower to be developed on Little Tennessee River.

Although there is little water power in the drainage basin of Ohio River except that on Tennessee River there is a large market for power in that basin, so that most of the potential sites, even those that are small, will doubtless utimately be utilized. The potential power of this basin is about 1,500,000 horsepower at low water, of which probably not more than 400,000 horsepower has been developed. A large part of the power developed is employed for municipal uses, but these uses are not increasing rapidly, so that practically all the new power developed is employed for industrial use, largely for making cotton goods and aluminum.

4. *St. Lawrence River*.—The St. Lawrence area includes the drainage basin of the Great Lakes and St. Lawrence River to its mouth at Pointe des Monts. Although the average elevation of the basin is not great the regulated flow and concentrated falls at Niagara and at points on the St. Lawrence furnish ideal conditions for the development of water power, and the cities of Canada and the United States furnish a market for the power. The plants near Niagara Falls together form the largest water-power development in the world. The rainfall in the basin ranges from 30 to 40 inches a year over most of the area, but at the head of Lake Superior the mean rainfall is between 20 and 30 inches. The precipitation is fairly well distributed through the year, but during the winter its accumulation on the ground in the form of snow results in a low stage of the rivers. Besides the Great Lakes and their connecting rivers and the St. Lawrence the principal sources of water power are Muskegon and Grand rivers, in Michigan, and Ottawa, St. Maurice, Saguenay, Outardes, and Manicuagan rivers, all of which enter the St. Lawrence in Quebec.

Water-power sites are fairly well distributed through this area, and the Provinces of Quebec and Ontario are especially favored, but in the region around Lake Erie there is relatively little potential power. Of the tributaries of Lake Superior, St. Louis River furnishes 57,000 horsepower at a plant near Duluth, Minn., and Kaministiquia River furnishes 34,000 horsepower at a plant near Fort William, Ontario. Many smaller plants are scattered through Minnesota, Wisconsin, and Michigan, but little additional power has been developed in this part of Ontario. Around Lake Michigan, in Wisconsin and Michigan, there are many small power plants, the largest of them on Menominee and St. Joseph rivers, in Michigan. On St. Marys River, which connects Lakes Superior and Huron, 34,000 horsepower is developed in the United States and 17,000 horsepower in Canada. The total potential power on St. Marys River is about 90,000 horsepower. The tributaries of Lake Huron in Ontario can furnish 160,000 horsepower, of which 56,000 horsepower is developed. The largest plants are two on French River, which have a combined capacity of 22,500 horsepower, used in mining and smelting and in making paper. In Michigan, on Au Sable River, there are plants that supply 64,000 horsepower for municipal uses, and there are many smaller plants on tributaries of Lake Huron.

At Niagara Falls, on Niagara River, which connects Lakes Erie and Ontario, there is the finest power site in North America. Here are combined a high head that is easily developed, a large uniform flow, and a market for the power. The unique scenic beauty of the Falls has prevented the complete utilization of the site, but the plants in operation have a capacity of 870,000 horsepower, of which 385,500 horsepower is on the United States side. The power actually developed amounts to about 700,000 horsepower. To this total should be added 12,000 horsepower developed on the Welland Canal and 42,000 horsepower developed at Decew Falls, 2 miles from St. Catharines, Ont., from water diverted from the Welland Canal over the Niagara escarpment. A license has been granted by the Federal Power Commission that will increase to 500,000 horsepower the installed capacity on the United States side of Niagara River. The Hydroelectric Power Commission of Ontario is now constructing an additional plant at Niagara Falls which will have an initial capacity of 300,000 horsepower and an ultimate capacity of 540,000 horsepower. The water is to be carried 12 miles through a canal and used with an effective head of 305 feet. A large part of the power at Niagara Falls is obtained from plants operating at heads of less than 200 feet, though the difference in level between Lakes Erie and Ontario is 327 feet. If the total flow of the river were used the Falls would furnish, under favorable conditions, about 6,000,000 horsepower. A plan whereby 60 per cent of the total flow of the river can be diverted for developing power is being considered.

Of the northern tributaries of Lake Ontario Trent River, the most valuable power stream, furnishes 45,000 horsepower out of 75,000 that is capable of development. Of the southern tributaries Genesee River furnishes 51,000 horsepower near Rochester, N. Y. The total capacity of the plants now in operation on Black River and tributaries is 104,000 horsepower and on Oswegatchie River 25,000 horsepower.

The potential power of St. Lawrence River at normal low water between the outlet of Lake Ontario and Lake St. Francis, at the eastern boundary of the Province of Ontario, has been estimated by the Dominion Water Power Branch at 1,000,000 horsepower, of which half would belong to the United States. Near Massena, N. Y., above Lake St. Francis, a plant having a capacity of 76,000 horsepower is used in the production of aluminum. Between Lake St. Francis and tidewater at Montreal there is a fall of 129 feet, which is concentrated in two stretches of 14 and 8 miles. The first stretch includes Coteau, Cedar, and Cascade rapids, in which the total fall is 84 feet, and the second includes Lachine Rapids, in which the fall is 45 feet. The potential power at low water in these two stretches of the river is about 2,000,000 horsepower, all in Canada. Of this amount 192,000 horsepower has already been developed by four plants, at Cedar Rapids, St. Timothée, Soulanges canal, and Lachine Rapids. Most of the power from these plants is used in Montreal and adjoining towns for lighting, electric railways, and general manufacturing.

Of the tributaries of the St. Lawrence from the north, Ottawa River has 690,000 potential horsepower, of which 71,000 horsepower has been developed. St. Maurice River has 650,000 potential horsepower. One plant at Shawenegan Falls has a capacity of 148,500 horsepower, and another, which is 12 miles above, at Grand Mère Falls, has a capacity of 120,000 horsepower. Transmission lines carry this power to Montreal, Quebec, and more than 40 other towns and cities. Several large industrial plants that are engaged in the manufacture of paper, aluminum, and various electrochemical products are in operation at Shawenegan Falls. Saguenay River, another tributary of the St. Lawrence, could supply 300,000 horsepower, and with a small amount of storage in Lake St. John this amount could be doubled. Between the Saguenay and the Atlantic Ocean there are nine large northern tributaries of the St. Lawrence that could furnish a total of more than 1,000,000 horsepower. The tributaries from the south could furnish much less power.

The developed power of the St. Lawrence drainage area aggregates more than 2,500,000 horsepower, and the potential power is estimated at 10,000,000 horsepower on the assumption that 60 per cent of the available flow at Niagara Falls may be diverted for this use. Most of the power developed in this area is applied to municipal uses. Buffalo, Toronto, Hamilton, and Niagara Falls are largely supplied with power from plants near Niagara Falls, and Montreal and Quebec are similarly supplied from plants on St. Lawrence and St. Maurice rivers. Power is used also in electrochemical industries, pulp and paper mills, mining, and general industrial plants.

5. *Upper Mississippi River*.—The upper Mississippi area includes the part of the drainage basin of Mississippi River that lies north of the Ohio on the east and the Missouri on the west. The rainfall in this area averages 30 to 40 inches a year except in Minnesota, where it is about 10 inches less, but as the fall in the river is slight the potential power at most of the sites is small. The principal tributaries of the Mississippi in this part of its course are Wisconsin and Illinois rivers from the east and Minnesota and Des Moines rivers from the west.

In Minnesota the plants on Mississippi River near Minneapolis and St. Paul have a total capacity of 60,000 horsepower, most of which is used in flour mills. There are a large number of smaller plants on the Mississippi and its tributaries.

In Wisconsin the plants on Wisconsin River have a total capacity of 90,000 horsepower. The largest plant, one at Prairie du Sac, develops 25,000 horsepower. There is a plant of 45,000 horsepower on Chippewa River near Chippewa Falls and a large number of small plants on Fox and Apple rivers. The largest users of hydroelectric power in Wisconsin except the public utilities are the paper and lumber industries.

In Illinois 45,000 horsepower is developed at Lockport, on the Sanitary Canal, which diverts water from Lake Michigan. A plant of 5,600 horsepower on Illinois River at Marseilles also uses the water of the Sanitary Canal.

A large plant on the Mississippi at Keokuk, Iowa, has a rated capacity of 170,000 horsepower, and most of the power is transmitted to St. Louis.

The potential power of this area is estimated at about 1,000,000 horsepower, and 600,000 horsepower has been developed. The power is used mainly for municipal purposes, but mills manufacturing paper, flour, wood products, and other articles also use large amounts.

6. *Missouri River*.—The Missouri River area includes the entire drainage basin of Missouri River. The annual rainfall is 10 to 30 inches in most of this area but increases to 40 inches in a few isolated mountain regions and along the lower course of the river, in Missouri, Kansas, and Nebraska. The streams have considerable fall at their headwaters, but farther down they flow more gently, for the country slopes gradually eastward from the foot of the mountains to the Mississippi. Because of this gradual slope and the low rainfall the potential power in the lower part of this area is small. The Missouri is navigable from a point a few miles below Great Falls, Mont., to its mouth. Jefferson, Madison, and Gallatin rivers unite near Three Forks, Mont., to form the main stream. The other principal tributaries are Yellowstone, Platte, and Kansas rivers, all coming from the south and west.

Six plants having a combined capacity of 220,000 horsepower have been constructed at Great Falls, Mont., and in the stretch of about 150 miles between Great Falls and Canyon Ferry, near Helena. In this stretch there remains about 90,000 potential horsepower. The power is sold to mines and smelters at Butte, Anaconda, and Great Falls and is also used for traction by the Chicago, Milwaukee & St. Paul Railway on 440 miles of its line from Harlowton, Mont., to Avery, Idaho. There are smaller plants on Madison, Big Hole, and Yellowstone rivers. A plant of 165,000 horsepower on Big Horn River near Hardin, Mont., is proposed. The total potential power in this basin in Montana is about 700,000 horsepower.

The power plants in Wyoming are few and small. Yellowstone River in Yellowstone Park has a fall of 2,300 feet between Yellowstone Lake and the northern boundary of the park, a distance of about 50 miles, and two falls, one of 109 and the other of 308 feet, occur in this stretch. If 70 per cent of the fall could be used and the flow equalized during dry years by using Yellowstone Lake for storage about 450,000 horsepower would be available. Without storage only about one-third of this amount could be supplied continuously. Big Horn River, a tributary of the Yellowstone, furnishes power for a plant having a capacity of 1,500 horsepower. At a dam of the United States Reclamation Service on Shoshone River, a tributary of the Big Horn, about 25,000 horsepower could be developed and a plant with an initial capacity of 2,700 horsepower is now being installed.

In Colorado there is a plant of 21,000 horsepower on Middle Boulder Creek near Boulder. This creek is a tributary of South Platte River, on whose headwater tributaries in Colorado are some small plants and con siderable potential power.

There is also some undeveloped power on the Missouri in South Dakota. The power developed in this drainage basin is utilized principally for mining, smelting, railway, and municipal uses.

7. *Lower Mississippi River*.—The lower Mississippi area includes the parts of the Mississippi drainage basin that lie south of the Missouri and of the Ohio. The annual rainfall is 10 to 20 inches along the western edge of the area except at a few places in the mountains, but it gradually increases toward the east and south until it reaches 40 to 60 inches. The slope of the surface, however, is slight and uniform, except in the mountains in the extreme western part of the area, and the potential power is small. The principal tributaries of the Mississippi in this stretch, Arkansas and Red rivers, enter from the west. There are only a few water power plants in this area, all small.

8. *Western Gulf of Mexico*. — The western Gulf area includes the drainage basins of all streams that flow into the Gulf of Mexico between Mississippi River and Cape Catoche in Yucatan. In the northern part of the area the rainfall is scant, except in Louisiana and eastern Texas, and the potential water power is relatively

small. In the southern part of the area, in a tract in Mexico that stands 5,000 feet or more above sea level, the rainfall is greater and considerable water power may be developed. The principal river of the area is the Rio Grande, which has little value for power because of the low rainfall in its basin and the extensive use of its water for irrigation.

In Mexico a power plant on Conchos River near Santa Rosalia has a capacity of 37,000 horsepower. A plant on Necaxa and Tenango rivers, from which power is transmitted 160 miles to Mexico City, operates under a static head of 1,452 feet and has a capacity of 40,000 horsepower. The total capacity of the plants that supply Mexico City is about 100,000 horsepower. A 17,000-horsepower plant on Rio Blanco near Orizaba and other plants in the vicinity that develop a total of 10,000 horsepower supply the cities of Puebla and Vera Cruz.

The undeveloped power in Mexico is considerable. On the Necaxa, for instance, there is about 50,000 additional potential horsepower, which may be made available under heads of 700 and 2,100 feet, and on Rio Blanco there is 200,000 horsepower. Mines and municipal uses offer a market for a large amount of power in this country.

9. *Gulf of California.*—The Gulf of California area includes the Colorado River drainage basin in the United States and extends to Capes San Lucas and Corrientes, in Mexico. The rainfall on some of the upper headwater tributaries of the Colorado reaches 30 to 40 inches a year, but over most of this area, including the portion in Mexico, the rainfall is much less. The rivers have a large fall, however, and there is much potential power on the Colorado and its principal tributaries.

Colorado River is formed by the union of Grand and Green rivers in southeastern Utah.[1] Its other principal tributaries are San Juan, Little Colorado, and Gila rivers, all entering from the east. Most of the potential power sites in the basin require high, expensive dams, yet they may prove to be economically feasible in connection with flood control and irrigation.

The potential power at eighteen of the largest sites in the Colorado River basin has been estimated at 2,000,000 to 6,000,000 horsepower, the amount depending on the method of development. The developed power in 1915 amounted to 78,000 horsepower, of which 35,000 horsepower was on Grand River and its tributaries and 26,000 horsepower on the Salt River irrigation system of the United States Reclamation Service.

In Mexico this area includes Yaqui, Mayo, Fuerte, and Santiago rivers. Santiago River, the largest of these streams, rises in the mountains and flows through Lake Chapala, which affords a means of cheap storage. Below the lake are the Juanacatlan Falls, near Guadalajara. Only a small amount of power has been developed at these falls for use in Guadalajara, and no estimate of their potential power is available, but it must be considerable. The aggregate potential power of Mayo, Humayo, and Santiago rivers has been estimated at 225,000 horsepower. The Guanajuato Power & Electric Co. has developed 26,000 horsepower in the State of Michoacán, south of the city of Guadalajara.

Probably less than 200,000 horsepower is developed in this drainage area, including territory both in the United States and in Mexico.

10. *Great Basin.*—The Great Basin area includes the inland basin between the Rocky Mountains and the Sierra Nevada. On most of this area the annual rainfall is less than 10 inches, although on some scattered tracts it is greater. Practically all the power sites are in the Sierra Nevada, on the western boundary of the basin, and in the Wasatch Mountains near Great Salt Lake, on the eastern boundary. More than 100,000 horsepower has been developed in this basin in Utah, most of it in small plants. The largest plants are three of 10,000, 10,000, and 12,000 horsepower on Ogden, Bear, and Provo rivers. There are three plants on Bear River in Idaho which, with the one on that river in Utah, have a combined capacity of 119,000 horsepower, and provision for 15,000 horsepower additional capacity has been made at one of these plants. There is also an application on file with the Federal Power Commission for a permit to develop 21,500 horsepower at four sites. In Nevada 12,000 horsepower is developed on Truckee River at four plants, and in California 38,000 horsepower is developed on Bishop Creek, a tributary of Owens River. The total potential power of this basin at low-water stages of the streams without storage would be comparatively small, but if the known storage sites were used the potential power might amount to 500,000 horsepower. The plants now constructed have a capacity of 250,000 horsepower.

11. *Upper south Pacific.* — The upper south Pacific area includes the drainage basins of all streams that flow into the Pacific Ocean between the northern boundary of the Klamath River basin and the south end of Lower California, at Cape San Lucas.

In Lower California the rainfall is scant, the drainage areas are small, and little water power can be made available.

In California there are many large plants, and probably more plants are now being constructed in this State than in any other area of the same size on the continent. The rainfall of California is heavy in the northern part of the State but decreases toward the south. Most of the drainage basins are small, but the mountains are high and the fall is so great that nearly all the plants utilize high head and small flow. The principal rivers are the Klamath and the Eel, on the north coast of California; the Sacramento, which drains the north-central part of the State; and the San Joaquin, which drains the south-central part and unites with the Sacramento a short distance above Suisun Bay. Kings and Kern rivers are physiographically tributary to the San Joaquin, but no water from Kern River has reached the San Joaquin in recent years, as much of the water is used for irrigation and the rest is evaporated from the Tulare Lake depression. Most of the water of Kings River is also lost either by irrigation or in Tulare Lake, but some of it flows to the San Joaquin.

The largest power plants in this area are on Klamath, Feather, Bear, Yuba, Kings, Kern, and San Joaquin rivers. On upper Klamath River and Falls Creek three plants together develop about 20,000 horsepower and much power is undeveloped. Pit River has a fall of 2,000 feet in 30 miles and a normal minimum flow of 2,500 second-feet, and it will yield about 450,000 horsepower at low water. The first plant on this stream, installed with a capacity of 36,000 horsepower, will probably be completed in 1921. On Feather River one company has plants in operation or under construction to supply 145,000 horsepower, and others now planned will develop a total of 700,000 horsepower. The capacity of one of these plants can be increased 115,000 horsepower by enlarging the power house and its equipment. The total potential power of Feather River will be developed by the use of a storage reservoir that has been completed to a capacity of 300,000 acre-feet and will have an ultimate capacity of 1,250,000 acre-feet. Other plants on tributaries of Feather River have an aggregate capacity of 60,000 horsepower. Large plants on other tributaries of Sacramento River include six plants on Cow and Battle creeks (total capacity 54,000 horsepower), two on Butte Creek (29,000 horsepower), and seven on Bear and Yuba rivers (105,000 horsepower).

Six plants which it is planned to build on the North Fork of Kings River and one on Kings River itself will

[1] The name of Grand River, in Colorado and Utah, has recently been changed to Colorado River by act of Congress.

have a combined capacity of 272,000 horsepower. All the preliminary engineering work has been completed and a road has been built, but other construction has not yet been begun. Two of these plants will have heads of 2,500 feet, the highest in the United States. The capacity of the present plants on Kings River and its tributaries amounts to 15,000 horsepower. On Kern River and its tributaries there are now plants that aggregate 45,000 horsepower, a 40,000-horsepower plant is being constructed, and two plants of 40,000 horsepower each are planned.

On the North Fork of San Joaquin River there is a plant that develops 24,000 horsepower, and plans have been made for a series of plants on Middle and South forks, Big Creek, Pitman Creek, Stevenson Creek, and San Joaquin River, which together will have a capacity of 868,000 horsepower. The present installed capacity at two of the proposed sites is 94,000 horsepower, and plants having a capacity of 57,000 horsepower are being constructed. On Stanislaus River, which is tributary to the San Joaquin above Stockton, there are plants that develop 68,000 horsepower, and on Mokelumne River, another tributary of the San Joaquin, one plant develops 29,000 horsepower. From still another tributary, Tuolumne River, water is to be diverted to supply the municipal needs of San Francisco, and the fall available in the aqueduct will generate 157,000 continuous horsepower, with a peak capacity of possibly 200,000 horsepower. Plants already built along the Los Angeles Aqueduct, which carries water diverted from Owens River, in the Great Basin drainage area, have a total capacity of nearly 100,000 horsepower. The total potential power of the sites on the aqueduct and tributary streams is 110,000 continuous horsepower, which by storage, already available, could be used to carry a peak load that would be much greater.

The total developed power in this area in California is more than 800,000 horsepower and at the present rate of increase will soon exceed 1,000,000. The potential power at low water is estimated at a little more than 3,000,000 horsepower, but this amount can probably be doubled by storage. Hydroelectric power in California is used in pumping for irrigation, in iron and cement mills, machine shops, mines, lumber and woodworking establishments, and pulp and paper mills, on docks and wharves, in electrochemical industries, and in public utilities.

12. *Lower north Pacific.* — The lower north Pacific area includes the drainage basins of all streams that flow into the Pacific Ocean between the Klamath River basin and the United States and Canadian boundary. Most of Washington, Oregon, and Idaho, parts of Montana and Wyoming, and the Columbia River drainage basin in British Columbia and Alberta are within the area. A large part of the area receives abundant rainfall, which, combined with a steep, rugged country, makes this area the richest in potential power in North America. The principal river, the Columbia, rises in British Columbia and, flowing south, is joined by Clark Fork from the east and by the Kootenai from the north. Other main tributaries are the Snake from the east, the Deschutes and Willamette from the south, and the Yakima from the north.

In Montana there is a plant of 40,000 horsepower capacity on Clark Fork at Thompson Falls. Flathead River, a tributary of Clark Fork from the north, can produce 300,000 continuous horsepower at six sites below Flathead Lake. The practicable storage in the lake could adapt the flow to any load factor, so that the capacity when plants are installed at these sites may reach 500,000 horsepower. In Washington a 200,000-horsepower plant on Clark Fork is projected.

In Idaho several of the many medium-sized plants are on Snake River, among them the 10,000-horsepower plant of the United States Reclamation Service on the Minidoka irrigation system. The main object of this plant was to supply power for pumping for irrigation, but it also furnishes light and power for domestic use.

In eastern Washington 189,000 horsepower is developed, mainly for electric lighting and street railways, although a large share is taken by cement works, mining, irrigation, and paper mills. The principal plants are near Spokane. In western Washington there are two plants of 29,000 horsepower total capacity on Snoqualmie River, one of 60,000 horsepower on White River, and one of 18,000 horsepower on Salmon River. Tacoma has a plant of 32,000 horsepower on Nisqually River, and Seattle has one of 21,000 horsepower on Cedar River. The Chicago, Milwaukee & St. Paul Railway is electrified for 210 miles from Othello to Tacoma and Seattle, the power being obtained from Snoqualmie and Spokane rivers.

In Oregon a 25,000-horsepower plant on Willamette River at Oregon City supplies power to a large paper company, and a 15,000-horsepower plant supplies power to a public-utility company. On Clackamas River two plants have a combined capacity of 46,000 horsepower. Sandy and Little Sandy rivers furnish 19,000 horsepower, mostly for use in Portland.

In British Columbia two plants on Kootenai River at Bonnington Falls have a total capacity of 42,000 horsepower, and there are several smaller plants.

Of the undeveloped sites in the lower north Pacific area the one at which the most power can be developed is The Dalles, on Columbia River in Oregon-Washington, where about 300,000 continuous horsepower can be developed and an equal additional amount can be made available for eight months of the year. The potential power of Deschutes River has been estimated at 457,000 horsepower, and its development, probably in 14 plants, is economically feasible whenever a market is available. On Snake River between Huntington, Oreg., and Lewiston, Idaho, there are 17 possible sites where 919,000 horsepower could be developed 90 per cent of the time from the present flow, or 800,000 horsepower could be developed after the river has been regulated for irrigation. By diverting the flow of Salmon River through a tunnel into the channel of the Snake and erecting a dam 540 feet high on Snake River a total of 345,000 horsepower could be otained 90 per cent of the time by using the present flow, or 298,000 horsepower after the river has been regulated for irrigation. On Salmon River above the tunnel site and below Stanley, Idaho, 250,000 horsepower can be developed at 26 sites by using the flow available 90 per cent of the time. In British Columbia there is a large amount of undeveloped power on Clark Fork in its short course in Canada, and on Kootenai River between Kootenai Lake and Columbia River.

The power developed in this area is used mainly by public utilities, but it is also used largely in connection with mines, smelters, irrigation, railroads, cement and paper mills, iron and steel works, shipyards, machine shops, and warehouses. The total developed power in this area is 750,000 horsepower, and the potential power is about 11,000,000 horsepower.

13. *Middle north Pacific.* — The middle north Pacific area includes the drainage basins of all streams that flow into the Pacific Ocean from the United States-Canada boundary to and including Yakutat Bay, Alaska. Most of it is in British Columbia, but it includes a narrow strip of southeastern Alaska. The rainfall is heavy, the country is generally high and mountainous, and water power is both plentiful and well distributed. The principal river is the Fraser, which drains an area paralleling the coast from Alaska to the Washington boundary. Its largest tributary is Thompson River, which enters from the east.

The developed water powers in this area are mainly in its southwestern part, near Vancouver and Victoria. On Burrard Inlet, 16 miles from Vancouver, at Lakes Coquitlam and Buntzen, 84,000 horsepower is developed. The drainage area that supplies water to this plant contains only 105 square miles, but the average annual rainfall for 11 years has been 153 inches. On Stave River 6 miles north of its junction with the Fraser there is a plant of 40,000 horsepower from which power is transmitted 36 miles to Vancouver, and at the mouth of Jordan River, on Vancouver Island, 36 miles west of Victoria, there is a plant of 25,000 horsepower.

The total developed power in this area is a little more than 250,000 horsepower. The undeveloped power at known sites is between 2,000,000 and 3,000,000 horsepower, and probably many large sites are still unknown.

14. *Upper north Pacific.* — The upper north Pacific area includes the drainage basins of all streams that flow into the Pacific Ocean between Yakutat Bay and Cape Prince of Wales. It comprises the southern half of Alaska and most of Yukon Territory in Canada. The area in Canada is drained by the headwater tributaries of Yukon River, which flows southwestward across central Alaska. The largest water-power plants are one of 15,000 horsepower near Port Snettisham, 35 miles southeast of Juneau, which supplies that city, and one of 10,000 horsepower on North Fork of Klondike River 26 miles from Dawson, Yukon Territory, which furnishes power to Dawson for lighting the city and operating the mines. The total developed power in this drainage area is about 65,000 horsepower, which is used mostly in mining. The undeveloped power is unknown but may amount to 2,500,000 horsepower.

15. *Arctic Ocean.* — The area on the Arctic Ocean includes the northern parts of Alaska, Canada, and Greenland, the limiting points being Capes Prince of Wales and Wilson, Dorchester and Dyer, and Holstenborg and Jensen. It includes those parts of Alaska and Yukon Territory that lie north of the basin of Yukon River, most of the Northwest Territories in Canada, and about three-fourths of Greenland. The largest river is the Mackenzie, whose principal tributaries are Athabaska, Slave, and Peace rivers. There is a small power site on Athabaska River within transmission distance of Edmonton, but the power available, about 9,000 horsepower, does not now justify the cost of development. Little is known of the undeveloped power resources of this area, but there seem to be no great concentrations of potential power.

16. *Hudson Bay.*—The area here considered includes the drainage basins of all streams tributary to Hudson Bay, to Fox Channel south of Capes Wilson and Dorchester, and to Hudson Strait west of Cape Wiggs and Olga River. It lies mostly in Canada, although Red River is largely in Minnesota and North Dakota and St. Mary River rises and flows for a short distance in Montana before crossing into Canada, where it joins Belly River, a tributary of the South Saskatchewan. The principal rivers, the Saskatchewan and Winnipeg, drain into Lake Winnipeg and thence through Nelson River to Hudson Bay. Many fairly large rivers also flow into Hudson Bay from northern Ontario and Quebec.

Bow River, a tributary of the South Saskatchewan, is one of the principal power streams in this area. Three plants on Bow River together develop 32,000 horsepower, which is used in Calgary for municipal purposes and manufacturing. A total of 48,000 continuous horsepower may be developed on this river with storage but only 20,000 horsepower without storage. On Winnipeg River 250,000 continuous horsepower, including that of the present plants, may be developed without storage, and 420,000 horsepower can be made available by storage. Much greater peak loads could be carried by increasing the capacity of the plants. Two plants on this river, which have a combined capacity of 82,000 horsepower, supply the city of Winnipeg. Another plant having an initial capacity of 84,000 horsepower and an ultimate capacity of 169,000 horsepower is being constructed. Nelson River, the outlet of Lake Winnipeg, has an ordinary minimum flow of 50,000 second-feet and a fall of 700 feet in 430 miles. This minimum flow, without any regulation of Winnipeg River, would develop 2,500,000 continuous horsepower at 19 power sites. On Abitibi River at Iroquois Falls, Ontario, there is a 53,000-horsepower plant, the power from which is used in the manufacture of paper.

In the part of Ontario that lies in this area 22,000 horsepower has been developed and about 250,000 horsepower is undeveloped. In Quebec there are no water-power plants in the Hudson Bay area, but there is considerable undeveloped power. On Rainy River, a tributary of Lake of the Woods that forms part of the boundary between Minnesota and Ontario, there are two plants—one in Ontario and the other in Minnesota—which have a combined capacity of 24,000 horsepower. About 5,000 horsepower is developed in the Red River drainage basin in the United States.

The total developed power in this area is about 225,000 horsepower, and the potential power is estimated at 5,500,000 horsepower. The developed power is used for municipal purposes, in pulp and paper mills, and in milling and general manufacturing.

17. *North Atlantic.*—The north Atlantic area includes the drainage basins of all streams that flow into the Atlantic Ocean east of Hudson Bay and north of St. Lawrence River and Cabot Strait. It includes the part of the Province of Quebec that drains into the Atlantic Ocean and the Gulf of St. Lawrence, all of Labrador and Newfoundland, and the southern part of Greenland. The area in Canada and Newfoundland is low, but Greenland is a high plateau. The precipitation, however, is small except in southern Greenland.

Little is known of the potential powers of Greenland. A 75,000-horsepower plant is said to be feasible on Bay d'Est River, in Newfoundland. Hamilton River below Lake Lobstick, in eastern Quebec, has a fall of 760 feet in 12 miles, of which 302 feet is concentrated at Grand Falls. The only large power plants in this area are in Newfoundland, where 60,000 horsepower is developed and used mainly in pulp and paper mills.

18. *Lower south Pacific.*—The lower south Pacific area is a narrow belt of high land between Cape Corrientes and the eastern boundary of Panama, in southern Mexico and Central America. The rainfall is plentiful, and the rivers, though small, have steep gradients and afford many potential power sites. In Mexico a number of small plants supply power, mainly for municipal use.

Guatemala has only eight water-power plants, most of them in this area. The largest plant has a capacity of 2,400 horsepower and supplies the city of Guatemala.

In Salvador only 2,700 horsepower is developed, and it is used for municipal purposes in San Miguel, Chalchuapa, Ahuachapam, Quezaltepeque, and the Santa Ana Department. The undeveloped power in Salvador is estimated at 200,000 horsepower.

Nicaragua has considerable potential power, but most of it is so situated that it can not easily be made available, and very little has been developed.

In Costa Rica there are a number of power plants, the largest of which are on tributaries of Virilla River. The total developed power for the country is estimated at 15,000 horsepower, and it is all in this area.

In the part of Honduras that lies in this area there is a small plant on Choluteca River at Tegucigalpa.

The rivers in Panama are short, but because of the heavy rainfall their discharge is relatively large, and if reservoirs were constructed to control the floods a large amount of power could be developed.

Although power sites are plentiful and well distributed in most of this area little power has been developed, because there is little manufacturing and no demand for power except for municipal use in the larger cities.

19. *Caribbean Sea and West Indies.*—The area whose waters are tributary to the Caribbean Sea includes a part of Yucatan and the northern and eastern slopes of Central America. With this area are grouped all the West Indies. On the mainland the rainfall is plentiful and the rivers have considerable fall, so that much power

could be developed. On the islands most of the rivers do not attain sufficient size to create any large amount of potential power. In the part of Hunduras that lies in this area there is a plant of 300 horsepower on Chamelicón River near San Pedro, and the Peña Blanca mines have two plants on San Juancito River with a total capacity of 1,800 horsepower. In Nicaragua there is a plant on the Rio Pis Pis 150 miles inland from the Atlantic coast, but the capacity is not known. Power is transmitted from this plant to the Eden mine. Lakes Nicaragua and Managua, in Nicaragua, are the largest fresh-water lakes between the Great Lakes and Lake Titicaca. Lake Nicaragua, which is 140 feet above sea level, drains into the Atlantic Ocean through San Juan River, on which there are five rapids that might be utilized for power. In Panama the only developed power is the Gatun plant, on the Panama Canal. This plant has a capacity of about 13,000 horsepower.

Of the West Indies, Cuba contains many streams, but they are short and have little value for power. Cauto River is the largest. The Moa and Guama cascades and Hanabanilla Falls are more than 300 feet high, but the amount of water passing over them is small. A plant of 3,000 horsepower on Matagua River 15 miles from Cienfuegos was reported to be under construction in 1913, but no record of its completion is available. In Haiti a small plant supplies Port au Prince. The island is high and the rainfall is plentiful, but the power resources are scattered among many small sites. In the Dominican Republic no water power has been developed, but it is proposed to build a 4,000-horsepower plant on a tributary of Rio Yaque del Norte 7 miles from Santiago. This river is 240 miles long and is navigable for canoes throughout. Porto Rico has developed 8,150 horsepower out of a total potential power of about 25,000 horsepower. Jamaica has one power plant having a capacity of 1,300 horsepower.

Statistics for North America.—The figures for the water-power resources of the United States in the following table (see also Pl. 8) are based on estimates made by the United States Geological Survey in 1908 for the National Conservation Commission and revised by the Commissioner of Corporations for his report on "Water power developed in the United States," 1912, and by the United States Forest Service in 1916. They include 518,000 horsepower as the share of the United States in the power at Niagara Falls under present treaties.

In comparing the figures in the tables here given with others for the same areas the basis of the estimates should be kept clearly in mind. The head was determined by dividing the river into sections of different lengths, the lengths chosen depending on channel slope, and the fall and flow of each section were determined from the best available source of information. The flatter portions of the river channels, which can never be profitably developed for power, were excluded. The total fall in each section and an assumed efficiency of 75 per cent were then used in calculating the potential horsepower. The use of storage was not considered; the minimum horsepower is that obtainable at minimum flow, and the maximum horsepower is that obtainable with the flow available for 50 per cent of the time. The mean flow for each of the lowest two seven-day periods in each year was determined, and the mean of these two means for the period of record was taken as the minimum flow. The estimates for both the minimum and the maximum horsepower are conservative. In some of the New England States complete development would probably require the installation of plants having a capacity of four times the estimated potential power at low water. If all the water power in the United States were similarly developed the total capacity of the plants would be 112 million horsepower, and if this estimate is correct the water-power resources of the United States are now only about 8 per cent developed.

Water-power resources and installed capacity of water wheels in the United States, by States and by geographic divisions.

State and division.	Total potential water power.				Installed capacity of water wheels.	
	Minimum.		Maximum.			
	Horsepower.	Per cent.	Horsepower.	Per cent.	Horsepower.	Per cent.
New England:						
Maine	443,000	1.59	809,000	1.50	412,000	4.46
New Hampshire	135,000	.48	246,000	.46	217,000	2.35
Vermont	94,000	.33	172,000	.32	223,000	2.41
Massachusetts	118,000	.43	228,000	.42	330,000	3.57
Rhode Island	6,000	.02	13,000	.02	43,000	.46
Connecticut	72,000	.26	137,000	.26	156,000	1.69
Middle Atlantic division:						
New York	1,037,000	3.71	1,698,000	3.15	1,300,000	14.06
New Jersey	44,000	.16	106,000	.20	38,000	.41
Pennsylvania	276,000	.99	684,000	1.27	397,000	4.30
East North Central division:						
Ohio	59,000	.21	178,000	.33	54,000	.58
Indiana	43,000	.16	118,000	.22	29,000	.31
Illinois	192,000	.69	345,000	.64	84,000	.91
Michigan	180,000	.64	293,000	.54	327,000	3.54
Wisconsin	358,000	1.28	670,000	1.24	318,000	3.44
West North Central division:						
Minnesota	232,000	.83	494,000	.92	224,000	2.42
Iowa	160,000	.57	382,000	.71	192,000	2.08
Missouri	72,000	.26	163,000	.30	27,000	.29
North Dakota	88,000	.31	207,000	.38	400	.00
South Dakota	43,000	.16	75,000	.14	18,000	.19
Nebraska	196,000	.70	366,000	.68	18,000	.19
Kansas	111,000	.40	269,000	.50	24,000	.26
South Atlantic division:						
Delaware	5,000	.02	11,000	.02	8,000	.09
Maryland and District of Columbia	48,000	.17	133,000	.25	20,000	.22
Virginia	492,000	1.76	870,000	1.62	157,000	1.70
West Virginia	381,000	1.36	1,051,000	1.95	20,500	.22
North Carolina	578,000	2.07	875,000	1.62	370,000	3.94
South Carolina	460,000	1.64	677,000	1.26	453,000	4.90
Georgia	374,000	1.34	627,000	1.16	342,000	3.70
Florida	8,000	.03	13,000	.02	11,000	.12
East South Central division:						
Kentucky	83,000	.30	197,000	.37	14,000	.15
Tennessee	463,000	1.66	761,000	1.41	222,000	2.40
Alabama	509,000	1.82	943,000	1.74	260,000	2.81
Mississippi	82,000	.11	63,000	.12	8,500	.09
West South Central division:						
Arkansas	22,000	.08	61,000	.11	6,100	.07
Louisiana	1,000	.00	2,000	.00	4,000	.04

Water-power resources and installed capacity of water wheels in the United States, by States and by geographic divisions—Continued.

State and division.	Total potential water power.				Installed capacity of water wheels.	
	Minimum.		Maximum.			
	Horsepower.	Per cent.	Horsepower.	Per cent.	Horsepower.	Per cent.
West South Central division—Continued:						
Oklahoma	75,000	0.27	208,000	0.39	4,600	0.05
Texas	255,000	.91	551,000	1.02	11,000	.12
Mountain division:						
Montana	2,749,000	9.84	4,331,000	8.03	420,000	4.54
Idaho	2,362,000	8.45	5,067,000	9.40	243,000	2.63
Wyoming	773,000	2.76	1,305,000	2.42	6,600	.07
Colorado	842,000	3.01	1,697,000	3.15	133,000	1.54
New Mexico	160,000	.57	439,000	.81	3,000	.03
Arizona	893,000	3.20	1,698,000	3.15	52,000	.56
Utah	743,000	2.66	1,318,000	2.45	122,000	1.32
Nevada	172,000	.62	276,000	.51	27,000	.29
Pacific division:						
Washington	4,932,000	17.65	8,647,000	16.04	487,000	5.27
Oregon	3,148,000	11.27	6,613,000	12.27	295,000	3.19
California	3,424,000	12.25	7,818,000	14.50	1,111,000	12.02
Summary:						
New England	868,000	3.11	1,605,000	2.98	1,381,000	14.94
Middle Atlantic division	1,357,000	4.86	2,488,000	4.62	1,735,000	18.77
East North Central division	832,000	2.98	1,604,000	2.98	812,000	8.78
West North Central division	902,000	3.23	1,956,000	3.63	503,400	5.43
South Atlantic division	2,346,000	8.39	4,257,000	7.90	1,381,500	14.89
East South Central division	1,087,000	3.89	1,964,000	3.64	504,500	5.45
West South Central division	353,000	1.26	822,000	1.52	25,700	.28
Mountain division	8,694,000	31.11	16,131,000	29.92	1,006,600	10.98
Pacific division	11,504,000	41.17	23,078,000	42.81	1,893,000	20.48
United States	27,943,000	100.00	53,905,000	100.00	9,242,700	100.00

The figures in the above table showing the installed capacity of water wheels in the United States are based on the capacity of the water wheels used in public-utility plants, as shown by the records of the United States Geological Survey; on the capacity of the water wheels used in manufacturing industries, as shown by the records of the Bureau of the Census; and on the capacity of water wheels that are not included in public-utility plants and in manufacturing plants, as deduced from figures showing developed water power compiled by the Bureau of the Census in 1908 for the report of the National Conservation Commission (Senate Document 676, 60th Cong., 2d sess.) and also published in Water-Supply Paper 234 of the United States Geological Survey. For a few States the reports of installed capacity of water wheels given by State commissions were accepted, and for some States it was assumed that there had been no change since 1908. The figures show installed capacity and include water wheels in plants of all sizes.

The estimated capacity of all stationary prime movers in the United States is shown in the following table:

Capacity of stationary prime movers in the United States.

Year.	Horsepower.		Percentage of water power.
	Total.	Water power.	
1900	17,500,000	3,300,000	18.8
1902	19,500,000	3,700,000	19.0
1904	22,500,000	4,100,000	18.2
1906	25,500,000	4,700,000	18.4
1908	29,000,000	5,360,000	18.5
1910	32,500,000	6,000,000	18.4
1912	36,000,000	6,700,000	18.6
1914	38,500,000	7,400,000	19.2
1916	42,000,000	8,200,000	19.5
1918	45,000,000	8,800,000	19.5
1920	49,000,000	9,500,000	19.4

NOTE.—The above estimates are based on the Conservation Commission's report of 1908; census reports of 1904, 1909, and 1914 on manufactures; and census reports of 1902, 1907, 1912, and 1917 on central electric stations and electric railways.

In 1917 electric railways had installed water wheels and turbines amounting to 627,983 horsepower. As many lines purchase their power probably over 1,000,000 horsepower of water power is used by electric railways. In 1914 manufacturing establishments had water-power plants installed as follows, but this does not represent all the water power so used, for much is purchased from central stations.

	Horsepower.	Per cent.
Textile manufacturing	390,478	21.4
Flour and grist mills	229,328	12.5
Lumber and timber products	94,103	5.2
Paper and wood pulp	876,741	48.0
All others	235,793	12.9
	1,826,443	100.00

The developed water power in Canada is estimated by the Dominion Water Power Branch as follows:

Developed water power in Canada, January 1, 1920.

Province.	Total water-wheel and turbine horsepower installed for use in—		
	Central electric stations.	Pulp and paper industry.	Other manufacturing industries.
Yukon	10,000		
British Columbia	211,043	46,962	46,094
Alberta	32,580		17
Manitoba	71,790		
Ontario	794,621	158,095	99,230
Quebec	623,088	249,332	270,961
New Brunswick	9,378	2,693	6,009
Nova Scotia	4,064	16,183	12,276
Prince Edward Island	227		1,789
	1,756,791	473,265	436,376

Province.	Total water-wheel and turbine horsepower installed.	Total horsepower actually employed.	Ultimate designed capacity, in horsepower, of plants now operating or under construction.
Yukon	13,199	11,349	13,199
British Columbia	308,167	276,795	350,832
Alberta	32,992	31,754	33,070
Manitoba	83,447	75,100	297,047
Ontario	1,015,726	934,015	1,460,920
Quebec	910,029	838,071	1,146,465
New Brunswick	18,080	16,657	29,115
Nova Scotia	34,323	29,359	52,202
Prince Edward Island	1,933	1,621	1,958
	2,417,896	2,214,721	3,384,808

NOTE.—The central-station power is developed for sale. Part of it is sold to pulp and paper and other industries, and in the table such part is included with the power that is directly installed in these industries. From plants included in this tabulation an average of 175,000 horsepower was exported in the year ending March 31, 1919.

The plants under construction in 1920 not included in the table will supply the following amounts of power, in horsepower: Ontario, 500,000; Quebec, 137,000; Manitoba, 77,000; Nova Scotia, 15,000; New Brunswick, 18,000. The undeveloped water power is estimated by the same authority as follows:

Undeveloped water power in Canada, by Provinces.

	Horsepower.
Yukon	100,000
British Columbia	3,000,000
Alberta	466,000
Saskatchewan	567,000
Manitoba	3,218,000
Ontario	5,800,000
Quebec	6,000,000
New Brunswick	300,000
Nova Scotia	100,000
Prince Edward Island	3,000
	19,554,000

SOUTH AMERICA.

A general idea of the location of the water powers of South America can be obtained by considering its topography. (See map on p. 4.) The great mountain system of the Andes, which has a mean altitude of 14,000 feet and includes peaks that reach 23,000 feet, extends along the entire western coast. This system so divides the drainage of the continent that 6,382,000 square miles is tributary to the Atlantic and only 407,000 square miles to the Pacific. Lakes Titicaca and Poopó and other inland basins receive the drainage of 106,000 square miles. The precipitation on the peaks of the Andes is heavy, and perpetual snow furnishes a reservoir that regulates to some extent the flow of rivers that rise in that region. As a result there are along the entire length and on both slopes of the Andes numerous streams that descend thousands of feet in a few hundred miles and furnish a series of potential water powers having high heads and moderate quantities of water that lend themselves to economical development.

The eastern part of South America slopes gently and comprises a narrow belt of high land along the Caribbean Sea, a comparatively low plateau across the center, which forms the divide between the tributaries of the Amazon and the Rio de la Plata, and a mountainous area along the eastern coast of Brazil. Several of the drainage basins extend almost to the Pacific, and their run-off is so great as to produce the largest concentrations of potential power on the continent.

In only two parts of South America is the rainfall meager. One, a narrow strip on the western slope of the Andes, extends from the northern boundary of Peru to the center of Chile; the other, a belt 50 to 300 miles wide on the eastern slope of the Andes, extends along the entire western boundary of Argentina, and in this belt the rainfall increases gradually toward the east. In the remainder of South America the annual rainfall is sufficient for the growth of ordinary crops, and over a large part of the continent it reaches 80 inches or even more.

For convenience in reference the continent has been divided into 14 drainage areas, which are numbered on the map in order down the west coast, up the east coast, and along Caribbean Sea, with the inland drainage last. This order will be followed in the text.

101. *North Pacific Ocean.*—A narrow strip that includes parts of Colombia, Ecuador, and Peru drains into the Pacific Ocean. Although the rivers in this strip are short they have a great fall and a fairly regular flow, as they are fed by the rains on the peaks of the Andes. In Colombia and Ecuador the rainfall is heavy along the coast as well as in the mountains, but in Peru rain falls only on the high plateaus and mountains. San Juan River, in Colombia, is the largest river on the Pacific slope of South America; its discharge reaches 50,000 second-feet. On its upper stretches and on its tributaries there is considerable potential power, but its lower reaches and those of some of its tributaries are navigable.

In Ecuador the Guayas and Esmeraldas are the only large rivers that enter the Pacific.

In Peru there are many streams on the Pacific slope. Most of these streams have small drainage basins, and those in the dry southern half of the country have little run-off. The only inter-Andean river that drains into the Pacific, the Huaylas, rises in Lake Conococha, 13,000 feet above sea level, flows northward parallel to the coast for 100 miles to join the Chuquicara, coming from the north, thus forming Rio de Santa, which turns to the west through the maritime Cordillera and empties into the Pacific.

The only water-power plants in this area furnish power for municipal use and for mining. The principal plants supply Quito in Ecuador and Lima and Arequipa in Peru. The total potential power in the north Pacific drainage area is estimated at 1,500,000 horsepower.

102. *South Pacific Ocean.*—The south Pacific area lies wholly in Chile and includes the belt draining into the Pacific Ocean from the northern boundary of Chile to the Strait of Magellan. Here, as in the northern Pacific slope, the rivers are short but have great fall. The rainfall increases from practically nothing in the northern part of Chile to 80 inches or more in the southern part. All the larger streams rise in the high peaks of the Andes, but most of those in the dry regions of northern Chile are lost in the sands before they reach the coast. The principal rivers are the Bueno, Biobio, Valdivia, and Maule—all in the southern half of Chile, to which practically all the available power is confined.

According to a census of the country made in 1916 the developed water power in Chile amounts to 39,600 horsepower. This does not include power used for mining, for which one plant, that of the Braden Copper Co., develops 16,000 horsepower. Other mining plants would probably increase the total for all purposes to 60,000 horsepower. In Chile, as in the rest of South America, the power thus developed is used chiefly for mining, municipal lighting, and street railways. The undeveloped water power in the area is estimated at 1,800,000 horsepower.

103. *Southern islands.*—The area here called the southern islands includes the islands south of the Strait of Magellan in Chile and Argentina and the Falkland Islands. The rainfall is not great, and the land is comparatively high. No developed water powers are known. The potential power is estimated at 800,000 horsepower, and most of it is in Chile.

104. *Lower south Atlantic Ocean.*—The lower south Atlantic area extends from the Strait of Magellan to Rio de la Plata and from the Atlantic Ocean to the Andes. Practically all the area is in Argentina, although one river extends into Chile near the Strait of Magellan. The rivers rise in the Andes, and although in their upper courses they run through a country of little rainfall their drainage basins are large and the available fall is sufficient to afford potential power. The principal rivers are the Santa Cruz, Chico, Deseado, Chubut, Negro, and Colorado.

The largest power plant in this area is at Mendoza, where about 2,700 horsepower has been developed and a plant having an ultimate capacity of 16,000 horsepower is under construction. There are also two small plants near San Juan. The potential power in the area is estimated at 2,100,000 horsepower.

105. *Rio de la Plata.*—The chief tributaries of Rio de la Plata are the Paraná and the Uruguay, which drain all of Paraguay and parts of Uruguay, Argentina, Bolivia, and Brazil. Rio Paraná, the most important power stream in South America, is formed by the union of the Paranahyba and the Grande. Along both these rivers there are a number of falls, of which the best known is that at Maribondo, on Rio Grande near

São Paulo, Brazil. The power available at this site has been estimated at 600,000 horsepower. The Tiete, another tributary of the Paraná, is rich in water power, and about 40,000 horsepower has been developed on it to supply the city of São Paulo. The principal falls on the Tiete are the Avanhandava, with 60,000 horsepower, and the Itapura, with 50,000 horsepower. The Paranapanema and the Ivahy, valuable power streams that lie farther south, are tributary to the Paraná. The first great falls on the Paraná are those of Uruhupunga, but they are drowned out at high water, so that their economic value is doubtful. At about the point where the Paraná becomes the boundary between Brazil and Paraguay the river plunges over the great cataracts of Sete Quedas (seven falls). The total difference in altitude from the top to the bottom of these falls is 375 feet, and the potential power at this site is undoubtedly immense, having been estimated by different authorities at 20,000,000 to 40,000,000 horsepower. The total potential power at the site may equal the smaller of these quantities for a part of the year, but the power that can be commercially developed is probably much less, owing to backwater below the falls and to variations in the flow of the river. For about 400 miles below Sete Quedas the rapids in the Paraná prevent navigation. In this section the principal tributary is the Iguassú, which enters from the east. For a short distance above its mouth the Iguassú forms the boundary between Brazil and Argentina, and in this stretch, about 6 miles from the confluence, occur the great Iguassú Falls, 230 feet high.

The Government of Argentina is investigating the engineering questions involved in developing Iguassú Falls and transmitting the power to Buenos Aires, a distance of about 800 miles. In a preliminary report the flow available 90 per cent of the time is estimated at 17,700 second-feet and the available head at 230 feet, which would yield 325,000 horsepower at 70 per cent efficiency. The report tentatively recommends the construction of a plant that will yield 228,000 horsepower, which it is estimated would furnish 168,000 horsepower in Buenos Aires. If half the flow of the river (Argentina's share) is used, it is estimated that this amount of power could be generated nine months of the year. As good coal must be imported and is very expensive this project may be carried out when financial conditions are favorable, as it has been pronounced physically and economically feasible.

About 100 miles below the mouth of the Iguassú the Paraná has cut a gorge 120 to 150 feet deep into its sandstone bed. The stream has considerable slope and a large discharge, and the potential power available in this stretch is great. The Paraná passes the last rapids at Encarnación, and thence to its junction with the Paraguay the fall is slight and the river has no value for power.

Paraguay River rises about 1,000 feet above sea level and, after falling 400 feet in its upper courses, has a sluggish current and a fall of only 600 feet in 2,500 miles.

The principal tributaries of the Paraguay and the Paraná that come from the Andes, named in order from north to south, are the Pilcomayo, Teuco, Bermejo, Salado, and Dulce. Most of the power sites on these streams lie in their upper courses, where the fall is considerable.

The Uruguay, which with the Paraná forms Rio de la Plata, has only one site where a large amount of power can be developed, but some of its tributaries from the east have small amounts of potential power. On the Uruguay near Salto two dams have been proposed for improving navigation and for providing power to be transmitted to Montevideo. About 60,000 horsepower could be developed here at low flow, and the project may later be carried out by the Government of Uruguay.

The principal developed powers in the Rio de la Plata drainage basin are 40,000 horsepower on the Tiete to supply São Paulo, Brazil; 12,500 horsepower near Córdoba and 5,000 horsepower at Tucumán, Argentina; and 500 horsepower near Potosí, Bolivia. Contracts have been let for the electrification of 28 miles of railroad from Jundiahy to Campinas, in Brazil, and the power will be furnished by the São Paulo Light & Power Co. There are small plants in Paraguay, but there is no record of any in Uruguay. The potential water power of this drainage basin is estimated at about 16,000,000 horsepower.

106. *Upper south Atlantic Ocean.*—The upper south Atlantic area embraces the Atlantic drainage from Rio de la Plata to the São Francisco. Most of the rivers are short coastal streams, but their fall is considerable, as a chain of hills and mountains extends along the coast northward from São Paulo. The principal rivers are the Jacuhy, Parahyba, Doce, Jequitinhonha, Pardo, and Contas. All are good power streams, as they have numerous falls that can be developed easily. At Bracuhy Falls, near Rio de Janeiro, there is a total drop of 2,887 feet and a mean flow of 105 second-feet, which could be obtained by the use of two reservoirs at sites that have been investigated. At the well-known Herval Falls, near Taquera, north of Porto Alegre, there is a sheer drop of 400 feet, which would afford a capacity of 100,000 horsepower if the mean annual flow could be utilized. Although the capacity would be much less during the low-water period it would still be considerable, and as the fall is not far from a railroad and several towns this site may be developed in the near future.

The principal power development in this area is that of the Rio de Janeiro Tramway, Light & Power Co. (Ltd.), which has diverted the Pirahy, a tributary of the Parahyba, by means of a tunnel into the Ribeirão das Lages, where about 75,000 horsepower has been developed by utilizing a head of 1,180 feet. On another tributary of the Parahyba 13,500 horsepower has been developed to supply the town of Nictheroy. The city of Bahia is supplied from a plant of 20,000 horsepower capacity on Paraguassu River, and an undeveloped fall on this river has a capacity of 21,000 horsepower. The total potential power in the upper south Atlantic area is estimated at 3,700,000 horsepower.

107. *Rio Sao Francisco.*—The Rio São Francisco area includes the entire drainage basin of Rio São Francisco, nearly 26,000 square miles. At the falls of Paulo Affonso, about 140 miles above the mouth of the river, the effective height is about 260 feet, although at extreme high stages the water below the falls rises 89 feet. The total power available at these falls is estimated at 2,000,000 horsepower, and that available during periods of low water at 400,000 horsepower. Several projects for using the falls have been advocated, as they are near the coast and the river is navigable below. Many of the tributaries of the São Francisco have a large value for power, especially the Paracatu, on which 20 falls are known.

The electric installations in the São Francisco basin are those of the São João del Rey Gold Mining Co. and the city of Bello-Horizonte. The total potential power of the basin is estimated at 1,700,000 horsepower.

108. *Lower north Atlantic Ocean.* — The lower north Atlantic area includes the basins of the streams that enter the Atlantic Ocean between the São Francisco and the Pará. The principal streams, named in order from south to north, are the Parahyba do Norte, Salgado, Paranahiba, Mearim, and Gurupy. No power sites of great value are known in this area, but the potential power in the whole area is estimated at 1,700,000 horsepower.

109. *Pará River.*—The area here considered includes the entire drainage basin of Pará River, which with its tributaries drains a long stretch of country that is bordered on the west by the basin of the Amazon. A range of mountains that extends through the center of

the Pará River basin and divides the Araguaya from the Tocantins may offer opportunities for developing small powers. The Tocantins, which drains 350,000 square miles, offers possible power at the Cachoeira Grande (great falls), 130 miles above the estuary into which it empties. The discharge is estimated at 360,000 second-feet. The falls of Fação and Catadupa, on Rio das Almas, a tributary of the Tocantins, are 108 and 216 feet high, respectively; but nothing definite is known of the stream flow. The Araguaya has considerable potential power in the stretch just below the great island of Bananal. There are probably many other power sites in this area, and the total potential power is estimated at 600,000 horsepower.

110. *Amazon River.*—The area here considered includes the entire basin of Amazon River. In their lower courses the Amazon and its tributaries have slight slopes and little value for power. Most of the potential water power of the area is in the Andes, in Bolivia, Peru, Ecuador, and Colombia, and on tributaries from the south in Brazil which have considerable flow and series of cataracts in regions that are largely unexplored. The Amazon rises in Lake Lauricocha, in the Peruvian Andes, flows northward in a deep gorge between the western and central Cordilleras nearly to the northern boundary of Peru, and then turns east at an altitude of 575 feet above sea level, having descended more than 13,000 feet from its source. The first large tributary is the Huallaga, which flows northward between the central and eastern Cordilleras. It rises at an altitude of 14,000 feet and joins the Amazon at an altitude of 540 feet. Numerous affluents that descend by numberless falls and rapids and drain regions of heavy rainfall afford power sites throughout their courses. The next large tributary is the Ucayali, also from the south. The headwaters of the Ucayali are the Apurimac, Mantaro, and Quillabamba, and lower down the stream is joined by the Pachitea. Rising at altitudes of about 14,000 feet, these rivers fall about 13,000 feet before they join the Ucayali. The Urubamba, a tributary of the Quillabamba, has a fall of 12,000 feet in 340 miles. The Ucayali, which flows in general northward, parallel to the Andes, affords but little potential power itself, as most of the fall occurs in its tributaries. Both the Ucayali and the upper Amazon drain sparsely populated regions, in which power is developed only at a few places for mining; the most notable plants supply mines around Cerro de Pasco, Peru.

Of the northern tributaries below the Ucayali the Napo, Putumayo, and Yapura rise on the eastern slope of the Andes in Ecuador and Colombia and flow eastward and southward to the Amazon. The potential water power on the Napo and Putumayo is confined to their extreme headwaters, where the drainage area is small; but the Yapura, which rises in the Colombian uplands, flows over a series of rapids to the falls below the Araracoara reefs, where there is a cascade of 100 feet. Rio Negro, also entering from the north, is the largest tributary of the Amazon, but as it is navigable for 450 miles there is little opportunity for the development of power in its course. Some of its tributaries that rise in the Colombian uplands, where the rainfall is heavy, have large fall and probably considerable potential power. Of the southern tributaries of the Amazon below the Ucayali the Javary, Juruá, and Purús have some potential power on their headwaters. The Madeira is formed by the confluence of the Beni and the Mamoré, which drain more than half of Bolivia and which with their numerous tributaries afford many power sites, chiefly on the Madre de Dios, the Beni, the Grande, and the Guapore. All these streams have large fall and considerable drainage areas and probably would yield more than 1,500,000 horsepower. Other tributaries of the Madeira are wholly in Brazil and have less fall. The Tapajos and the Xingú, the last tributaries of the Amazon from the south, are obstructed in their middle courses by rapids and falls from which considerable power could be developed.

The developed power in the Amazon basin is very small, probably 15,000 to 20,000 horsepower in Peru, used mostly in mining, and 5,000 to 6,000 horsepower in Bolivia, used for municipal purposes. The potential power in the Amazon basin is estimated at about 16,000,000 horsepower.

111. *Upper north Atlantic Ocean.*—The upper north Atlantic area includes the streams draining into the Atlantic Ocean between the Amazon and the Orinoco. It embraces British, Dutch, and French Guiana and small parts of Brazil and Venezuela. The eastern half of this area is drained by the Oyapok, which forms the boundary between Brazil and French Guiana, and the Maroni, which separates French and Dutch Guiana. There is a fall of 246 feet on the Oyapok, but little else is known concerning it. The rivers in this drainage area rise in a rather low range of mountains and are short, but they are valuable for power, as the run-off resulting from the annual rainfall of 100 inches, well distributed through the year, is great. The potential power of British Guiana probably exceeds the total for the remainder of this area. The Essequibo is the largest river in British Guiana. The other large rivers are the Berbice and Corentyne. The Potaro, a tributary of the Essequibo, is the richest stream in potential power. On it are the famous Kaieteur Falls, which have a total drop of 820 feet and a single vertical fall of 740 feet. At high stages the river is 250 to 400 feet wide at the falls, but this width decreases to 50 or 60 feet during periods of extreme drought. The potential power at this site is estimated at 125,000 horsepower at low water. The Potaro also has several smaller falls—the Amatuk, Pakatuk, and Tumatumari. There are large deposits of bauxite in British Guiana, and some of the extensive water powers may be developed in connection with the production of aluminum.

So far as known there are no water-power plants in the upper north Atlantic drainage area, but the potential power is estimated at nearly 4,000,000 horsepower.

112. *The Orinoco.*—The area here considered includes all streams tributary to Orinoco River, which drains an area of heavy rainfall and ranks third in volume among the rivers of South America, being exceeded only by the Amazon and Rio de la Plata. It is navigable for 1,300 miles above its mouth, and the total fall in that distance is 920 feet. At the Atures rapids, about 50 miles above the mouth of the Meta, the Orinoco falls 30 feet in 6 miles, and its total fall including the Maipures rapids, 45 miles farther up, is 70 feet. The tributaries of the Orinoco in both Colombia and Venezuela have considerable fall, and as the rainfall and run-off are heavy their potential power is great. The principal tributaries are the Ventuari, Caura, Paragua, and Caroni from the east and south, wholly in Venezuela, and the Guaviare, Meta, and Apure from the west. Of these streams both the Caroni and the Caura have great potential power.

On the Caroni there is a fall of 60 feet at the town of Caroni, near the mouth of the river, above which the drainage area is about 38,500 square miles and the annual rainfall more than 70 inches. A conservative estimate of the potential power at this site, even at ordinary low water, is 125,000 horsepower, and the mean flow would yield 600,000 horsepower. A contract has recently been let by the Government of Venezuela for an electric railway from San Félix, on Orinoco River, to the Guasipati gold fields, to be run by hydroelectric power from Caroni Falls.

On the Caura, at the rapids of Pará, 130 miles above the mouth, there is a fall of 200 feet. The potential power at this site is estimated at 135,000 horsepower at ordinary low water, and the mean flow would yield 675,000 horsepower. The tributaries of the Orinoco that enter from the west are navigable in their lower courses but have power sites on their headwaters.

The developed water power in this drainage area is small, if there is any. The total potential power is estimated at 2,000,000 horsepower.

113. *Caribbean Sea.*—The area here considered extends from the mouth of the Orinoco to Panama. In Venezuela it includes a narrow strip along the coast where the basins are small but the fall is considerable, and as the rainfall is abundant the area would evidently afford considerable power. In Colombia three large rivers, the Magdalena, Sinu, and Atrato, flow in parallel courses from south to north. The Atrato flows between the western and central Cordilleras, the Magdalena flows between the central and eastern Cordilleras, and the Sinu drains a small area near the Caribbean coast. The Magdalena, except for a break of 20 miles near Honda, is navigable for 830 miles. It rises at an elevation of 14,000 feet, and its upper courses and tributaries are of great value for power. On one tributary, the Funza, at a point 28 miles from Bogotá, are the magnificent Tequendama Falls, 475 feet high, over which there is a discharge estimated at 4,000 second-feet. The Saravita, a tributary of the Sogamosa, falls 2,400 feet in 3 miles. The Cauca, the principal tributary of the Magdalena, is characterized by rapids and many power sites. The Sinu is a sluggish stream. The tributaries and headwaters of the Atrato offer many good power sites.

About 4,500 horsepower has been developed near Caracas, in Venezuela, and perhaps 25,000 horsepower in Colombia. Most of this power is used for municipal purposes, but some of it is used for mining. Bogotá has a 5,500-horsepower plant. The potential power of the area is estimated at 1,800,000 horsepower.

114. *Interior basins.*—Lakes Titicaca and Poopó receive the drainage from more than 40,000 square miles in Bolivia, Peru, and Chile. Lake Titicaca, which is on a plateau 12,500 feet above sea level, has an area of nearly 5,000 square miles and is the largest lake in South America. Its principal tributary, the Ramis, forms the outlet of Lake Arapa. Lake Titicaca has an extreme depth of more than 700 feet, but discharges through Rio Desaguadero into Lake Poopó, which is only 4 to 13 feet deep. The evaporation and seepage in the lakes and rivers balance the run-off of the entire area. The Desaguadero is navigable throughout its length. Lake Titicaca could be drained into the Pacific by a long tunnel, but this project is not considered financially feasible. So far as known there is no developed water power in this area, and the potential power is small. There are many other small inland basins in South America, especially in Argentina.

EUROPE.

A large part of Europe is less than 1,000 feet above sea level. The mountainous areas are in the Scandinavian peninsula, along the eastern edge of European Russia, and in a broken strip along the southern part of the continent from the Caucasus Mountains to Spain. The rainfall on the whole is plentiful; the only considerable areas on which it is less than 20 inches are in eastern and northern Russia and in parts of Finland, Sweden, and Spain. Europe has one-third of the total developed hydroelectric power in the world, ranking next to North America, which has about one-half.

The water powers of Europe are discussed in this atlas by countries rather than by drainage areas. The information can be presented more clearly and concisely in this way because the statistical information available is arranged by countries and not by drainage areas.

Norway.—Norway occupies the western part of the Scandinavian peninsula, and the main watershed of the peninsula forms most of its eastern boundary. Nearly two-thirds of its total area of 124,000 square miles lies south of Trondhjem Fiord, has a general oval outline, and has a maximum width of about 250 miles. The country north of Trondhjem Fiord is a belt scarcely exceeding 50 miles in width, which borders the Arctic Ocean and extends around the north end of Sweden and Finland.

Although the highest land is along the eastern boundary, the greater part of southern Norway is a mountainous plateau with a watershed line that practically coincides with its longitudinal axis. The streams in the southeastern part drain southward to the Skagerrack, and those in the western part drain in a general westerly direction into the Atlantic and Arctic oceans. To this plateau, which rises abruptly from the coast to altitudes of 3,000 to 5,000 feet, are due most of the water-power resources of the Kingdom. The country has a mean altitude of about 1,600 feet, which is nearly 1,000 feet greater than that of the remainder of the peninsula.

In northern Norway and on the Atlantic coast of southern Norway the watershed line is near the heads of the deeply indented fiords. The rivers flow perpendicularly to the coast line, are comparatively short, and have steep slopes and many falls (Valur Fos, 1,150 feet; Vettis Fos, 853 feet; Vring Fos and many others, in excess of 400 feet). The principal rivers, however, head between the coastal range and the range on the eastern boundary, flow in a southerly direction between these ranges, and empty into the Skagerrack. The largest of these, the Glommen, drains an area of 16,000 square miles.

Many lakes, which lie in the long, narrow valleys along the edge of the central plateau and at the heads of the fiords, offer opportunities for storage and add materially to the value of the streams for the development of power.

Although Norway extends for nearly half its length north of the Arctic Circle its climate, particularly along the coast, is so greatly influenced by the warm ocean currents that the fiords, even those in the extreme north, do not freeze over. The lowest winter temperatures are in the interior of southern Norway and in Finmarken, in northern Norway.

The precipitation is greatest along the western slope of the plateau of southern Norway, where it reaches an annual average in excess of 80 inches. Along the northwestern coast the average precipitation is 50 to 60 inches, and along the southern coast it is 40 to 50 inches. On the eastern slope of the plateau the rainfall is still less, but the generally high average precipitation, combined with the topographic features already mentioned, produces unusually favorable conditions for the development of cheap and abundant water power.

No systematic survey of the water-power resources of Norway has been made, and estimates of the total power available vary widely. Much of the potential power of northern Norway may never be practicable of development. The greater part of the power resources, however, is in southern Norway, where development is practicable and will be limited only by the demand. It is estimated that the amount that may be commercially developed is at least 5,500,000 horsepower.

The following table for southern Norway, except the cities of Christiania and Bergen, was published in the Norwegian yearbook for 1919:

Water power available in southern Norway in 1919.

.	Undeveloped horsepower.	Horsepower at State-owned sites.	Developed horsepower.
Östfold	351,000	23,000	200,000
Akershus	80,000		33,000
Hedemarken	327,000	37,000	11,000
Opland	782,000	38,000	14,000
Buskerud	908,000	280,000	75,000
Vestfold	30,000		2,000
Telemark	1,069,000	167,000	370,000
Austagder	336,000	10,000	46,000
Vestagder	688,000	95,000	45,000
Rogaland	1,136,000	182,000	54,000
Hordaland	1,762,000	52,000	275,000
Sogn og Fjordane	1,412,000	28,000	33,000
Möre	650,000	43,000	92,000
	9,531,000	955,000	1,250,000

The estimate of undeveloped power undoubtedly contemplates the use of storage. The Industristatistik for 1915 gives a table of developed power by districts, from which the following figures for Christiania, Bergen, and northern Norway are taken:

Developed power in Christiania, Bergen, and northern Norway in 1915.

	Horsepower.
Christiania	8, 661
Bergen	13, 462
Nord-Trondelag	19, 236
Nordland	11, 175
Tromsö	2, 786
Finmarken	972
State owned	1, 761
	58, 053

The horsepower developed from water in Norway as a whole increased about 40 per cent between 1915 and 1919. If this rate of increase is assumed for the districts included in the above statement a total of 80,000 horsepower is obtained for these districts in 1919, and the addition of this to the developed power shown in the first table gives a total for Norway of 1,330,000 horsepower. The following table shows the progress of the development of water power in Norway since 1900:

Power developed in Norway since 1900.

Year.	Water power.		All other power.		Total horsepower.
	Horsepower.	Per cent.	Horsepower.	Per cent.	
1900	160,588	67.4	78,012	32.6	238,600
1901	172,000	66.7	86,000	33.3	258,000
1902	180,000	67.2	88,000	32.8	268,000
1903	194,000	67.9	92,000	32.1	286,000
1904	206,000	67.8	98,000	32.2	304,000
1905	225,392	68.0	106,408	32.0	331,800
1906	251,000	70.1	107,000	29.9	358,000
1907	294,000	73.1	108,000	26.9	402,000
1908	316,000	74.4	109,000	25.6	425,000
1909	347,000	75.9	110,000	24.1	457,000
1910	449,794	80.3	110,206	19.7	560,000
1911	578,000	77.0	173,000	23.0	751,000
1912	710,000	74.9	238,000	25.1	948,000
1913	793,000	74.0	279,000	26.0	1,072,000
1914	859,000	73.4	311,000	26.6	1,170,000
1915	920,000	73.0	341,000	27.0	1,261,000
1916	1,175,000	76.3	365,000	23.7	1,540,000
1917	1,225,000	76.0	388,000	24.0	1,613,000
1918	1,275,000				
1919	1,330,000				

The yearly figures for total horsepower and those for developed water power for 1900, 1905, 1910, and 1915 are taken from the Industristatistik. A census of water power was apparently taken every five years. For the intervening and later years the amounts have been estimated, mostly from figures showing the total developed power, which are available for each year. The estimate of developed water power for 1919 was obtained as explained in the preceding paragraph.

The distribution of the total power generated in 1917 among the industries is shown below. The State enterprises are mainly railroads, and practically all the power they used was generated by steam. There was also a 21,000-horsepower steam plant in Finmarken, the power from which was used largely in mining.

Distribution of power in Norway by industries in 1917.

	Horsepower.	Per cent.
Chemical industries	476,675	32.9
Manufacture of paper and of leather and rubber goods	213,154	14.7
State enterprises (mostly railroads)	184,493	12.8
Lighting	165,985	11.7
Mining and production of ores, etc	78,763	5.4
Manufacture of articles of wood, bone, horn, etc	69,885	4.8
Manufacture of food, drink, etc	43,811	3.0
Transportation [a]	43,664	3.0
Manufacture of machinery, etc	41,751	2.9
Materials and equipment for heat, light, and power	27,960	1.9
Textile industries	20,043	1.4
Agriculture and lumbering	18,234	1.2
Production of stone and other mineral materials	17,914	1.2
Municipal enterprises (except lighting)	14,955	1.0
Construction work	12,826	.9
Foundries and metal manufactures	10,313	.7
Printing, lithography, etc	2,797	.2
Clothing industry	2,642	.2
Miscellaneous	155	.1
	1,446,020	100.0
Losses	112,948	
Reserve plants	54,315	
	1,613,283	

[a] Exclusive of State railroads, which are included under State enterprises.

On the lower Glommen River, in Östfold, there are four sites having a total capacity of 300,000 horsepower, of which 188,000 horsepower is developed. On Maane River at Rjukan there are two sites having a capacity of 239,000 horsepower, all of which is developed. On the Tysse i Odda there are two sites having a total capacity of 300,000 horsepower, of which 83,000 horsepower is developed. On Matre River there is a site having a capacity of 96,000 horsepower, of which 74,000 horsepower is developed. At a site on Lilledals River there is 91,700 horsepower, all developed. The largest State-owned site, one at Norefallene, on Nummedalslaagen, in Buskerud, has a capacity of 196,000 horsepower, none of which is developed.

The utilization of water power for chemical industries in Norway is particularly noteworthy. Plants of 100,000 to 200,000 horsepower have been installed for producing nitric acid from atmospheric nitrogen. This industry requires cheap power, and the Norwegian sites, which have concentrated falls and large volumes of water, are particularly well suited for it. Furthermore, many of these plants are close to tidewater at the heads of fiords, and their products can be loaded directly upon ocean-going freighters.

Water power has been developed in Norway by the State to some extent, though less than in Sweden. Unutilized sites owned by the State have a capacity after regulation of about 1,000,000 horsepower, of which 200,000 to 300,000 horsepower is reserved for the electrification of railroads.

Sweden.—Sweden occupies the eastern half of the Scandinavian peninsula. Its average width is less than 200 miles, and its length is about 1,000 miles. Its western boundary coincides approximately with the watershed between the Atlantic Ocean and the Gulf of Bothnia, and from this watershed the rivers of northern and central Sweden flow in a general southeasterly direction to the Gulf. A watershed of lower altitude divides southern Sweden into two parts, one of which drains into the Baltic Sea and the other into the Kattegat.

Of the total area of Sweden, which is about 173,000 square miles, less than 60,000 square miles, or about one-third, rises more than 1,000 feet above sea level, and about half lies below 660 feet. The highest mountain peak, Kebrekaise, is 7,000 feet high.

As the streams of Sweden in general flow transversely across the country, none of them are large. Only six rivers have drainage areas exceeding 10,000 square miles. The minimum flow of the Göta, the largest river of Sweden, is about 11,000 second-feet, and the ordinary high flow is about 30,000 second-feet. On most of the other streams the ratio between flow at the high and the low stage is much greater, ranging between 25 and 35 to 1. The full utilization of the water for the development of power therefore requires storage, for which Sweden is particularly favored by its numerous lakes. The aggregate area of these lakes is 14,000 square miles, or about 8 per cent of the area of the country. Eight lakes have areas of more than 100 square miles each, and the largest of these, Lake Venern, covers 2,150 square miles. This abundance of lakes and the fact that most of the northern drainage areas in particular are covered with forests of conifers will make it possible to regulate the discharge of many of the streams and to increase greatly their potential power.

Although about 15 per cent of the area of Sweden lies north of the Arctic Circle, the warm ocean currents and winds give the country a comparatively mild climate, the average temperature for January ranging from 30° F. in the extreme south to 3° F. in the extreme north. The winter temperature is sufficiently low to require precautions against anchor and frazil ice but not low enough to prevent the utilization of water powers even in the extreme north. The Swedish Government has built and is now operating a power plant on Lule River at Porjus, north of the Arctic Circle.

The precipitation is greatest in the mountainous areas in the north and along the watershed between Sweden and Norway, where it averages about 40 inches a year and reaches 80 to 120 inches on some of the mountain peaks. The moisture brought by the warm winds from the Atlantic is nearly all condensed either on the mountain range along the western boundary or on the coastal range in Norway, so that the precipitation in the interior of northern Sweden is small. The average annual rainfall for the entire country is about 20 inches.

The progress of the development of water power in Sweden and its distribution among the industries are shown by the following tables:

Power developed in Sweden from 1896 to 1918.

Year or period.	Waterpower.		All other power.		Total horsepower.
	Horsepower.	Per cent.	Horsepower.	Per cent.	
1896-1900	168,770	56.8	128,335	43.2	297,105
1901-1905	253,663	55.8	201,294	44.2	454,957
1906-1910	373,481	56.0	293,663	44.0	667,144
1906	311,901	55.2	252,872	44.8	564,773
1907	330,756	54.4	276,263	45.6	607,019
1908	351,370	55.0	288,268	45.0	639,638
1909	394,141	55.3	318,315	44.7	712,456
1910	479,237	59.0	332,547	41.0	811,784
1911	505,184	59.8	338,391	40.2	843,575
1912	619,772	62.6	370,318	37.4	990,090
1913	704,546	61.9	434,358	38.1	1,138,904
1914	774,235	61.5	465,629	38.5	1,209,864
1915	844,168	63.9	476,875	36.1	1,321,043
1916	924,780	65.7	483,301	34.3	1,408,081
1917	953,797	65.0	513,374	35.0	1,467,171
1918	1,037,020	67.7	494,192	32.3	1,531,212

Distribution of power among industries in Sweden in 1918.

	Per cent.
Gas, water, and electric plants	30.1
Mining and metals	25.9
Printing, paper making, etc	19.6
Wood industries	8.3
Food products, etc	5.1
Quarrying, stone work, cement, etc	3.8
Clothing and textiles	3.5
Chemical industry	2.9
Leather, hair, and rubber goods	.8

In the following table the first column shows the potential power based on the flow available nine months of the year. If all this power were developed the capacity of the plants would probably equal the figures in the second column. The power worth exploiting is that which it would be financially feasible to develop at the present time if there were a market. The figures for developed power show the turbine capacity of plants built or under construction. The last column compares the probable capacity of plants if all the potential power were developed with the capacity of plants built or under construction.

Distribution of potential and developed water power in Sweden, in brake horsepower, 1917.

Region.	Total.	Probable installation.	Worth exploiting.			Developed.	Percentage of probable development.
			State.	Private.	Total.		
Upper Northland	1,722,000	2,410,000	310,000	593,000	903,000	105,400	4.37
Northland and Lower Dalarne	1,829,000	2,560,000	89,000	1,449,000	1,538,000	402,474	15.72
Central Sweden	62,000	87,000	7,000	77,000	84,000	70,036	80.50
Eastern Sweden	219,000	307,000	28,000	252,000	280,000	109,611	35.70
Skane Province	26,000	37,000		27,000	27,000	6,294	17.01
Western Sweden	574,000	804,000	258,000	422,000	680,000	411,281	51.15
	4,432,000	6,205,000	692,000	2,820,000	3,512,000	1,105,096	17.83

Power generated in Sweden in 1917.

District.	Water power.		Total power.	
	Horsepower.	Per cent.	Horsepower.	Per cent.
South Sweden (Götarike):				
Malmöhus	1,738	0.18	48,155	3.28
Kristianstad	4,117	.44	27,897	1.90
Blekinge	16,869	1.77	26,768	1.82
Kronoberg	13,669	1.43	26,172	1.78
Halland	48,473	5.08	63,680	4.34
Jönköping	20,857	2.18	38,234	2.61
Kalmar	12,287	1.29	28,515	1.94
Götland	167	.02	3,680	.25
Östergötland	50,739	5.32	68,676	4.68
Skaraborg	29,935	3.14	38,902	2.65
Elfsborg	136,795	14.33	146,693	10.00
Göteborg and Bohus	9,690	1.02	36,895	2.52
	345,336	36.20	554,267	37.77
Central Sweden (Svearike):				
Stockholm	2,073	.22	97,720	6.66
Upsala	61,306	6.43	67,578	4.61
Södermanland	11,234	1.18	28,427	1.94
Vestmanland	32,065	3.36	45,599	3.11
Örebro	56,198	5.91	67,718	4.62
Vermland	101,917	10.68	113,987	7.77
Kopparberg	129,890	13.62	167,338	11.40
	394,683	41.40	588,367	40.11
North Sweden (Norrland):				
Gefleborg	38,435	4.02	74,423	5.08
Jemtland	17,385	1.82	20,648	1.40
Vesternorrland	77,951	8.17	120,389	8.20
Vesterbotten	22,596	2.37	32,077	2.19
Norrbotten	57,411	6.02	77,000	5.25
	213,778	22.40	324,537	22.12
Grand total	953,797	100.00	1,467,171	100.00

The Hydrographic Bureau of the Swedish Government has been working for several years on a detailed survey of the potential water power of the Kingdom and in 1919 issued a report giving the results obtained up to the end of 1918. The statistical yearbook for Sweden and a volume dealing with industrial statistics, both published by the Central Statistical Bureau, give detailed data on the primary power used in Swedish industries. The amount used in 1918 was 1,531,000 horsepower, of which 67.7 per cent was generated by water and 32.3 per cent by steam and gas. The plants under construction in 1917 would increase the total developed water power to 1,105,000 horsepower. The amount of water-generated power has been constantly increased, and if the rate of increase in previous years has been maintained the total present water-power installation is probably not less than 1,200,000 horsepower. The most extensive plants are on the Dal, where at the end of 1917 there were 49 plants having a capacity of 240,905 horsepower, on the Göta 22 plants having a capacity of 149,684 horsepower, and on the Lule 4 plants having a capacity of 76,635 horsepower.

Since 1906, when the Riksdag approved the Government development of Trollhättan Falls, the State has taken an active part in water-power development. Under the administration of the Royal Waterfall Board plants have been erected at Trollhättan, on the Göta a short distance below Lake Venern (155,000 horsepower), at Elfkarleö (75,000 horsepower), and on the Lule at Porjus (75,000 horsepower). The Government has also adopted the policy of electrifying the railroads and is proceeding with the work at a cost of several million dollars yearly.

Russia.—At the outbreak of the World War the total area of Russia in both Europe and Asia was 8,416,145 square miles, or one-seventh of the land area of the globe and about 42 per cent of the combined area of Europe and Asia. European Russia, which then contained 2,123,120 square miles, is separated from Asia on the south by the range of which Mount Ararat is the culminating point and by the Black Sea and on the east by the Ural Mountains, which extend from the Arctic Ocean to the Ust Urt plateau (the watershed between the Caspian and Aral seas) and the Caspian Sea.

At the present time (in 1921) the exact boundaries of European Russia are uncertain. Finland, Esthonia, Courland or Latvia, Lithuania, Poland, and Ukraine are new countries that include large areas which were formerly within the western and southwestern parts of the Russian Empire. In addition territory that was formerly Russian has been added to Rumania. In the Caucasus region Georgia, Azerbaijan, and Armenia have been created out of land that was formerly a part of Russia or Turkey. These new States or countries contain most of the European water-power resources of the former Russian Empire.

In the central part of European Russia there is a plateau which stands only 750 to 850 feet above the level of the Baltic Sea and which forms the watershed between the Baltic Sea and the Black and Caspian seas. This plateau contains many lakes and marshy areas in which the rivers of European Russia have their headwaters, some of which are very close together. The Volga, Dnieper, and Dvina, for example, rise in the same marshy area. This plateau lies so much nearer to the Baltic Sea than to the Caspian and Black seas that the rivers which flow from it to the Caspian and Black seas are five or six times as long as those which flow to the Baltic, but the Baltic streams have a correspondingly greater slope.

The character and the size of the rivers of European Russia are determined by the character of the rainfall and the relief. In European Russia in general there is comparatively little rainfall, and it is only the great size of the drainage basins, due to the even relief, that makes the rivers of Russia the largest in Europe.

The rivers in most of northern European Russia are icebound several months in the year, but those in the far south do not freeze at all. The line connecting points where the water is frozen for about 180 days during the year passes south of Archangel, near the 60th parallel of north latitude. The ice on the northern rivers attains in January a thickness of 10 to 25 inches or more, varying according to the temperature.

The annual precipitation in European Russia ranges from less than 11.5 inches to about 25 inches. The least rain falls in the southern part, in Samara and Saratof, and a little more falls in the northern part. The maximum seasonal precipitation in nearly all of European Russia occurs in summer. In northern Russia, north of latitude 60°N., the most rain falls during August; in central Russia, north of latitude 50°N. in the west and north of 53°N. in the east, during July; and in southern Russia, as far south as the Caspian Sea, during June.

The height of the waterfalls is closely related to the relief. Where the rivers cross the low central plateau their fall is measured in tens of feet. This low fall prevails over most of European Russia except the Ural region and the region adjoining Finland, where some of the falls are 150 feet high. Most of the highest waterfalls in the mountainous regions, such as the Ural Mountains, are on streams that, owing to the small size of their basins and their steep gradients, have rather small and irregular run-off. In the comparatively level regions around the Baltic Sea and in northern Russia the falls are not high but the discharge is great, because the catchment areas are very large. In the northwestern region (Archangel and Olonetz) the run-off is more even, owing to the control exercised by the many lakes, which serve as reservoirs.

Most of the water power in European Russia is on its borders. Central Russia has no large water powers but many small ones, which are estimated to aggregate from 250,000 to 750,000 horsepower.

The Baltic region includes the lower parts of the basins of the rivers that empty into the Baltic Sea, such as the Velikaia, a tributary of the Narova, as well as the Msta, a tributary of the Volkhof, which empties into Lake Ladoga. The Narova now belongs to Esthonia. The source of water power in this region is the rapids, such as the Volkhofskie rapids, which have a fall of about 30 feet in a distance of 6 miles. Most of these rapids obstruct navigable rivers. They will probably be utilized in the near future, as the coal used in this region, all of it imported, is very expensive.

The water power in the Baltic region is estimated at 150,000 to 200,000 horsepower, and the principal sources are as follows:

	Horsepower.
Velikaia	20,000–25,000
Msta	30,000
Volkhof	60,000

In the Ural region the meager rainfall and the small size of the basins of the rivers are the fundamental features that determine the character of the potential water power. There are numerous water-power sites, but they can yield not more than 2,000 to 3,000 horsepower each, and many of them can not be utilized without reservoirs. The largest sources of power are the Chusovaya and the Bielaya, tributaries of the Kama, which can yield more than 100,000 horsepower each. The necessity for water power in the Ural region is great, because most of the forest there has been cut and fuel is scarce. The total potential water power in the region is 500,000 to 1,500,000 horsepower. A small part of it is already utilized.

In northwestern European Russia, which comprises parts of Archangel and Olonetz, there are many lakes, two of which, Lakes Ladoga and Onega, are large. The boundary between Finland and Russia now passes through Lake Ladoga. In the development of water power some of these lakes will serve as reservoirs. The discharge of the rivers here is comparatively large. The waterfalls are more or less concentrated, and the general conditions for the development of water power are better than in other parts of Russia. The lake region has been only slightly investigated, but its general features are similar to those of Finland and Sweden. Some of the rivers that have been more or less thoroughly examined are the Suma (about 70,000 horsepower), the Vyga (up to 160,000 horsepower), and the Kem (180,000 to 200,000 horsepower).

The total quantity of water power in the lake region is estimated at 1,000,000 to 3,000,000 horsepower.

Total potential water power in European Russia.

Region.	Minimum horsepower.	Maximum horsepower.
Central Russia	300,000	1,000,000
Baltic region	150,000	300,000
Ural region	500,000	1,500,000
Lake region	1,000,000	3,000,000
	1,950,000	5,800,000

The capacity of most of the plants, of which there are not many in all Russia, hardly exceeds a few hundred or at most a few thousand horsepower. Most of the hydraulic plants in Russia, which furnish power for small factories, sawmills, etc., are small. An investigation made by the Russian Technical Society of Petrograd in 1910 showed that the total developed water power of Russia was about 250,000 horsepower, of which the small stations developed 80 per cent.

After deducting 123,000 horsepower for Finland and 50,000 horsepower for the remaining area lost by Russia approximately 75,000 horsepower remains as the total developed power in 1910 in the area now included in European Russia. Since 1914 there has been little or no development, so that the total developed power in Russia in 1920 was probably not more than 100,000 horsepower.

Finland.—The greater part of Finland is 1,000 feet or more above sea level, but it contains no continuous chains of hills—only a succession of separate hills that run across its northern part and thence southeastward. The relief is similar to that in Archangel and Olonetz, in Russia, which adjoin Finland. The rivers of Finland carry large volumes of water but have slight fall.

Although it would seem that the streams which drain toward the Arctic Ocean and the White Sea could yield considerable water power they flow in an area where the temperature is so low that they are never likely to be of much economic value. The streams that empty into the Gulf of Bothnia from the east are similar to those that empty into it from the west. As the periods of low temperature in this region are long the development of many of these streams, particularly the northern ones, will be difficult. The upper Bothnia drainage basin (Uleaborg) contains from 600,000 to 1,200,000 horsepower.

The streams in the southern Bothnia region (Vasa and Abo-Björneborg) drain smaller areas and have less discharge than those in the northern Bothnia region, but they are better adapted to regulation by lake storage. Their potential power is estimated at a minimum of 100,000 horsepower and a mean of 250,000 horsepower.

The most favorable water-power sites in Finland are in the lake region, including Kuopio, St. Michel, Viborg, and parts of Uleaborg and Tavastehus. The falls are concentrated in rapids between stretches of still water, and though the heads are rather low the large volume of flow and the possibility of nearly complete regulation by storage in hundreds of lakes, many of them large, make this one of the best regions in Finland for the development of water power. It is estimated that this region could produce 800,000 horsepower.

The statistical yearbooks of Finland for 1916 and 1918 contain the figures given in the accompanying tables concerning the primary power developed in that country.

From 1912 to 1916 the developed water power in Finland was increased 26,000 horsepower, and from 1915 to 1916, during the war, it was increased 4,500 horsepower. If the rate of increase last given is applicable to the period 1916–1920 the total developed power in 1920 was about 185,000 horsepower.

The potential water power of Finland is estimated at 1,500,000 to 2,500,000 horsepower.

Primary power developed in Finland, 1909-1916.

Year.	Water power.		Steam and gas.		Total (horsepower).
	Horsepower.	Per cent of total.	Horsepower.	Per cent of total.	
1909	119,485	57.4	89,229	42.6	208,714
1910	123,064	54.0	105,085	46.0	228,149
1911	133,766	55.0	109,375	45.0	243,141
1912	138,465	53.0	122,500	47.0	260,965
1913	143,657	50.8	138,806	49.2	282,463
1914	154,560	51.7	144,948	48.3	299,508
1915	160,031	51.0	153,851	49.0	313,882
1916	164,773	51.9	152,509	48.1	317,282

Distribution of water power by industries in Finland, 1916.

	Horsepower.	Per cent of total.
Pulp and paper manufacture	92,742	56.3
Manufacture of food, drink, etc	28,880	17.5
Lighting, waterworks, transportation	22,004	13.4
Textile industries	7,621	4.6
Foundries and metal manufactures	6,760	4.1
Miscellaneous	6,766	4.1
	164,773	100.0

Esthonia, Latvia, and Lithuania.—Narova River, in Esthonia, has a fall of 100 feet in a distance of 45 miles, and half of this fall is confined within a distance of 4½ miles. Part of this fall has been utilized in a plant near Ivangorod (Narva), which in 1910 was described as the only large plant in Russia, but its exact capacity is not known. The total potential power of Narova River is estimated at 70,000 horsepower. The Dvina in its lower course crosses this area but can afford little power.

Although the Memel (or Nieman), which flows partly in Lithuania, is a long river, the country it traverses is low and it can probably furnish not more than 50,000 horsepower. The total potential water power of these countries is estimated at 200,000 horsepower, of which probably not more than 20,000 horsepower is developed.

Poland.—Poland lies north of the Karpathian Mountains, in which are the headwaters of the Vistula, the only large river in the country. The Vistula and the other streams that rise in these mountains should furnish 75,000 to 100,000 horsepower. The lower reaches of the Vistula have flat gradients and are of no value for power. The parts of West Prussia and Posen that were transferred to Poland should supply 55,000 horsepower, and the area ceded to Poland by Russia should supply an additional 50,000 horsepower. The total undeveloped power at low water is therefore about 175,000 horsepower. From figures available for Prussia and Galicia in 1908 and for Russia in 1910 the total developed power in what is now Poland is estimated at 66,000 horsepower in 1910 and 80,000 horsepower in 1920.

Ukraine.—The boundaries of Ukraine are uncertain, but it is assumed that they include all of southwestern Russia as far east as the Sea of Azof.

The water-power resources of the region consist of the rapids of the Dniester (about 100,000 horsepower), of the southern Bug (about 40,000 horsepower), and of the Dnieper. All these rapids occur where the rivers pass through the continuation of the Karpathian foothills and are of comparatively small fall. The Dniester rises in Ukraine, but through a large part of its course it forms the boundary between Ukraine and Rumania, and at least a third of its potential water power must be credited to Rumania.

The site that will afford the largest potential water power is at the Dnieper rapids, between Ekaterinoslaf and Alexandrovsk. These rapids are in the navigable part of the Dnieper and constitute one of the greatest obstacles to navigation between the Black and Baltic seas. A scheme for their utilization has been worked out in detail, but the construction of dams and power plants was prevented by the World War. The total potential water power of this southwestern region of the former Russian Empire, which now embraces Ukraine and several other small republics, is estimated at 425,000 to 1,400,000 horsepower. Any estimate of the developed power must be very rough, as there are now available only the general figures for Russia in 1910 and for Galicia in 1908, but these figures indicate that the developed power in this area in 1920 was about 40,000 horsepower.

Caucasus region.—The region of the Caucasus is occupied by three new States—Georgia, Azerbaijan, and Armenia—and contains water-power resources amounting to several million horsepower. A few rivers that have been studied could yield more than 1,500,000 horsepower, which is concentrated chiefly in the more humid parts of the western Caucasus. The falls are high, some of them measuring more than a thousand feet, and the discharge of the rivers is large, so that the power in this region can be developed cheaply. At many sites the cost will be within the limit of the profitable establishment and operation of electrometallurgical and electrochemical industries, which require the cheapest power.

Among the rivers of the Caucasus region that have been more or less thoroughly investigated the following may be mentioned:

	Horsepower.
Northern Caucasia:	
Terek	100, 000
Malaia (Little) Laba	95, 000
Belaia	20, 000–30, 000
Kuban	60, 000–70, 000
Trans-Caucasia:	
Rion	180, 000–200, 000
Ingur	50, 000
Belaia Aragva	60, 000
Coast of Black Sea:	
Kodov, with tributaries	210, 000–220, 000
Bzib	100, 000
Mzinto	60, 000

The total potential water power in the Caucasus region may be estimated at 5,000,000 to 12,500,000 horsepower. Probably not more than 5,000 horsepower is developed, all of it in small units.

Germany.—The water-power resources of Germany are found mainly along its southern and western boundaries, in the Alpine regions of southern Baden and Bavaria, and along the upper reaches and tributaries of the Rhine and the Danube. The lower reaches of the principal rivers of Germany, such as the Rhine, the Weser, the Elbe, and the Oder, have gradients so flat that their large volumes of water do not afford power sites that can be profitably utilized. Some potential water power is found on the headwaters of the Weser in Westphalia and Thuringia, on the tributaries of the Elbe in Prussian Saxony, and on the upper Oder. The chief water powers of the Elbe, however, are on its headwaters and upper tributaries in Bohemia, now a part of Czecho-Slovakia.

The estimated potential water powers of Prussia are distributed as follows:

	Horsepower.
East Prussia (including plebiscite area)	47, 000
Silesia	65, 000
Saxony	63, 000
Westphalia	50, 000
Other provinces	25, 000
	250, 000

Most of the water power of Baden is in the stretch of the Rhine between Neuhausen, at the falls of the Rhine, and the city of Breisach. In this stretch there is about 400,000 horsepower, half of which is assigned to Baden and half to Alsace-Lorraine and Switzerland, which here border the Rhine. In Baden there is also considerable water power in the Black Forest, particularly in the valleys of the Murg, Kinzig, Wutach, Alb, and Wehra. The total power for Baden is estimated at 280,000 horsepower.

The estimated water power of Württemberg is about 58,000 horsepower, two-thirds of which is on the Danube, Neckar, Enz, and Nagold, and one-third on the Kocher and the Jagst, in the north, and on the Schussen and the Argen, which empty into Lake Constance, in the south.

The largest water-power resources of Germany are in Bavaria. The southern tributaries of the Danube, which rise in the Alpine areas of Swabia and Upper Bavaria, can furnish a total estimated water power of 1,900,000 horsepower, 37 per cent of which, or 703,000 horsepower, is capable of development. The reduction of the figure last given by an efficiency factor of 75 per cent gives an effective horsepower of 527,000. The remaining part of Bavaria, in which the surface is flatter, is estimated to have only 138,000 horsepower, making a total of 665,000 horsepower for the whole of Bavaria.

For the remaining subdivisions of Germany no reliable estimates of potential water power are available, but the aggregate amount is small. The items and the total for the subdivisions described above are as follows:

	Horsepower.
Prussia	250, 000
Baden	280, 000
Württemberg	58, 000
Bavaria	665, 000
	1, 250, 000

No recent data are available concerning the amount of water power that has been developed. Figures published in 1912, presumably representing conditions in 1907, give the amount and distribution of primary power listed below, except that the figures for Prussia have been corrected to allow for the loss of parts of West Prussia and Posen.

Primary power installed in Germany in 1907.

Subdivision.	Water power.		All other power.		Total (horsepower).
	Horsepower.	Per cent of total primary power.	Horsepower.	Per cent of total primary power.	
Prussia	250,000	4.9	4,901,000	95.1	5,151,000
Baden	65,000	26.7	179,000	73.3	244,000
Württemberg	69,000	30.1	160,000	69.9	229,000
Bavaria	213,000	33.2	429,000	66.8	642,000
Saxony	122,000	15.0	688,000	85.0	810,000
All others	70,000	5.5	1,208,000	94.5	1,278,000
	789,000	9.4	7,565,000	90.6	8,354,000

The figures for water power presumably represent the capacity of the water wheels installed rather than the effective power actually developed. Without doubt a much larger total is developed to-day. The most significant fact, however, is the minor part that water power plays or could play in German industry, for the total water-power resources of the country, even in 1907, were less than one-sixth of the industrial power required.

From 1895 to 1907 the capacity of the water-power plants installed in Germany increased at an average rate of 20,000 horsepower annually. The total capacity of the installed plants in 1920 is estimated at 1,000,000 horsepower.

Austria.—Austria lies wholly in the drainage basin of the Danube. Some of the principal tributaries are the Inn, which drains the northern slopes of the Tyrolean Alps; the Enns, which drains the northern slope of the Styrian Alps; and the Drave, which, through its tributary the Mur, drains the southern slope of the Styrian Alps and the Carinthian Alps. Most of the potential water power of Austria is in the Alpine region, on the headwaters of the Drave, the Mur, the Enns, and the Inn.

The four provinces of Vorarlberg, Tyrol, Styria, and Carinthia contained less than 10 per cent of the area of the Empire of Austria-Hungary but were credited with 44 per cent of its water power. Practically all the former area of these provinces is now included in Austria, the only considerable loss being the southern part of Tyrol, drained by tributaries of the Adige, which has been added to Italy. The total potential water power of Austria is estimated at 3,000,000 horsepower, of which 2,000,000 horsepower is at 283 surveyed sites. Plants at 16 of these sites are under construction.

Potential water power at surveyed sites in Austria.

Subdivisions.	Number of sites.	Horsepower.
Styria	85	446, 000
Upper Austria	28	434, 000
Carinthia	42	344, 000
Lower Austria	32	308, 000
Tyrol	48	278, 000
Vorarlberg	26	130, 000
Salzburg	22	112, 000
	283	2, 052, 000

The editors of "Elektrotechnik und Maschinenbau," a publication of the Electro-Technical Society of Vienna, estimate the developed water power in Austria in 1920 at 150,000 horsepower. This estimate is understood to include only plants of 1,000 horsepower or more. The American commissioner in Austria places the total developed power in July, 1921, at 205,000 horsepower. After the armistice was declared the Austrian Government adopted a program for electrifying part of the railroads, but construction has not yet been started. An appropriation of 75,000,000 crowns was made by the State in 1919 for the enlargement of hydroelectric plants and for assistance to such associations as will form a part of a new national power system. All water power plants will be built by the State, and it is planned to install machinery capable of a maximum output of 500,000 kilowatts, this work to be completed in 50 years.

Hungary.—Hungary, like Austria, is wholly in the drainage basin of the Danube. The principal tributaries of the Danube within its borders are the Theiss, which drains the southern slopes of the main Karpathians, and the Drave, which forms a part of its southern boundary. The potential water-power resources of Hungary are estimated at 150,000 horsepower, and the developed power in 1920, as estimated from figures available for 1908, is about 30,000 horsepower.

Czecho-Slovakia.—With the exception of Bohemia, which is in the drainage basin of the Elbe, and of the part of Silesia that is in the drainage basin of the Oder, all of Czecho-Slovakia is in the drainage basin of the Danube, and the principal tributary of the Danube in the country is the March, which drains Silesia and Moravia. The Little Karpathian Mountains extend along the eastern edge of Moravia, and the Tatras and the west end of the main Karpathians, which form the northeastern boundary of the country, contain many power sites. The potential water-power resources of Czecho-Slovakia, including the small plebiscite area in Silesia, are estimated at 420,000 horsepower. The power developed in this area amounted in 1908 to 30,000 horsepower and in 1920 to about 40,000 horsepower.

Jugo-Slavia.—The Dinaric Alps, which extend along the coast of the Adriatic, turn most of the drainage of Jugo-Slavia eastward to the Danube, whose principal tributary is the Save, which in turn has two main tributaries, the Drina and the Morava. The Vardar, in southern Serbia, flows southward to the Gulf of Saloniki. Water-power sites are plentiful throughout the country, but little progress has been made in utilizing them. More than 230,000 horsepower may be obtained in the basin of Lim River. An unknown amount of power could be obtained by diverting water from the Tara into the basin of the Moraca, in Montenegro, and many power sites are available on the Ibar. Engineers have estimated that 340,000 horsepower can be developed in the part of the basin of the Vardar that lies in Jugo-Slavia.

In Dalmatia there are four plants on Kerka River, which have a total capacity of 31,600 horsepower and furnish power to carbide furnaces. Cetina River is capable of furnishing 200,000 horsepower, and a contract was let before the World War for a plant of 40,000 horsepower near Almissa. A plant of 3,500 horsepower furnishes power for municipal uses in Belgrade. Nearly all the minor plants are at flour mills, whose machinery is driven directly by water power. Seventy-nine such mills were in operation in Serbia in 1905. In the city of Leskovatz about 350 horsepower is used by textile mills.

In 1911 the Government of Montenegro, now part of Jugo-Slavia, granted a concession for the construction of two hydroelectric power stations, one of 80,000 horsepower capacity, at Kolashin, on Tara River, and one of 5,000 horsepower capacity, at Podgoritza, on Moraca River. The Kolashin plant will supply power to the iron mine near Antivari.

The total potential power in Jugo-Slavia is estimated at 2,300,000 horsepower, of which 1,200,000 horsepower is within the boundaries of the former Kingdom of Serbia, 500,000 horsepower in Bosnia and Herzegovina, and 200,000 horsepower in Montenegro. The developed power amounted to about 104,000 horsepower in 1909 and is estimated at 125,000 horsepower in 1920.

Rumania.—Transylvania (formerly part of Hungary), Bukowina, and Bessarabia have been transferred to Rumania, whose water-power resources have been thereby largely increased. The rainfall is plentiful. The whole country except Bessarabia is mountainous, and water-power sites are numerous and well distributed. The principal rivers are the Danube, the Pruth, which flows into the Danube, and the Dniester, which forms the northeastern boundary of the country. The Maros, a tributary of the Theiss, in Hungary, drains the northern slope of the Transylvanian Alps. The potential water power of Rumania is estimated at 1,100,000 horsepower, of which 300,000 horsepower is in territory recently acquired. The developed power is estimated at 30,000 horsepower, and most of it is used at small mills where it is not converted into electricity.

Bulgaria.—The Balkan Mountains extend across Bulgaria, and the Rhodope Mountains form a part of its southern boundary. Although the precipitation is much less in Bulgaria than along the west coast of the Balkan peninsula the mean annual rainfall amounts to 26 inches and produces sufficient run-off to furnish a large amount of potential power. The north half of the country is drained by tributaries of the Danube, most of the southern part is drained by the Maritza, and the southwest corner lies in the basin of the Struma. It has been estimated that 150,000 horsepower can be developed in the part of the basin of the Struma that lies in Bulgaria. There are a few small hydroelectric plants in Bulgaria, but the power developed by water is used chiefly in flour and woolen mills, whose machinery is driven directly by water power. The undeveloped power, however, represents a natural resource that can be made highly serviceable in the industrial development of the country. Part of the electric power required by Sofia is supplied by a 1,600-kilowatt plant at Pantcharevo, where a head of 180 feet is used.

In 1910 the capacity of water motors and turbines installed in Bulgaria amounted to 5,810 horsepower. In 1920 it was about 8,000 horsepower. The water-power resources of Bulgaria are estimated at 1,200,000 horsepower.

Albania.—The annual precipitation in Albania is 40 to 60 inches, so that although the country is small it contains abundant water power. The principal rivers are the Drin, Shkumbi, Semeni, and Viosa. There are many sites for storage reservoirs, in which variations of 3 to 6 feet in water level represent large storage capacity. The Drin and its tributaries can furnish 410,000 horsepower if available storage sites are utilized, although the utilization of the large basins of Ohrida and Presba lakes, which border on three States, involves difficult questions of water rights. Albania is probably more backward even than the other Balkan States in the utilization of its water power, which is used only by small flour and spinning mills. No exact figures for the developed power are available, but it is estimated roughly at 1,000 horsepower and the potential power at 500,000 horsepower.

Greece.—In most parts of Greece the conditions are unfavorable for the development of water power. In the Province of Thessaly torrential streams can produce considerable power during the rainy season, but they become dry ravines during the rainless season. The construction of hydroelectric plants is therefore not practicable unless storage reservoirs can be provided. A Swiss engineer, in a report made to the Greek Government in 1920, estimates that the waterfalls of Macedonia can produce 350,000 horsepower, of which 286,000 horsepower would be obtained from Vistritza River. This estimate probably contemplates the use of storage. The developed power is contributed mainly by the cataracts of Verris, Niausta, Vodena, and Vladova. The waterfalls of Verris, above and below the town of Veria, can produce 2,000 horsepower, of which about 600 horsepower is now used by flour and spinning mills. The waterfalls of Niausta, in Aripitza River, could yield 4,000 horsepower if modern hydraulic machinery were installed. In 1914 about 1,480 horsepower was used by spinning mills. In addition to the power available at Niausta 1,000 horsepower may be developed at a waterfall not far from the village of Mouskoni, near Niausta. In order to obtain this power it would be necessary to augment the flow at the cataract by diverting water from Aripitza River. The waterfalls at Vladova are formed by the outflow from Nisson Lake and other waters near Vladova. The falls are 490 feet high and can produce 6,000 horsepower, none of which has been developed. The waterfalls of Vodena, which are fed by springs and by water flowing from Vladova Falls, are capable of yielding 7,000 horsepower. Of this amount spinning mills were using 1,060 horsepower and flour mills 1,000 horsepower in 1914. The potential power in Greece is estimated at 250,000 horsepower, of which 6,300 horsepower was used in 1920.

Turkey.—Turkey in Europe is now a small area with meager water-power resources.

Italy.—The total water-power resources of Italy are estimated at 5,500,000 horsepower at ordinary river stage, 3,800,000 horsepower at ordinary low flow, and 2,700,000 horsepower at extreme low flow. Of these quantities 500,000 horsepower at ordinary river stage, 300,000 horsepower at ordinary low flow, and 200,000 horsepower at extreme low flow represent a rough estimate of the power resources of the part of Tyrol that has recently been acquired by Italy.

Most of the potential power is in the Alps and Apennines, in northern Italy, on streams that flow from these mountains to the Po. The combination of great slope in the mountain streams with well-sustained discharge from melting glaciers at the sources and from artificial storage in mountain lakes that have been converted into reservoirs has made the Alpine region of Italy one of the richest in all Europe in potential water power. The provinces of Piedmont, Lombardy, and Venetia are best supplied not only with water-power plants but with valuable sites that are not yet utilized. The part of the Austrian province of Tyrol drained by the Adige was ceded to Italy and has much potential power as well as some utilized power sites. The minor part of the power of Italy is well distributed through the central and southern parts of the country, generally in power plants or at unutilized sites of small capacity.

A total of about 1,100,000 horsepower has already been developed and used for the ordinary public utilities—tramways, lighting, heating, and small power markets; for the operation of railroads; and for textile, paper, electrochemical, and metallurgical industries.

Sicily had 10,000 horsepower of developed water power in 1918, and this was being increased to 25,000 horsepower. Its potential power at low flow has been estimated at 145,000 horsepower, and that of Sardinia at 18,000 horsepower.

Switzerland.—Switzerland is at the headwaters of the Rhine and the Rhône and of tributaries of the Danube and the Po. The rainfall is plentiful, and the flow of the streams is to some extent equalized by numerous lakes, aided by glaciers, so that the potential water power is great, even during periods of low flow. Lakes that can be cheaply adapted to storage may be used to increase the potential power.

In a paper published in the Annales de géographie in November, 1918, Léon W. Collet, former director of the Swiss Bureau of Waters, gives the available data on the developed and undeveloped power of Switzerland. Most of the figures given here are taken from Collet's paper.

The potential water power has been estimated at 750,000 horsepower at low water and 2,500,000 horsepower for flow available six months of the year, and one engineer states that 3,000,000 horsepower may be developed at low water with storage. An estimate made by the Bureau of Waters January 1, 1914, follows:

	Horsepower.
For ordinary low flow	878,000
For nine months' flow	1,374,000
For six months' flow	2,504,000
For flow equalized by reservoirs	2,173,000

Undeveloped power in Switzerland, in net continuous horsepower.

River basin.	For ordinary low flow.	For nine months' flow.	For six months' flow.	For constant flow by means of storage reservoirs.
Rhine, from its source to the Aar	212,372	331,937	601,269	597,507
Aar	109,398	199,650	338,445	383,491
Reuss	66,622	107,669	246,695	155,077
Limmat	35,540	65,961	142,661	112,128
Rhine, from the Aar to Hunigue	78,170	117,466	155,001	98,270
Rhône	182,097	258,130	294,715	392,710
Tessin	125,940	200,804	347,534	243,030
Adda	6,860	11,605	24,325	58,890
Inn	58,585	77,110	147,430	125,125
Adige	2,200	3,320	5,510	7,010

Water-power plants of more than 20 horsepower in operation in Switzerland January 1, 1914.

Minimum constant capacity (horsepower).	Number of plants.	Total mean capacity at time of development (horsepower).
20-99	561	36,042
100-999	217	92,909
1,000-4,999	41	139,927
5,000-9,999	10	100,940
10,000 or more	6	117,400
	835	487,218

Water power used by industries in Switzerland in 1914.

	Number of plants.	Total capacity (horsepower).			Percentage of mean total.
		Maximum	Minimum.	Mean.	
Hydroelectric power plants	258	563,235	207,473	311,816	63.98
Textile industries	222	41,497	18,976	31,016	6.39
Food and drink	88	6,580	3,564	5,162	1.06
Chemical and electro-metallurgical industries	26	201,148	60,285	113,834	23.36
Paper making and printing	44	11,516	4,085	7,471	1.53
Wood working	91	5,611	3,172	4,245	.87
Reduction of metals	32	5,844	2,498	4,331	.89
Machinery and apparatus	23	2,008	1,335	1,940	.40
Jewelry and clock and watch making	6	766	346	451	.09
Construction materials and salt works	45	9,462	4,797	6,952	1.43
	835	848,017	306,531	487,218	100.00

One of the interesting features of the developed power in Switzerland is the large number of small plants. The plants having capacities below 20 horsepower numbered 6,025, and their total capacity was only 38,880 horsepower, or an average of about 6 horsepower each.

On January 1, 1918, the number of plants of more than 20 horsepower had increased to 840, and their capacity at mean stage had increased to 556,200 horsepower. If to this we add the 38,880 horsepower developed in the smaller plants, we get a total of 595,080 horsepower developed at mean stage. The maximum installed power in 1914 amounted to 848,000 horsepower for plants of more than 20 horsepower, and accordingly the maximum installed power on January 1, 1918, would be 968,000 horsepower for plants of more than 20 horsepower and 1,007,000 horsepower for all plants. If the rate of increase between 1918 and 1920 was the same as that between 1914 and 1918 the maximum installed capacity on January 1, 1920, would be

1,067,000 horsepower. This is apparently 189,000 horsepower more than the total potential power at low water; but in 1914 the maximum installed capacity of plants of more than 3,000 horsepower at low water was 716,000 horsepower, and their capacity at low flow was only 258,000 horsepower. At Olten and Gösgen, on the Aar, the installed capacity is 80,000 horsepower and the capacity at minimum flow is only 17,000 horsepower. At Augst-Wyhlen, on the Rhine, the installed capacity is 62,400 horsepower and the capacity at minimum flow is 24,000 horsepower. Considerable progress has been made in combining plants that have large and continuous power but no storage with plants that have high head and storage. Such a combination lends itself to an apparent large overdevelopment. A plant at Lake Fully, in the Valais district, utilizes the remarkably high head of 5,413 feet.

Under present conditions of regulation of flow about 43 per cent of the total potential water power at low water in Switzerland is developed, but if the potential storage can be made available then only 17 per cent of the potential power at low water is developed. As most of the means of storage will ultimately be utilized the percentage last given is probably more nearly correct.

Denmark and Netherlands.—At one water-power site in Denmark on Guden River 1,500 horsepower has been developed. Aside from this there is no potential water power in either Denmark or the Netherlands. Denmark imports hydroelectric power from Sweden over a submarine cable.

Belgium.—There is said to be some potential water power in eastern Belgium, but it can not be great. A project for the prevention of floods on Ourthe River would make a head of 300 feet available at the town of La Roche. There are 26 small water-power plants in Belgium in which the maximum capacity is 40 horsepower and the total capacity 700 horsepower.

Great Britain.—On the whole the British Isles are low, but a plentiful supply of rain well distributed through the year gives them some potential power. The annual rainfall for the whole area averages 39 inches, but at places in the Scottish highlands, in Wales, and in small areas in the English lake district it exceeds 100 inches. The largest potential powers also are in the Scottish highlands, where, according to an estimate by Alexander Newlands, 375,000 horsepower can be made available for a 12-hour day. This estimate shows the potential power at individual sites and takes no account of any means of storage or of lack of means of storage, so it may be assumed to represent the total potential water power of Scotland without regulation. The continuous power would be half this amount, or perhaps 200,000 horsepower. A later estimate, based on studies of the Water Power Resources Committee, places the continuous power available at 400,000 horsepower, including the use of storage incidental to the development of the sites. The largest developed power in the British Isles is also in this district, at Kinlochleven, where there is a 30,000-horsepower plant for the production of aluminum, to be supplemented by the development of 72,000 additional horsepower at Fort William. The flow is controlled, however, and this amount of power is available for only a 12-hour day. The same company has a 7,000-horsepower plant at Foyers, on Loch Ness.

The water powers of Scotland occur at many sites, nearly all of which can be utilized easily and cheaply. Most of the potential power sites in England and Ireland are on rivers that have low heads. Ireland is favored by the fact that it is a low plateau on which the rivers attain their maximum size before they descend rapidly to the sea in the last few miles of their courses. Wales is a rugged country somewhat similar to northern Scotland, and considerable power has been developed there.

By comparison of the figures showing rainfall and altitude in the different countries of Great Britain and by computation from the estimates of potential power at known sites in Scotland similar estimates have been made for England, Wales, and Ireland. These estimates represent the potential power during a 12-hour day, and they have been reduced almost one-half to represent continuous power.

Estimated potential water power in Great Britain.

	12-hour horsepower.	Continuous horsepower.
Scotland	375,000	200,000
England	281,000	150,000
Wales	109,000	60,000
Ireland	359,000	175,000
	1,124,000	585,000

By the use of storage the above figures could be practically doubled, as the total potential power in Great Britain, with the use of storage incidental to the development of the sites, has been estimated by the Water Power Resources Committee at 1,000,000 horsepower.

These estimates do not include possible tidal power. A scheme for the utilization of the tidal power at the mouth of Severn River proposes the development of 350,000 horsepower during a 10-hour day.

The total developed water power of Great Britain is estimated by the water-power committee of the Conjoint Board of Scientific Societies at 210,000 horsepower.

Iceland.—Iceland is mountainous, and the precipitation in the southern half is 40 to 60 inches, so that it has a large amount of potential power. The island itself supplies practically no market for power, so that its development must wait the establishment of electrochemical or other industries which require large amounts of cheap power and whose products could be shipped to Europe and America. The Thjorsa is the largest river in Iceland, and six possible sites on this river and its tributaries are said by Saetermoen, a Norwegian engineer, to have a potential capacity of 1,114,000 horsepower. No power has been developed, and the resources of the island are not well known. An estimate based on rainfall and altitude would make the potential power about 500,000 continuous horsepower at ordinary low flow.

France.—The water powers of France are found along the eastern and southern borders, in the Vosges, Jura, Alps, and Pyrenees. The largest powers are in the northern Alps and on the Avre, Isère, and tributaries of the Rhône. The Rhône itself has potential power estimated at 822,000 horsepower at low water. Concessions have been granted for the construction of plants to utilize this power, and it is expected that all the plants will be completed by 1925. In the southern Alps there are many power plants on the Drome and Durance. At Fond-de-France (Buda) a head of 3,440 feet is utilized.

The water powers of Alsace-Lorraine are in the Vosges Mountains and along the Rhine. Those in the Vosges have high heads and numerous sites for storage reservoirs; those along the Rhine have low heads and no storage sites except such as are provided naturally by the lakes at its headwaters. If half of the water power of the stretch of the Rhine that forms the eastern boundary is credited to Alsace-Lorraine the total for those provinces is about 100,000 horsepower.

Some idea of the location of the water powers of France and the relative importance of the several regions can be obtained from the following tables, which are taken from official, consular, and commercial reports. The first table shows the estimated potential power of the country and the third the distribution of plants completed since 1915 and of those planned for completion before 1921. Though all this power may not have been developed by 1921 the figures indicate the relative amount of development taking place in different regions. The plants already completed develop 738,000 horsepower in the Alps and 217,500 in the Pyrenees, and these amounts together constitute two-thirds of the total developed power in France.

Potential water power in France.

Region.	Horsepower.	
	Low water.	Average flow.
Northern Alps	1,000,000	2,000,000
Southern Alps	1,300,000	2,600,000
Central Alps, Vosges, Jura Mountains	900,000	1,800,000
Pyrenees and elsewhere	1,500,000	3,000,000
	4,700,000	9,400,000

Use of developed water power in the Alpine region of France.

	Horsepower.	Per cent.
Light and power	291,000	39.4
Electrometallurgical industry	255,000	34.6
Electrochemical industry	147,000	19.9
Electric traction	16,000	2.2
Paper mills, sawmills, etc	23,000	3.1
Other industries	6,000	.8
	738,000	100.0

Of the above total developed power the drainage basin of the Isère supplied 427,000 horsepower and that of the Durance 112,000 horsepower.

Water-power plants planned or completed in France since 1915.

	Horsepower.
Alps	428, 000
Pyrenees	185, 000
Central France	200, 000
Jura and Vosges	35, 000
West	2, 000
	850, 000

Distribution of water power in France, by industries.

	Horsepower.
Industrial uses, including light and traction service	308, 000
Electrochemistry	216, 000
Electrometallurgy	326, 000

Progress in development of water power in France.

	Horsepower.
Prior to 1899	150, 000
1905	450, 000
1910	650, 000
1913	750, 000
1914	800, 000
1918	1, 250, 000
1921 (estimated)	1, 600, 000

Of the contemplated increase between 1918 and 1921, plants having a capacity of 175,000 horsepower were being constructed in 1919.

The following estimates were prepared by the Secretary of Public Works:

Potential water power on navigable streams in France.

	Horsepower.
Streams flowing into the North Sea	18, 072
Seine River	26, 736
Smaller streams flowing into the English Channel	1, 520
Loire River	279, 047
Smaller streams flowing into the Atlantic Ocean	19, 933
Garonne River	322, 978
Adour River	2, 298
Rhône River	1, 536, 645
Smaller streams flowing into the Mediterranean Sea	34, 805
	2, 242, 034

The total developed power in France in 1920 is estimated at 1,400,000 horsepower, and the total potential power at low water at 4,700,000 horsepower.

Spain.—Spain has a higher average altitude than any other country in Europe and contains many power sites, but the rainfall is small except on the northeastern coast. The principal rivers, all of which afford potential power, are the Duero, Tagus, Guadiana, Guadalquivir, and Ebro. The largest plants are on Ebro River; on Segre River, a tributary of the Ebro; and on Júcar River west of Valencia. The power is transmitted to Barcelona, Valencia, and Madrid, where it is used for municipal and industrial purposes. A commission has investigated the potential water powers of Spain with a view to their utilization by the Government, including a transmission system covering the whole country. The following table, from the Electrical World of July 19, 1919, gives an estimate, prepared by this commission, of the undeveloped power at sites of 2,000 horsepower or more:

Waterfalls in Spain having potential power.

	Horsepower.
Atlantic slope of León and Galicia	70, 000
Asturias	40, 000
Santander	30, 000
Ebro before reaching Saragossa	65, 000
Rivers from slopes of the Pyrenees	490, 000
Ebro, from Saragossa to the Atlantic Ocean	130, 000
Duero in Spain	90, 000
Duero on Portuguese frontier	150, 000
Tributaries of the Duero	50, 000
Tagus	110, 000
Tributaries of the Tagus	50, 000
Guadiana	35, 000
Guadalquivir and other Andalusian rivers	40, 000
Júcar and Cabriel	90, 000
Other rivers on Mediterranean slope	60, 000
Minor falls	500, 000
	2, 000, 000

The following table has been compiled from the official Anuario estadístico de España:

Hydroelectric power installed in Spain in 1917.

Company.	Potential horsepower.	Horsepower in use.
Large plants:		
S. A. Fuerzas y riegos del Ebro	301,700	35,283
S. A. Energia eléctrica de Cataluña	200,000	50,000
S. A. Hidroeléctrica española	44,000	44,000
S. A. Sociedad general de fuerzas hidro-eléctricas	42,000	42,000
S. A. Hidroeléctrica ibérica	30,000	16,000
S. A. Unión eléctrica madrileña	21,000	14,000
Canal de Isabel II	18,000	6,000
S. A. Eléctricas reunidas de Zaragoza	12,600	12,600
Narciso H. Vaquero y Cía	12,000	6,000
S. A. Eléctrica de Viesgo	11,500	11,500
S. A. Hidráulica Santillana	{ 30,000	----------
	9,750	9,750
S. A. Fuerzas motrices del Gándara	9,000	9,000
S. A. Porvenir de Zamora	8,000	4,500
54 other companies	108,794	100,924
Medium-sized plants (29 companies)	14,795	14,795
Small plants (74 companies and firms)	7,945	7,945
	881,084	384,297

The potential water power of Spain at ordinary low flow, including the total potential power at sites already utilized, is estimated at 4,000,000 horsepower. Statistics prepared by the Unión eléctrica española show that the developed water power in 1920 was about 600,000 horsepower.

Portugal.—Except along the Spanish border Portugal is a low region, and although the rainfall ranges from 20 inches in the south to 40 or even 60 inches in the north, the potential power is not great. Three of the large Spanish rivers, the Duero (Douro), Tagus, and Guadiana, cross Portugal. Of these the Duero is estimated to have 217,000 potential horsepower in the part of its course where it forms the boundary between Portugal and Spain. Half of this power would therefore belong to Spain. Other small powers would probably increase the total for Portugal to 300,000 horsepower. There are no large water-power plants in the country, and the total developed power is estimated at 10,000 horsepower.

ASIA.

Asia, the largest continent, is about 1,000,000 square miles larger than North America and South America combined. The chief feature of its drainage system is the great plateau between India and China, the highest plateau in the world, which ranges in altitude from 10,000 to 27,000 feet. From this plateau the surface slopes northward to the borders of Siberia, but even there it has an altitude of 2,000 feet. The high country continues toward the west, extending south of the Caspian and Black seas almost to Constantinople. This high plateau is the source of all the large rivers of Asia. (See map on p. 4.)

A second characteristic of Asia is the extent of the inland drainage system, which has an area greater than that of the United States. The drainage basin of the Caspian Sea extends into Europe and includes the Volga and the Ural, whose basins constitute a large part of European Russia. Another feature of the drainage is the scarcity of fresh-water lakes: Lake Baikal and Lake Balkash are the only large ones. The south side of the high plateau is well watered by the moisture carried by warm winds from the Indian Ocean, but the high mountains intercept all the moisture borne by these south winds, and the cold winds from the north bring little rain. (See map on p. 5.) The largest part of the continent therefore receives comparatively little precipitation; only India, French Indo-China, and a strip along the coast of China that reaches Sakhalin Island and Japan have a plentiful supply. The rivers flowing northward therefore do not attain large size until they reach their lower levels, and their potential power is correspondingly small. Although there is considerable power in the well-watered sections, which are the most thickly inhabited, little of it has been developed, except in Japan. This lack of development is not due to any lack of need of power, for more than half the inhabitants of the world live in Asia. The richer and better-educated people are beginning to realize the convenience of electric light, and some manufactures are springing up, so here and there over the continent hydroelectric plants are gradually being built. Japan, however, when it turned to manufacturing, soon learned the advantages of using water power and has developed nearly as large a percentage as the Scandinavian countries. In dividing Asia into drainage basins it was combined with Europe, for these two continents are physically one and their drainage basins overlap. The following descriptions, however, are confined to the parts of the basins in Asia.

201–205. *Arctic Ocean.*—The rivers that drain into the Arctic Ocean, the largest of which are the Ob, Yenisei, and Lena, rise along the northern edge of the great plateau of Asia and are navigable practically throughout their courses. The rainfall in the region is on the whole rather scant, being 10 to 20 inches a year in the southern half and less than 10 inches in the northern half, but as the basins are large the rivers carry a great deal of water. Their value as sources of power, however, in comparison with the large area of the basins, is small and is limited to a few of the headwater streams in the middle of the continent. No water power has yet been developed in this area, but as the Trans-Siberian Railroad crosses the high region south of Lake Baikal some power may eventually be developed for the electrical operation of this railroad.

212. *Caspian Sea.*—The great inland drainage basin that is tributary to the Caspian and Aral seas is in part in Asia and in part in Europe. The Caspian Sea receives several large rivers from Europe but no large one from Asia. Two rivers reach the Aral Sea, the Syr or Jaxartes and the Amu or Oxus. Many streams rise on the high plateaus of Afghanistan and Turkestan, but only two of them attain sufficient size in their upper courses to survive the loss from seepage and evaporation in their lower courses; all the others gradually disappear in the sands of the desert. The rainfall even in the upper parts of their drainage basins averages less than 20 inches a year, and it is less than 10 inches in the lower parts, so that although the streams have considerable fall in the mountainous areas they are not large, and their potential power is comparatively small. The flow of these streams in their lower courses is diminished by the use of their waters for irrigation.

213. *Central Asiatic basin.*—The great Desert of Gobi is in an inland drainage basin whose principal river, the Tarim, rises in the mountains of eastern Turkestan and empties into the marshy tract called Lake Lob. The river has considerable fall, as some of the mountains on its headwaters exceed 20,000 feet in altitude, and accounts by travelers indicate that the discharge in its middle courses at times reaches several thousand second-feet. Besides the Tarim a few other rivers descend from the mountains that surround this basin, but they are all absorbed in the desert. The country as a whole is very sparsely populated, for the rainfall is too scant to support agriculture without irrigation. The power resources are small.

210–C. *Eastern Mediterranean and Dead Sea.*—The part of Asia that lies within the eastern Mediterranean drainage area consists of the basins of a few short streams of Asia Minor and Syria that flow into the Mediterranean Sea. The country is comparatively high, but except in a narrow belt along the coasts the annual rainfall is less than 20 inches. The streams that empty into the Aegean Sea are formed by small tributaries from the mountains, which do not assemble into rivers until they are near sea level. The power sites along them are therefore generally of little or no value. The rivers that empty into the Mediterranean are very short and have steep slopes, and as most of the rainfall in this area occurs in the spring they fluctuate greatly in flow. A comparison of the plants that might be constructed on these rivers with the power plant on Cydnus River at Tarsus indicates that units of not more than 75 horsepower, and only five or six of these, having a total capacity of 300 horsepower, might be installed in this part of the area.

Only two water-power plants are known in this area. Tarsus has a lighting system supplied by an 80-horsepower plant on Cydnus River. Damascus has a hydroelectric plant, which is said to be a small affair, old and out of date. Before the war application had been made for a concession to utilize a waterfall at Lake Yummuneh. The fall is less than 100 feet, and as it is near the headwaters of Orontes River the amount of water is necessarily small, and not more than 100 horsepower can be developed. Orontes River is a small stream, which rises about 50 miles north of Damascus and flows parallel to the coast as far as Antakieh, the ancient Antioch, where it turns to the west and enters the Mediterranean. Jordan River would seem to afford some opportunity for the development of power. After leaving the swamp called Lake Huleh the Jordan falls 690 feet to the Sea of Galilee, in a distance of almost 10 miles, and from the Sea of Galilee to the Dead Sea it falls 610 feet in about 68 miles. No records of discharge are available, but the river is said to be barely fordable at extreme low water. On the assumption that the discharge is 750 second-feet and that 50 per cent of the fall can be utilized about 40,000 horsepower could be developed. Altogether the potential power of these drainage areas in Asia is small, and only a few hundred horsepower has yet been utilized.

211. *Black Sea.*—The Asiatic tributaries of the Black Sea, the largest of which is the Kizil, in Asia Minor, comprise many small streams, which rush down the steep slopes and might develop 20 to 50 horsepower each, but their number and potential power are not known. For the electrical supply of Constantinople a plant at the falls on Sakaria River has been proposed. A unit above the falls will have a head of 175 feet and

will furnish 14,000 horsepower; another unit below the falls will have a head of 115 feet and will furnish 7,650 horsepower. As these estimates assume that half the flow of the river may be diverted above the falls for municipal use the total potential power at this point is about 43,000 horsepower. Storage is possible, and more hydroelectric power might be produced farther up the river, so that although exact data are lacking the estimate of a total potential power of 65,000 horsepower for Sakaria River seems reasonable. By comparison of the drainage areas of other rivers flowing into the Black Sea whose rainfall, gradients, and other power characteristics are similar, the following estimates of potential power are obtained:

	Horsepower.
Kizil River	100,000
Yeshil River	40,000
Chorok River	30,000

No developed power is known in this region, and the undeveloped power is estimated to be about 300,000 horsepower.

214. *West Indian Ocean.*—The principal rivers whose waters reach the Indian Ocean between the Red Sea and Cape Comorin are the Tigris and the Euphrates, which drain a large part of Asiatic Turkey, and the Indus, the great river from which India takes it name.

Arabia has no available power: it is a desert without enough water even for irrigation.

The Tigris and the Euphrates offer the greatest amount of potential power in southwestern Asia. Both rise in the Taurus Mountains, where the sources of their headwater tributaries are 5,000 to 8,000 feet above sea level, and they flow in roughly parallel courses southeastward for 600 and 1,000 miles, respectively, to Bagdad, where they are 115 feet above sea level; and from Bagdad they flow for 590 miles through a combined delta system to the Persian Gulf. Although they are two distinct streams for the greater parts of their courses, they constitute a single drainage system and have always been used jointly for irrigation. Surveys had been made by a British engineer and the restoration of the ancient irrigation systems had been begun when, in 1914, the work was stopped by the outbreak of the World War. This work has been resumed since the Turkish armies were driven from the region, and it will eventually reclaim a large area. In connection with the irrigation system a small amount of power might be developed.

On the Tigris at the site of the ancient structure known as Nimrod's dam a head of 40 feet can be made available, and as the minimum flow of the river is 10,000 second-feet this head should produce about 30,000 horsepower. On the Euphrates near Bagdad a head of 30 feet is available, which with the minimum flow—10,000 second-feet—should produce 25,000 horsepower. The flow of the Tigris at flood stage, in March, April, and May, is 180,000 second-feet, and that of the Euphrates is 120,000 second-feet. At that time the head and consequently the power available would be greatly reduced unless large reserve turbine capacity could be provided. In the stretch of 500 miles above the proposed irrigation system near Bagdad the rivers fall 1,000 feet. Most of this fall occurs in the lower part of this stretch, where there may be some natural power sites. The banks are high, in few places as low as 50 feet and in general ranging from 100 to 300 feet. No large storage sites are available, but the fall could be concentrated at some places by dams constructed for the development of power. If 20 per cent of the 1,000-foot fall were utilized as head the combined minimum flow of the two streams, namely, 20,000 second-feet, would afford an aggregate of 325,000 horsepower, generated at many stations.

Although Persia is high the annual rainfall is less than 10 inches and the rivers are too short to attain large size. No developed power is known and the potential power is small.

The Indus rises high on the plateau of Tibet and drains a large intermountain area in Kashmir before it turns southward toward the lower levels. Although the rainfall in the higher parts of its drainage area is small the total area is so large that it becomes a considerable river before it leaves the higher altitudes, and the potential power on its upper course must be great. Jhelam River leaves the Kashmir Valley, which it drains, at an altitude of 5,000 feet and drops rapidly to the Chenab, a tributary of the Panjnad, which joins the Indus at an altitude of less than 1,000 feet. On the Jhelam about 11 miles above Srinagar there is a 7,000-horsepower plant, which originally supplied power to a silk factory in Srinagar and lighted that city. The factory has burned, and the plant has a capacity greater than the demand, although it uses only a small part of the available flow and was designed for an ultimate output of 20,000 horsepower. Power was supplied from this plant to dredge Jhelam River at the point where it leaves the Kashmir Valley in order to lower the water level during floods and to reclaim about 90,000 acres of land. Five electrically operated dredges were used in this work. It is also proposed to use this power to operate an aerial cableway 75 miles long across the Himalaya Mountains, which separate Kashmir Valley from the plains of northern India. Another hydroelectric plant in this region is in Afghanistan 50 miles north of Kabul. This plant, which was built by the same American engineer that installed the plant in Kashmir, has a capacity of a little more than 2,000 horsepower and is practically complete, but owing to the assassination of the Amir in February, 1919, and the resulting disturbances it has never been operated. As no fuel is available in Kabul and as wood is brought many miles to that city on the backs of camels, hydroelectric power should be a great benefit to this region. At Simla, a summer resort on the headwaters of Sutlej River in India, there is a plant for municipal lighting and pumping. This plant has a capacity of 1,800 horsepower, and a 700-horsepower extension is being added. The State of Patiala has installed a small plant for municipal use.

The Western Ghats are a range of mountains that extend along the west coast of the peninsula of India from Bombay southward for about 500 miles. The drainage areas of the streams in these mountains are small, but there is a fall of 3,000 feet, and there are sites for storage which might augment the natural flow so as to produce considerable power. About 43 miles from Bombay, to which the power is transmitted for industrial use, there is the largest hydroelectric plant in Asia outside of Japan. The rainfall from the middle of June to the middle of September in this region averages 175 inches, and this water is stored on two small streams to provide power for this plant, which has a capacity of about 60,000 horsepower. The demand for power exceeded the supply almost from the start, and as the capacity at the site is estimated at 110,000 horsepower for 300 days of 12 hours each year, considerable extensions are planned. The stream flow is practically all controlled, and this is a considerable advantage, as the load is entirely industrial. A plant is also under construction in the Andra Valley, where the potential power is about 100,000 horsepower. The total potential power of the Western Ghats is more than 500,000 horsepower.

The total power developed in the west Indian Ocean drainage area is about 75,000 horsepower, most of which is used for industrial purposes. The main undeveloped powers are those of headwaters of the Indus and those in the Western Ghats. As the development of the potential power on the Tigris and Euphrates would require very large plants and as the demand is small the chance for development is slight. The total potential power of the whole drainage area is about 6,500,000 horsepower.

215. *East Indian Ocean.*—The principal rivers that flow into the Bay of Bengal and drain southern Tibet, more than half of India, and the western part of the Malay Peninsula are the Salwin, Irrawaddy, Brahmaputra, and Ganges, rising on the Tibetan plateau, and the Mahanadi, Godavari, Kistna, and Kaveri, in southern India. This region is well watered, the rivers in the Himalayas have a large fall, and much of the potential power of Asia is in this drainage area.

Salwin River rises high on the plateau and attains a considerable size before it begins to drop to the lower plains. The Brahmaputra drains a large area along the southern Himalaya Mountains. About 200 miles west of Lassa it is more than 12,000 feet above sea level, and it crosses the northern border of India at an altitude of about 500 feet. As the river is large the power available in this stretch must be great, but as the upper basins of both the Salwin and the Brahmaputra are inhabited by half-savage Mongols, few white men have ever entered the country, and the development of power there, except on a small scale, is remote. The Irrawaddy rises at the edge of the mountains and in its upper reaches has potential power, but in its middle and lower courses it is a sluggish stream, navigable for 1,200 miles above its mouth. A ridge along the Malay Peninsula furnishes some power sites, but the drainage basins are small and no power can be developed without storage. All the developed powers in the peninsula are in the Federated Malay States, and, with the exception of a lighting plant at Kwala Lumpur, they are used only for mining. Two of the largest plants are in the State of Pêrak and have capacities of 440 and 1,500 horsepower, respectively.

In its upper courses the Ganges has considerable fall, the rainfall is heavy, and there is much potential power. Most of the sites, however, are unsurveyed and little known. To supply Delhi a concession was granted for a plant on Jumna River, on which 25,000 horsepower is available in a 12-mile stretch, but its construction has been delayed. Halfway between Mussoorie and Dehra, in the upper Ganges basin, there is a plant of 2,500 horsepower. In the independent State of Nepal, on the southern slope of the Himalaya Mountains, there is a plant of 650 horsepower, and at Darjiling, south of Sikhim, there is a plant of 900 horsepower. On Kaveri River, in southern India, in the Mysore Government, there is a plant having a capacity of 22,500 horsepower, which transmits power to the Kolar gold mines and to Bengalur and Mysore. In this locality there is said to be 100,000 horsepower capable of development, and as the demand exceeds the present supply and the plant has been a profitable investment extensions may be expected.

The island of Ceylon is high, and its minimum annual rainfall exceeds 100 inches, so it has abundant water power. The continuous power that could be made available at known sites is estimated at 264,000 horsepower, provided some water is stored. The potential sites have recently been examined by an engineer, who in his report to the Government recommends what is known as the Aberdeen-Laxapana scheme, named from two towns about 45 miles east of Colombo, near the junction of Kehelgomu and Maskeliya rivers, where the plant would be built. The catchment area is only 125 square miles, but by storage 96,000 horsepower can be made available under a gross head of 1,900 feet. An initial capacity of two or three units of 12,000 horsepower each is recommended. The power would be used in Colombo for electric lighting and railways, and a large percentage of it would be used by the tea industry, both in driving machinery and in drying. Most of the power used on the island is developed at small plants that supply tea factories, but no information is available as to the total quantity of power developed in this way.

The potential power of the entire east Indian Ocean drainage area is estimated at 23,000,000 horsepower, of which about 75,000 horsepower is developed.

216. *China Sea.*—The area draining into the China Sea extends from Singapore to Yangtze River and includes the eastern half of the Malay Peninsula, most of Siam, French Indo-China, and a tract in the southern part of the Chinese Republic. The principal river system is that of the Mekong, but West River, in China, and the Menam, in Siam, also drain considerable areas. The country drops down from the high Tibetan plateau to sea level. The rainfall on 90 per cent of the area exceeds 60 inches, and water power is abundant, but the people are poor, and little power has been developed.

The Mekong rises in the mountains of eastern Tibet and for a thousand miles drains a narrow valley between the Salwin and the Yangtze. Its fall is great, but as its drainage basin is narrow it carries relatively little water. In its middle course there is a series of tranquil navigable stretches separated by rapids, and most of the power sites are probably in this section. Red River, which empties into the Gulf of Tonkin, has many rapids. Little is known of West River except that it drains a well-watered country and has considerable fall on its upper courses. The Menam drains a large part of Siam, and probably there are many potential sites in the upper half of its basin. In the Malay Peninsula there are many small power sites, and in the Federated Malay States some power has been developed for mining. A plant in the State of Pahang has a capacity of 1,000 horsepower, but the stream flow is irregular, and the power available is often less than the capacity. Although the potential power in this region is estimated at 13,000,000 horsepower the plants reported develop only 2,000 horsepower.

217. *Yangtze River.*—The Yangtze, one of the two main rivers of China, is a great artery of transportation. It rises on the plateau of Tibet, flows southeastward parallel to the Salwin and Mekong for hundreds of miles, and finally turns to the northeast. Power could be developed not only on the upper course of the Yangtze but in its middle course, where it runs through gorges that could probably be dammed to obtain additional power. The tributaries also have much power, but little is known concerning them. The Min, a tributary from the north, falls 9,000 feet in 150 miles north of Chengtu. The Min supplies water for a large irrigation system, which was built about 250 B. C. The potential power of the Yangtze basin is estimated at 10,000,000 horsepower, but though the area is densely populated practically no water power has been developed. There are innumerable small power plants in China, almost all current wheels, which operate rice mills. Their efficiency is low, and their total capacity is undoubtedly small.

218. *Middle Pacific Ocean.*—The middle Pacific Ocean area includes the continental drainage from Yangtze River to Amur River and the Japanese Islands from Taiwan to Kurile Strait. The principal river on the mainland is the Hwang, the second great river of China. It rises north of the Yangtze, on the same great plateau, but flows northward. The Hwang, like the Yangtze, is valuable mainly for transportation; its potential power is much less than that of the Yangtze, as the rainfall in its basin is less and its tributaries would afford less power. The Liao drains considerable territory in the northern part of this area. Chosen (Korea) is mountainous and has abundant rainfall and great power resources. An American gold-mining company has a plant of 800 horsepower on a branch of Seisen River and has recently installed a plant of 1,600 horsepower on Kuron River, in northern Chosen. There is a plant of 220 horsepower at Gensan, employed for municipal use.

The Japanese Islands are mountainous and have a heavy rainfall, which is fairly well distributed through the year, although there is some variation with the seasons, and the melting snows cause large fluctuations. As the largest rivers drain areas of only 6,000 to 8,000 square miles there can be no great concentrations of power, but small sites are fairly well distributed through the islands, and the growth of manufacturing has led to the utilization of many of them. The principal islands of the main group, named in order from south to north, are Kyushu, Shikoku, Honshu, Hokushu, and Sakhalin. The best power area extends along the western half of Honshu, from the region of Toyama Bay to the mouth of Shinano River and thence directly across the island to the eastern coast. This area contains half the undeveloped power of the island. The largest streams of the region are Shinano, Jintsu, Sho, Kurobe, Hime, and Agano rivers on the west and Abukuma River on the east. The principal cities of Honshu are on the east coast, south of the area of large power resources, but Tokyo and Yokohama are within easy transmission distance of the power sites. Tokyo now receives a large amount of power from the upper Fuji and Kinu rivers. Power from a 60,000-horsepower plant on Nippashi River at the outlet of Lake Inawashiro is also transmitted 145 miles to Tokyo. Other large plants have been built near Nagoya and Gifu, on Nagara, Hida, and Kiso rivers. On the west side of Honshu there are large plants on Kudzuryu, Sho, Jintsu, Joganji, and Kurobe rivers.

The following table, taken from an official report, shows the growth of hydroelectric development in Japan:

Hydroelectric power developed in Japan, 1903–1916.

Year.	Plant capacity (kilowatts).	Year.	Plant capacity (kilowatts).
1903	13,124	1910	112,932
1904	16,409	1911	143,831
1905	18,547	1912	233,339
1906	25,195	1913	321,596
1907	38,622	1914	416,586
1908	60,121	1915	449,220
1909	73,507	1916	469,634

These figures indicate a turbine capacity of about 700,000 horsepower in 1916. In 1920 the capacity was about 1,000,000 horsepower.

The principal uses of electric power in Japan, as shown by a report issued in 1918 but apparently giving results for 1916, were as follows:

Electric power used in Japan, 1916.

	Horsepower.
Miscellaneous appliances	104, 244
Electric lamps	267, 200
Textile factories	94, 970
Machine shops	176, 746
Chemical works	90, 376
Food and drink factories	53, 613
Mines and metal refineries	152, 951
Miscellaneous factories	56, 630
	996, 730

In addition 4,077 motor cars, with 415 trailers, were operated over 891 miles of line by power obtained from steam and gas as well as from water. Out of a total capacity of primary power of 805,000 kilowatts the hydroelectric power amounted to 470,000 kilowatts.

The following figures are in part abstracted from a publication of the Japanese Government and in part from newspaper articles, but the totals given in the newspaper estimates agree fairly well with those given by the Government:

Water-power resources of Japan, in horsepower.

	Developed.	Under lease.	Unexploited.	
			Low water.	Mean flow.
Kyushu	138,297	236,377	137,000	263,000
Honshu	763,376	2,090,051	2,141,000	4,377,000
Hokushu	57,140	79,667	202,000	401,000
Shikoku	32,693	36,774	78,000	179,000
	991,506	2,442,869	2,558,000	5,220,000

At mean flow, according to these figures, the total potential power amounts to about 8,000,000 horsepower. At low water it would be little more than half as much, for undoubtedly some of the power developed and under lease depends on storage.

Nothing is known of the potential power on Sakhalin, but it probably equals that of Hokushu.

The island of Taiwan (Formosa) is mountainous and well watered. The annual rainfall ranges from 70 to more than 100 inches, and a steep mountain range, which in places rises to altitudes exceeding 10,000 feet, extends for the length of the island from north to south. The Government of Taiwan, in association with private interests, is building a plant of 130,000 horsepower at the outlet of Lake Candidius on the Dakusuikei (muddy water). The capacity can be increased to 185,000 horsepower when required. This power will be used to supply the whole island. Four plants having a combined capacity of 8,150 horsepower are already in operation, and another with a capacity of 8,000 horsepower is near completion.

The developed power in the middle Pacific Ocean drainage area amounts to more than 1,000,000 horsepower, all of it except a few thousand in Japan. The potential power at low water is estimated at 8,600,000 horsepower.

219. *Amur River.*—The basin of Amur River is about equally divided between China and Siberia. The Amur rises in the lower northeastern part of the plateau region, and its upper course lies in a country of low rainfall. Both the main river and the tributaries have considerable fall, and the potential power amounts to 1,500,000 horsepower. No developments are known.

220. *North Pacific Ocean.*—The area along the north Pacific from Amur River to Bering Strait is one of little rainfall and few power sites. The peninsula of Kamchatka, however, is mountainous and has an annual precipitation ranging from 10 inches at the north to 40 inches at the extreme south. There are probably some power sites in this region, but none of them seem to have been utilized.

AFRICA.

Africa is a great elevated plateau which drops abruptly to the sea near the coast. (See map on p. 4.) This configuration produces great concentrations of power, due to the large size that the rivers attain in their lower courses, where the falls occur. In northern Africa, however, the rainfall is less than 10 inches a year, and the potential water power is therefore small. In southern Africa also, especially its western half, the rainfall is small, but in tropical Africa, comprising a strip along the Gulf of Guinea, the entire basin of the Kongo, and the headwaters of the Nile, the rainfall is abundant. (See map on p. 5.) Throughout this region power sites are numerous, and on the lower Kongo there are the greatest concentrations of potential water power in the world. The water-power resources of Africa are described below by drainage basins, the description beginning at the mouth of the Nile and proceeding westward and around the continent.

302. *Mediterranean Sea west of the Nile.*—The streams that enter the Mediterranean from Africa west of the Nile are subject to great fluctuations and can furnish little continuous power without extensive storage. The rainfall in this region is moderate to low and occurs during the short winter season. Between the Nile and

Tunis there are no permanent streams that have potential power. In Tunis and Algeria a little power can be developed on streams that rise in the mountains and flow northward to the Mediterranean.

What can be done to develop water power in Algeria without storage is well shown by a water-power plant of 130-horsepower capacity, with steam reserve, constructed in 1911 on the Bou Sellam for use at a zinc-concentrating plant of the Société des mines de zinc. At this place, though floods of 10,000 second-feet occur, the summer flow is insufficient to supply the water wheel, which uses less than 50 second-feet. All but about ten of the principal streams of the region go dry during the summer.

303. *North Atlantic*.—The streams that flow into the Atlantic Ocean and the Gulf of Guinea between the Strait of Gibraltar and Niger River vary widely in their characteristics. The Sebu, Um-er-Rebia, Tensift, and Dra, all south of the Strait of Gibraltar, rise in the high Atlas Range and flow westward to the Atlantic. These streams drain a region of winter precipitation amounting to 30 inches or less. Neither the total rainfall nor its seasonal distribution is favorable to the development of water power, and although the streams have steep slopes in their upper reaches the power resources are meager.

Between the Dra and the Senegal the rainfall is less than 10 inches a year and no power can be developed.

The Senegal is navigable for many miles from the coast. It is fed by summer rains only, and more than half the annual rainfall of 50 to 60 inches in the head-water region occurs in July and August. Very little of the drainage area stands more than 1,500 feet above sea level, and in general the slopes are flat and the distribution of rainfall is unfavorable to the development of power without storage, except in small units.

The conditions on the Senegal are repeated on the Gambia, which is navigable for more than 400 miles from its mouth. This river discharges a great quantity of water, but its prevailing flat slope and the poor seasonal distribution of the rainfall in its basin make it unavailable for water power except in its upper reaches, and even there power can be developed only with storage. Similar conditions prevail on the Koli (Rio Grande). The main upper tributaries of the Senegal, Gambia, and Koli all rise close together in the mountains of the west coast.

In the region along the coast from the Koli to the Niger the rainfall is greater and more continuous, and although a large proportion of it occurs in summer and the fluctuations of stream flow are great, the rainfall in winter is sufficient to assure a well-sustained low flow in the streams. The surface in this region rises steeply from a narrow belt of low coastal plains to a plateau or hill country that stands 3,000 to 6,000 feet above the sea. The streams rise in the mountains and in their middle courses fall rather abruptly from the plateau in cascades and rapids and at many places are confined in narrow gorges. The lower reaches of most of the rivers are navigable. The principal streams are Great Skarcies, Little Skarcies, Rokelle, Bum, and Sulima rivers, in Sierra Leone; Loffa, St. Pauls, and St. Johns rivers, in Liberia; Cavally River, forming a part of the boundary between Liberia and the Ivory Coast; Sassandra, Bandama, Komoe, and Bia rivers, on the Ivory Coast; Ankobra and Pra rivers, on the Gold Coast; Volta River, a stream nearly 1,000 miles long, on the Gold Coast and in the British mandate in Togo; Sio, Haho, Mono, and Weme rivers, in Dahomey and the French mandate in Togo; and Ogun, Oshun, and Benin rivers, in Nigeria.

The entire coast region of Guinea abounds in good water-power sites, but there is now little market for power in this region. A scheme for electrifying the railroad that runs inland from Freetown, Sierra Leone, by means of water power is one of the few power projects that have been suggested.

304. *Niger River*.—The Niger, like many other African rivers, comprises a series of navigable stretches in which there is little fall and a series of rapids in which the river descends from one plateau to another. These features, which are in general favorable to the development of water power, are possessed also by its tributaries. The concentrations of fall either in rapids or in abrupt falls delimit the stretches of river in which the development of water power may be practicable.

In two respects, however, the Niger is unlike most other African rivers: there are no rapids in its lower course, for it descends nearly to sea level several hundred miles from its mouth; and it loses a great quantity of water in its middle course, largely by evaporation in the Sahara and perhaps also in part by seepage. This loss of water is so great that the stream bed for a stretch of several hundred miles is practically dry except during and immediately after the rainy season, though both above and below this stretch the river contains sufficient water to permit navigation throughout the year. Because of this condition the upper part of the river basin, which had been entered by way of Gambia and Senegal rivers and is relatively populous, healthful, and attractive, was well known for a long time before the mouth and the lower basin had been discovered. Even to-day information in regard to the middle course is extremely meager because of the difficulties of transportation through it.

The Niger basin extends from a region of high rainfall in the mountains, where its headwaters rise, into a region where the rainfall decreases downstream, and through a zone of extreme aridity, in the Sahara, into the region of tropical rains, in which its lower course and lower tributaries are situated. No records of measurements or estimates of its discharge are available, although records of stage extending over at least four or five years have been made by the French Navigation Service in the stretch of the river between Kulikoro and Timbuktu.

The information available in regard to the amount of potential power in this basin and the cost and practicability of its development is indefinite and does not warrant more than a mention of areas in which power sites on tributary streams may be found, of stretches of the main river in which power sites probably exist, and of a few special sites, without an attempt to estimate the potential power at any particular site or even in any particular area.

The southern and western tributaries of the Niger above Kurussa (800 miles or more above Timbuktu) probably afford power sites. From Kurussa to Bamaku, a distance of perhaps 200 miles, the river is understood to be navigable. From Bamaku to Kulikoro, about 40 miles, there are rapids, of which two (Sotuba and Kenie) are especially notable. Sotuba is said to have a fall of about 20 feet in a distance of half a mile. From Kulikoro to Ansongo, a distance of more than 1,000 miles (about 625 miles above Timbuktu and 425 miles below), the river is navigable at all seasons, except between Timbuktu and Ansongo, where navigation becomes increasingly difficult at low water as Ansongo is approached, because of the loss of water already mentioned. Between Ansongo and Bussa most of the river is little known, but there are many narrows and rapids. Just below Bussa are the rapids of Garafiri, which extend over a stretch of about 3 miles, and the great rapids at Wuru, where the fall is said to be 40 feet in about three-fourths of a mile. From Wuru to the sea the river is navigable at all seasons.

The Benue, the principal tributary of the Niger, enters it from the east within the lower navigable stretch. It is itself navigable from its mouth throughout most of its course, for a distance of more than 500 miles. Its eastern and northern tributaries doubtless contain power sites, and special mention is made of a fall of 165 feet on the Kibbi, a northern tributary.

305-A. *Middle Atlantic.*—The streams that flow into the Gulf of Guinea and the Atlantic Ocean between the basins of the Niger and the Kongo drain mountainous territory that receives a very heavy rainfall, and though they are subject to material variation in stage they have a well-sustained low flow. Rapids and sheer falls are numerous. The principal streams are Cross River, in Nigeria; Sanaga, Nyong, and Campo rivers, in the French mandate of Kamerun; and Ogowe and Kwilu rivers, in French Kongo. The falls of the Sanaga near Edia are estimated to be capable of yielding 450,000 horsepower, and the total potential power in the region is several million horsepower.

306. *Kongo River.*—The drainage basin of the Kongo and its tributaries covers about 1,500,000 square miles, nearly all of which is well watered. The tributary streams, themselves large rivers, in general flow from their sources to the central basin of the Kongo in a succession of rapids, falls, or gorges, where the conditions are favorable for the development of power. The Chambezi, the headwater stream, rises at an elevation of 6,000 feet and within a short distance becomes a large river, but the power sites on it are confined to its upper reaches and tributaries. The outlet of Lake Bangweolo, which receives the Chambezi, is called Luapula River. This stream, before it reaches Lake Moero, passes successively over a thundering cataract known as Mumbutata or Mamcirima Falls, a series of several rapids, and finally over Johnston Falls, all of which appear to afford potential power of great but unknown magnitude. After leaving Lake Moero the Luapula crosses the Kebara and Mugila mountains in a series of rapids having a total fall of 1,000 feet and joins the Lualaba to form the Kongo. The two main headwater streams of the Lualaba flow through the Mitumba Range in deep gorges in a succession of rapids for 40 or 50 miles. Here also there are great opportunities for the development of water power. Kongo River below the junction of the Lualaba and Luapula falls only 180 feet in 500 miles above Stanley Falls. The slope is concentrated, however, at such places as Dia Rapids, the narrow gorge known as Porte d'Enfer, and the rapids near Nyangwe and Nendwe, all in a stretch of 125 to 150 miles. Several tributaries of the Kongo afford potential power. The Lukugu is a swift stream that drains mountainous territory and receives the overflow of Lake Tanganyika, which has been continuous since 1879. The evaporation from this magnificent lake appears to be too great in proportion to the inflow for the development of much water power from its outlet, but a lowering and control of the level of the lake by suitable outlet works may eventually afford a large amount of power on the Lukuga. A float measurement made at the outlet of the lake in March, 1920, during the rainy season, showed a discharge of about 7,000 second-feet. The larger tributaries of Lake Tanganyika are Russisi River, which drains Lake Kivu and falls 2,200 feet between the two lakes; Kalambo River, which has a sheer fall of 600 feet just before entering the lake; and Momba River, which is reported to be capable of yielding 100,000 horsepower.

The main tributary of the Kongo from the north, Ubangi River, is navigable for 350 miles from its mouth to Zongo Rapids and thence for another 350 miles to the confluence of the Welle and the Mbomu, which form the Ubangi. Although the main stream affords little opportunity for the development of power, the Welle and the Mbomu, both large rivers, have many falls and rapids on their lower reaches and on their headwater tributaries. Lindi Falls, on Lindi River; Yambuya Rapids and several falls on the upper reaches of Aruwimi River; and Lubi Falls, on Itimbiri River, are other notable power sites on northern tributaries of the Kongo.

The main tributary of the Kongo from the south is Kassai River, which has a flow of more than 300,000 second-feet. Wissman Falls, on the Kassai, and the many rapids and falls on its northward-flowing tributaries afford immense power resources. Other southern tributaries of the Kongo, though many of them are large streams, are of relatively minor value for water power, though the Lomami has good power sites in its upper reaches.

Stanley Falls, on the middle Kongo, consist of seven cataracts having a total fall of about 200 feet in 60 miles. From 10,000,000 to 15,000,000 horsepower may possibly be developed in this locality, though the engineering problems involved are difficult. On the lower Kongo, below Stanley Pool, there are eighteen falls and rapids that have a total drop of 500 feet in less than 90 miles, and just above tidewater there are ten falls and rapids that have a total drop of 300 feet in less than 60 miles. More than 100,000,000 horsepower could be developed in these two stretches. The engineering problems of development would be exceedingly difficult, and the construction of power plants on these stretches might be impracticable even if a market were available for this enormous quantity of power.

The Kongo affords greater water-power resources than any other river system in the world and more than all the other rivers in Africa. In fact, more than one-fourth of the potential water power of the world is in this one river basin. This great resource is undeveloped. Schemes for the construction of a plant of 113,000 horsepower on the lower river, to be used for electric operation of a railway, and of another plant of 20,000 horsepower at Koni Falls, on the Lufira, a tributary of the upper Lualaba, have been proposed.

305-B. *Upper south Atlantic.*—The streams that flow into the Atlantic Ocean between Kongo and Orange rivers drain a narrow belt of low land, which is flanked by mountains that form the western rim of the great central plateau of southern Africa. The rainfall decreases rapidly toward the south, and most of the southern streams are dry for a great part of the year.

The principal river of the region is the Kuanza or Coanza, which lies wholly within Angola. It rises at an altitude of 5,000 feet and within a short distance becomes a large stream. Its potential water power is confined to the headwater streams and to a stretch of the main river where it crosses the escarpment of the plateau and drops to the sea. This lower stretch is broken by many rapids and falls that offer favorable opportunities for the development of water power in plants of large capacity. The westernmost of these falls, Cambamba or Livingstone Falls, is 70 feet high, and from its foot to the sea, a distance of 100 miles, the stream is navigable and of no value for power. Many of the smaller coast streams of Angola have power sites of material value. One site on the Katumbela has been partly developed and is capable of yielding 4,000 to 20,000 horsepower, according to the stage of the river. In this area fluctuation of stage, which becomes greater toward the south, limits the development of power without storage.

Kunene River forms a part of the boundary between Angola and Southwest Africa, a mandate of the Union of South Africa. The Kunene flows generally southward through the uplands of Angola, accumulating a large volume of water; it then turns westward, breaks through the plateau escarpment, and finally reaches the Atlantic Ocean. Its gradient in the upland region is flat, but beginning with the Kavala Rapids, at an elevation a little more than 3,200 feet above the sea, it passes over a series of rapids and falls where power could be cheaply developed. At Kavala Rapids the fall is 38.4 feet in a little over a mile; at Chimbombe Rapids it is 68 feet in a few miles; from Chimbombe Rapids to Rua Cana Falls it is 246 feet in 16 miles; and at Rua Cana Falls it is 406 feet in 1¼ miles. Below Rua Cana Falls the river is little known, but its total fall is more than 2,300 feet in the 200 miles between Rua Cana and its mouth. Monte Negro Falls, 110 miles below Rua Cana, are said to be higher than Rua Cana. At its minimum flow the Kunene would furnish about 80,000 horsepower, but with the flow available 50 per cent of the time it should furnish over 1,500,000 horsepower. The conditions are favorable for storage.

There are no perennial rivers between the Kunene and the Orange, though some of the streams flow for the greater part of the year and might be of some value for power if they were regulated by storage.

307. *Orange River.*—The drainage basin of Orange River is one of the largest in Africa, comprising more than 400,000 square miles, half of which, however, is unproductive of run-off. The extreme headwaters are in Mont aux Sources, in southeastern Africa, at altitudes of more than 10,000 feet. In the region from which the Orange receives most of its water there is a short season of heavy rainfall, but little rain falls there during the remainder of the year. Most of the streams are dry or nearly dry for three or four months, and though they have ample slope and a number of high falls the development of power on them without storage is impracticable, except in small units. A few small towns are lighted by electricity generated in part from water power, but no considerable development has been attempted. The Vaal, a large tributary 750 miles long, has a perennial flow, but in the dry year of 1905–6 its total discharge was only 184,000 acre-feet, nearly 90 per cent of which was flood flow. Below the Vaal no perennial tributaries enter the Orange. A stretch of the river that may contain valuable power sites, in spite of the small and irregular flow, lies between the mouths of Molopo and Hartebeeste rivers, where the Orange falls more than 400 feet in 16 miles and then flows through a rocky gorge for many miles. In general, however, there are only a few power sites in the basin of Orange River, and storage must be used at all of them in order to develop power.

305-C and 308. *Lower south Atlantic and south Indian Ocean.*—The lower south Atlantic drainage area includes the basins of the streams that flow into the Atlantic Ocean between Orange River and Cape Agulhas. The south Indian Ocean drainage area includes the streams that flow into the Indian Ocean between Cape Agulhas and Zambezi River, an area containing a narrow belt of flat coastal plain flanked by mountain ranges, which rise steeply from altitudes of 5,000 to more than 10,000 feet. The streams, except the Limpopo and Save, in the northeast corner of the region, are not more than 200 or 300 miles long. Their slopes are steep, and many of them have magnificent waterfalls. The average annual rainfall increases in general from less than 10 inches near the mouth of Orange River to about 50 inches at the mouth of the Zambezi, and in nearly all of the region it is more than 20 inches. The variation from year to year is considerable, and the distribution throughout the year is unfavorable to continuous stream flow, so that any large development of power must depend on storage. There are not many storage sites in the region, but on all the larger streams there are some sites where power can be developed without regulation, and at a few such sites it has been developed for local electric lighting and for other uses. The aggregate potential power of the region is considerable, though it is scattered over many sites. The principal rivers, named in order from west to east, all but the first three of which are tributary to the Indian Ocean, are the Buffels, Olifants, Berg, Breede, Gouritz, Gamtoos, Sunday, Great Fish, Great Kei, Umzimvubu, Umzimkulu, Umkomanzi, Umgeni, Tugela, Maputa, Komati, Limpopo, Save, Busi, and Pungue.

Features worthy of special note are a 20-mile bend on the Great Fish, with ends only 2 miles apart and differing in altitude by 200 feet; a fall of 375 feet on the Tsitza, a tributary of the Umzimvubu; a fall of 350 feet just above a series of cascades on the Umgeni; the large drainage area (8,000 square miles) and considerable flow of the Tugela, which rises at an altitude of 11,000 feet, drops precipitately 1,800 feet, and has falls also in its lower course; a series of cascades which occur in a narrow gorge on the Komati where it breaks through the hills to the coastal plain at a point from which it is navigable 200 miles to the sea; and the cataracts of the Save. The Limpopo, which is more than 1,000 miles long, is by far the largest stream of the region. It is navigable for about 100 miles from its mouth all the year and for a greater distance in the rainy season. It rises in the central plateau of Africa and descends the plateau escarpment through rocky ravines. The Toli Azime Falls form one of its noteworthy features. A scheme for the development of 40,000 horsepower on the Limpopo in eastern Transvaal has been proposed, but on account of the availability of cheap coal it has not been carried out. The great market for power in this region is in the Rand mining district, where more than 400,000 horsepower developed with coal as fuel is used by a few mining companies.

309. *Zambezi River.*—Although the drainage basin of Zambezi River is three times as large as France, its water-power resources are believed to be limited to two or at most three stretches of the main river (Karoabassa Rapids, Victoria Falls and the canyon below, and probably a series of rapids about 100 miles above Victoria Falls), to Shire River and its tributaries, and to the headwater tributaries of the Zambezi in the eastern part of Angola and the northern part of Rhodesia. In other parts of its course the Zambezi is generally navigable and its fall is too small for the development of water power. The tributaries other than those mentioned probably have in general too great a range in discharge and too little flow at low water to yield reliable power.

The headwater tributaries drain a plateau which divides this basin from that of the upper Kongo and in which the rainfall is relatively high. The power sites are at falls and rapids where the streams descend to the level of the plateau that includes the fan-shaped central basin of the Zambezi and its tributaries, in which the streams have so little fall that they are navigable. Explorers make special mention of Supuma Cataract, on upper Zambezi River, in the extreme northwestern part of Rhodesia.

The information available concerning the rapids about 100 miles above Victoria Falls is extremely meager and general; it only shows that they form a break in continuous navigation and possibly a source of power.

At Victoria Falls the river falls abruptly about 350 feet, and in the gorge and rapids below, which extend for a distance of 50 miles, there is an additional fall of about 1,100 feet. The potential power of the falls and rapids has been estimated at 750,000 continuous horsepower and would doubtless be much greater at all stages above low water.

For 600 miles below Victoria Falls and rapids the Zambezi is navigable and has no considerable concentrations of fall, but there are some narrow gorges with rapid current. The range of stage is so great, however, that the development of power does not seem practicable, although it must be recognized as a possibility in connection with works for improving navigation.

The Karoabassa Rapids are about 60 miles long and have a total fall reported to be 150 feet and a range in stage of 80 feet. No definite information is available as to concentrations of fall within this stretch. Between the rapids and the ocean, a distance of 360 miles, navigation is continuous.

Shire River, the outlet of Lake Nyasa, is tributary to Zambezi River in the navigable stretch between Karoabassa Rapids and the ocean. The Shire is navigable from its mouth for about 125 miles and from the outlet of Lake Nyasa downstream for about 100 miles. Between these two navigable stretches there is a series of cataracts 50 miles long, in which the river makes the greater part of its descent of 1,600 feet from Lake Nyasa to sea level. Under ordinary climatic conditions the potential power in the rapids of the Shire is enormous. The river drains about 50,000 square miles above the outlet of the lake, of which about 10,000 square miles is within the lake itself. The average annual rainfall in the basin of the Shire ranges from perhaps 50 or 60 inches in the highlands of its upper tributaries to perhaps 30 or 35 inches at the south end of the lake. The precipitation varies widely from year to year, however, and may be low during a period covering several consecutive years. As a consequence of low rainfall during such a period the lake has at times recently been so low that there has been little or no outflow from it, the river above the rapids has thus become too shallow for navigation, and the potential power of the rapids has been greatly decreased. The information available indicates that a dam might be built at the outlet of the lake to store enough water during years of great rainfall to compensate for the lack of water in years of deficient rainfall, so it may thus be possible to maintain the navigation and the power resources of the river continuously. Power sites may probably be found on the tributaries of Lake Nyasa.

310. *North Indian Ocean*.—The streams that flow into Indian Ocean, the Gulf of Aden, and the Red Sea between Zambezi River and the Mediterranean end of the Suez Canal have slight potential power except on those in the part of East Africa that is under British and Portuguese control, which has a narrow coast belt flanked by the escarpment of the central African plateau. The rainfall in the region is small. There is potential water power along streams in a few mountainous regions near the edge of the plateau and along streams that drop from the plateau to the coastal belt. The principal streams are the Lukugu, Lurio, Mtepwesi, Msalo, Rovuma, Rufiji, Pangani, Sabaki, Tana, and Juba. All these have extensive potential power resources. The Chuguli and Pangani falls, on the Rufiji, are noteworthy power sites. Below Pangani Falls the Rufiji is navigable to its mouth. Pangani River is fed by the glaciers of Mount Kilimanjaro, the highest mountain in Africa, and is 250 miles long. Along the Pangani there are many rapids and falls; one at Thale is 65 feet high, and another at Ruani is 360 feet high. These falls are estimated to be capable of yielding about 70,000 horsepower at extreme low water, and a plant having a capacity of 80,000 horsepower has been planned to utilize the total head of both falls in one project. Along the Sabaki there are valuable power sites, most of them near its headwaters. One tributary drains the east slope of Mount Kilimanjaro. Lugard Falls, on the Sabaki 100 miles above its mouth, is the lowest place at which power can be developed. Tana River drains the Kikuyu country, and its tributaries flow over many falls and rapids that could furnish power. At a plant on one of these tributaries about 900 horsepower has been developed. Other tributaries of the Tana rise on Mount Kenia. The main stream is navigable for 300 miles from its mouth and is without value for power in this stretch. Juba River has three main tributaries, the Web, Ganale Gudda, and Daua, all swift-flowing streams with many rapids and falls. Juba River below the mouth of the Daua has a flat slope and is without value for power.

301. *Nile River*.—The principal power sites on the Nile are in the upper or southern part of its basin, where the rainfall is greatest and the slopes are steepest. Different parts of the Nile are known, in order downstream, as the Somerset Nile, the Bahr-el-Jebel, and the White Nile. The principal tributaries are the Albertine Nile system (comprising Albert Nyanza and its tributaries), the Bahr-el-Ghazal, the Sobat, the Blue Nile, and the Atbara.

The 240-mile stretch of the river between Victoria Nyanza, the great lake that is regarded as its source, and Albert Nyanza is called the Somerset Nile. The tributary streams of Victoria Nyanza rise far south of the Equator, in the mountainous region east, south, and west of the lake. The catchment basin of the lake covers about 90,000 square miles. The lake itself has an area of about 24,000 square miles and stands about 3,700 feet above sea level. It is in a region of almost continual rain and is fed by many tributaries. Kagera (Tangura), the largest tributary, drains a mountainous region of heavy rainfall which divides this drainage basin from that of Lake Tanganyika. This river is 400 miles long and is navigable for 70 miles in its lower course. A partial measurement made in October, 1892, indicated that its discharge then was about 50,000 second-feet. In the dry season of July, 1889, Stanley made a partial measurement that indicated a discharge of 5,000 to 6,000 second-feet. Along the tributaries of this river there are doubtless sites where considerable power could be developed. Smaller tributaries of Victoria Nyanza that drain areas south and west of the lake probably also offer sites for the development of power. The eastern tributaries drain a region in which the rainfall is much smaller and more variable, and in the dry season most of them contain little or no water.

The Somerset Nile falls about 1,400 feet in the 240 miles of its course, chiefly in two stretches. In the first stretch, about 50 miles long, extending from Victoria Nyanza to Lake Choga, it falls about 225 feet; in the second, about 50 miles long, extending from Foweira to the foot of Murchison Falls, it makes most of its remaining fall. Between these two stretches the river (including Lake Choga) is navigable for 100 miles, and below Murchison Falls it is navigable to Albert Nyanza.

The discharge of the Somerset Nile is well sustained by the equalizing influence of Victoria Nyanza, and the minimum flow is believed to be about 20,000 second-feet, so that the river could yield more than 2,000,000 continuous horsepower. There are no doubt several sites along its course at which great power could be developed.

The principal tributaries of the Somerset Nile enter it in Lake Choga from the east, and their headwaters are in the mountainous area that culminates in Mount Elgon, which stands at an altitude of about 15,000 feet. There are probably power sites along these tributary streams.

The Albert Nyanza drainage system, or Albertine Nile, after receiving the Somerset Nile near the outlet of the lake, forms the Bahr-el-Jebel. The drainage area, exclusive of the Somerset Nile, is apparently about 12,000 square miles, including the surfaces of Albert Nyanza and Albert Edward Nyanza. The rainfall in the basin is heavy, especially in the mountain divide between Albert Edward Nyanza and the headwaters of Lake Tanganyika and in the Ruwenzori Mountains, north of Albert Edward Nyanza, which may reach an altitude of 18,000 feet and which contain large glaciers. Mpanga River, which flows into Albert Nyanza, is the principal stream draining this range and may have power sites at its headwaters. Other tributaries of these lakes may also afford opportunities for the development of power.

Semliki River, which connects Albert Edward Nyanza and Albert Nyanza, is about 150 miles long and is largely unmapped and unexplored. In 75 miles of its middle course it is said to include a series of rapids in which the aggregate fall is about 800 feet. The minimum flow is about 3,000 second-feet. The lakes are slightly brackish, probably because they receive waters from salt springs and salt deposits on their shores, especially at Katwe, near Albert Edward Nyanza, where there are old crater lakes. The salt deposits are large and are a source of supply for the natives of all central Africa. There is no indication that the brackishness of the lake waters is due to concentration by evaporation.

The Bahr-el-Jebel, as the Nile is called between Albert Nyanza and Lake No, the mouth of the Bahr-el-Ghazal, falls about 1,000 feet in its total length of 600 miles. Of this fall about 600 feet is concentrated in a distance of about 125 miles between Dufile and Gondokoro, including the Fola, Kerbora, Gugi, Makedo, and Baden rapids. There may be sites where considerable power can be developed in this stretch, but elsewhere the only obstructions to navigation of the river are the "sudd" dams formed by vegetation. The discharge is estimated at 20,000 second-feet at low water.

The Bahr-el-Ghazal, which unites with the Bahr-el-Jebel in Lake No to form the White Nile, is reported to have a small discharge and to act more as a reservoir than as a tributary. It is navigable for 300 miles or more from its mouth. Along its headwater streams, which adjoin those of northern tributaries of the Kongo and extend into a region of heavy rainfall, there are probably sites where some power might be developed.

The White Nile, as the river is called between Lake No and Khartum, is navigable throughout its length and will afford no water power. In the White Nile and in the lower courses of the Bahr-el-Jebel and Bahr-el-Ghazal there is a gradual loss of water by evaporation.

Sobat River brings to the White Nile the white water from which this part of the river is named. Its discharge is said to be as great as that of the White Nile above the junction of the two streams. Its drainage basin, which has an area of 55,000 square miles, is mountainous in part, and the tributary streams descend from the mountains in falls and rapids that represent potential power sites. The Sobat itself is navigable throughout its course from the confluence of its tributary streams to its junction with the White Nile.

During the flood season the Blue Nile (Bahr-el-Azrek) is even larger than the White Nile, but at low water it is only about half as large. The mean discharge at the mouth of the river in summer is reported to be about 5,500 second-feet. The headwater tributaries are on the mountains and plateaus of Abyssinia, in a region where the rainfall in summer is great, but there is a long dry season and therefore a wide range between the high and low stages of the tributaries, so that their power resources are relatively small, yet they probably offer many water-power sites for plants of small capacity. The Blue Nile has little fall in its lower course and is navigable from the border of Abyssinia to Khartum, a distance of nearly 500 miles.

Atbara River, which is tributary to the Nile about 200 miles below Khartum, is at times of flood a large stream, but in the dry season it carries little or no water and it will probably afford no valuable power sites, yet there may be some such sites on its tributaries.

In a stretch of about 1,800 miles between Khartum and the Mediterranean the Nile has an aggregate fall of about 1,300 feet, including six concentrations sufficiently great to be called "cataracts." The Aswan dam was built at the first cataract, primarily to divert water for irrigation, yet incidentally it afforded a site capable of yielding 150,000 horsepower for five months in the year, but the power has not yet been developed. At the five other cataracts the fall is so slight that the river is navigable through all of them at high stages of the water. These cataracts will probably not be developed for power except in connection with the improvement of the river for navigation or irrigation.

312. *Kalahari Desert.*—The interior drainage basin known as Kalahari Desert, in central South Africa, borders on the drainage basins of the south Atlantic, Orange River, south Indian Ocean, and Zambezi River. Okavango River is the only large main stream in the Kalahari basin. The Okavango and its principal tributary, the Kuito, are both navigable for many miles. Minor power resources may be found at the extreme headwaters, but no valuable power sites are known. Below the mouth of the Kuito the Okavango is a relatively rapid stream and within a stretch of 40 miles it includes six low falls, one of which is known as Popa Falls. None of these falls appear to afford favorable opportunities for the development of water power.

311. *Sahara Desert and Lake Chad.*—The Sahara, which is a region of scant rainfall and is without water power, lies south of the Mediterranean drainage area and west of the Nile. The larger streams of the basin of Lake Chad, except Shari River, are too small during the dry season to be of value for power. Some tributaries of the Shari that drain a rather well watered mountainous region in the French mandate of Kamerun and the French territory to the east and that include many rapids and falls may afford opportunities for a moderate development of power.

313. *Eastern Horn basin.*—An interior basin of irregular shape that lies mainly between the north Indian Ocean drainage area and the basin of the Nile contains two rivers, the Omo and Hawsh, which appear to afford considerable potential power. The Omo is a perennial stream that rises in the mountains of Abyssinia at an altitude of 7,600 feet and has many tributaries. It is navigable in a short stretch that extends upstream from its mouth at Lake Rudolf, in the Great Rift Valley, and above this stretch it is a rapid stream broken by Kabobi and other falls. The Hawsh also rises in the mountains of Abyssinia but discharges its waters into Lake Aussa, which lies in a depression several hundred feet below sea level, near the eastern coast. It fluctuates widely in flow with the wet and dry seasons but apparently affords opportunity for the development of power at several places near its headwaters. A small hydroelectric plant has been constructed on it at Addis Abeba for local lighting. There are minor power resources on smaller streams in the basin.

OCEANICA.

Oceanica includes innumerable islands in the Pacific Ocean, which have a wide range in size. The largest is Australia, which is by some considered a continent; the smallest are the tiny islands of Micronesia, which even on large-scale maps are represented only by dots. The rainfall in Oceanica, except in Australia, is plentiful, and the potential water powers on islands whose area is sufficient to contain large rivers are considerable. The islands have been divided into ten groups.

401. *New Zealand.*—North Island and South Island are the two principal areas in the New Zealand group. The rainfall is abundant, and both islands include high mountainous areas that contain many lakes, which are available for storage.

On North Island the highest mountains are near the southeastern coast and the largest rivers drain toward the north and west, but in its extreme northern part the island is too narrow to contain large rivers. The Waikato, the largest river on the island, rises a little south of its center, flows 40 miles to Lake Taupo, which has an area of 238 square miles and stands 1,200 feet above sea level, and after leaving the lake flows by a sinuous course to the west coast south of Auckland. Below the lake 167,000 horsepower can be developed at six sites. There are also possible power sites along other streams on the island. The total potential power on North Island is estimated at 500,000 horsepower.

On South Island there is a high mountain range called the Southern Alps, which extends along the entire west coast. The rainfall is greater than on North Island, the lakes are numerous, and the rivers, although they are short, will yield considerable power. Some of the unutilized sites that may afford the largest amount of power are at Lake Tekapo, 400,000 horsepower; Ohau Lake, 250,000 horsepower, both about 50 miles from Timaru; Lake Wakatipu, on Kawarau River 140 miles from Dunedin, 375,000 horsepower; Te Anau Lake, near George Sound, 750,000 horsepower; and Manipori Lake, near Smith Sound, 420,000 horsepower. The last two, if developed, would have power houses on the seaboard. The total undeveloped power on South Island is estimated at 3,300,000 horsepower.

The Government of New Zealand not only controls the unutilized power sites but, together with city and borough councils and other Government agencies, controls 90 per cent of the developed power. Since 1918 a complete scheme for supplying power to both North and South islands has been adopted. The plans for

North Island involve an expenditure of $36,000,000, of which $22,000,000 has been appropriated for constructing plants at Manganao, Waikara Moana, and Arapuni, which will have a total ultimate capacity of 160,000 horsepower and will be distributed by lines measuring in all 1,420 miles and traversing the whole island. The Government has also taken over the 9,000-horsepower Horahora plant, originally installed by a mining company near Cambridge, and has appropriated $7,800,000 for increasing its capacity and for extending the transmission line to supply power to surrounding towns and to the dairying industry. It is announced that 1,000 milking plants, 6 dried-milk factories, and 20 cheese and butter factories near Cambridge will take power from this station.

The largest plant on South Island is at Lake Coleridge, where 12,000 horsepower is developed for use in Christchurch, 70 miles distant. In 1919 an appropriation was made for the purchase and installation of machinery to increase the capacity of this plant to 36,000 horsepower, and in 1921 16,000 horsepower will be available. A loan of $7,300,000 has been authorized for the construction of a hydroelectric plant of 20,000 horsepower capacity near Lake Monowai, 60 miles from Invercargill, to supply the south end of the island.

In 1910 the total capacity of the hydroelectric plants in New Zealand was 19,300 horsepower, and on March 31, 1919, it was 36,000 horsepower, generated at 26 plants. In addition about 9,000 horsepower was utilized directly from water wheels. This mechanical power was used chiefly in mining, refrigeration, dairying, milling flax and flour, and making paper and lumber. The electric power was used in mining, smelting, and electrochemical processes and for municipal purposes. Although little progress was made from 1910 to 1919, the plants now under construction will increase the total capacity by several hundred per cent within the next two or three years.

The developed water power in New Zealand amounts to 45,000 horsepower, and the potential power obtainable by the use of storage is estimated at 3,800,000 horsepower. As lakes are numerous and should obviously form a part of any plan of development an estimate that did not involve their use would not fairly represent the power resources.

402. *Tasmania.*—Tasmania, the so-called Switzerland of the South, is said to be the most mountainous island on the globe. The rainfall is plentiful, and mountain lakes and water-power sites are abundant. The largest river, the Derwent, heads in numerous lakes on a plateau that stands about 3,000 feet above sea level. The largest lake is Great Lake, which covers 28,000 acres. Others are St. Clair, Echo, and Arthur lakes, each covering about 10,000 acres. The Government of Tasmania has constructed at Great Lake a plant of 20,000 horsepower, which transmits power to Hobart, the capital. Zinc-reduction plants take 4,250 horsepower, and plants that produce calcium carbide take 3,500 horsepower. The demand for power is so great that the plant is being enlarged. The capacity of the site is estimated at 70,000 horsepower. Contracts already made amount to 42,000 horsepower, and negotiations are being carried on for 50,000 horsepower additional. One contract for metallurgical work calls for 25,000 horsepower. Launceston, a port on the north coast, has its own plant of 1,600 horsepower, and a mining company at Queenston develops 10,500 horsepower, chiefly for use in its mines. A plant at Latrobe has a capacity of 75 horsepower. The Government of Tasmania also proposes to develop 60,000 horsepower at two sites on King River to supply the mines along the west coast. In Tasmania, as in New Zealand, the development of water power has been retarded in recent years but is now progressing rapidly. The total developed hydroelectric power on the island is 34,500 horsepower, and the total potential power is estimated at 400,000 horsepower.

403. *Australia.*—Although Australia is nearly as large as the United States its water-power resources are small. Half the island has an altitude of less than 1,000 feet, and only a few peaks and a narrow mountain range in the eastern part exceed 2,000 feet. The rainfall is meager, and only a narrow belt along the eastern and northern coasts is well watered. The principal rivers are the Darling and the Murray, which unite before reaching the sea, but at low water their combined flow is small. The only potential water power is in the mountains that border the east coast, and the cost of its development would be so high that no plants have been built. The chief electrical engineer of New South Wales has investigated schemes for development at eighteen sites and estimates that the total potential power at these sites is 300,000 horsepower. The most valuable sites are on Clarence and Snowy rivers, where 100,000 and 137,000 horsepower, respectively, can be developed. In Victoria it is proposed to use the water of Kiewa River and other streams between that and the Snowy. The potential power on these streams is estimated at 100,000 horsepower. In Queensland the Cairns district has over 150,000 horsepower awaiting development. The Barron River Falls, 19 miles from Cairns, are 1,000 feet high, and their potential power is estimated at 10,000 horsepower. The following table is taken from the preliminary report of the water-power committee of the Conjoint Board of Scientific Societies, published in London in July, 1918:

Potential power in Australia.

	Horsepower.
Australian Alps	300, 000–500, 000
Blue Mountains	25, 000–50, 000
New England Range	200, 000–500, 000
Cairns district	100, 000–250, 000
	625, 000–1, 300, 000

The estimates are based on a few investigations and a good knowledge of conditions. A study of the water-power resources of New South Wales is being made under the authority of the State, and some of the more promising schemes may be carried out, but so far no development has been reported.

404. *New Guinea.*—New Guinea, the second largest island in the world, is mountainous and has a rainfall of more than 80 inches a year and abundant water-power resources. A range of high mountains that includes many peaks exceeding 10,000 feet in altitude extends along its central and northern parts. Most of the island is drained by three rivers—the Ambernoh in the northwest, the Fly in the southeast, and the Kaiserin Augusta in the northeast. The interior of the island has been only in part explored. The discharge of Fly River at its mouth during the rainy season was estimated by an explorer at 327,000 second-feet, and the discharge of the Strickland at its junction with the Fly was estimated at 196,000 second-feet. In the second report of the water-power committee of the Conjoint Board of Scientific Societies, published in March, 1919, the potential power of Papua, the old British part of the island, is estimated at 10,000,000 horsepower, and that of former German New Guinea at 7,000,000 horsepower. These estimates probably represent the potential power at mean stream flow by the use of storage. The potential power at ordinary low flow, as indicated by the rainfall and the altitude, is probably about 5,000,000 continuous horsepower. No power plants have been reported.

405. *Philippine Islands.*—The Philippine group consists of several hundred islands, but most of the potential water power is on the two largest, Luzón and Mindanao. Luzón is traversed throughout its length by moderately high mountain ranges, on which the annual rainfall at many places exceeds 100 inches. The streams of the island would no doubt afford a large amount of potential power, but no systematic study of possible power sites has been made, and only general

estimates can be given. A concession was granted in 1913 for the use of the water of Caliraya River, in Laguna Province, near Manila, but apparently the plant was not built. The largest river of Luzón is the Cagayán, at the north end. The principal rivers of Mindanao, which is mountainous and receives a heavy rainfall, are Mindanao and Agusan rivers. The Mindanao, in the southwestern part of the island, receives the waters of Liguasan and Bulúan lakes. The Agusan, in the northeastern part, drains several small lakes in its middle course. This island is sparsely populated, and little is known of its water powers. There appear to be no large power plants in the Philippines, and the potential power indicated by the altitudes and the rainfall is about 1,500,000 horsepower.

406. *Celebes.*—Although the Dutch have inhabited the island of Celebes for two centuries little is known of its interior. The island is curiously shaped, having four large peninsulas that reach out from a small central nucleus, and along the center of each peninsula there is a mountain chain. The annual rainfall exceeds 100 inches. The rivers head in numerous lakes, which could be used for storage. The principal rivers are the Sadang, in the southwest peninsula, and the Bahu Solo, in the southeast. Studies by the Dutch Government cover the eastern half of the central nucleus and a small part of the southeast peninsula. The most promising power sites so far surveyed are between Posso Lake and the sea, where 100,000 horsepower could be developed at two sites, and in the Malili basin, where 15,000 horsepower could be developed at four sites. The potential power of this region is estimated at 150,000 horsepower, and that of the whole island at a minimum of 1,000,000 horsepower. The information available indicates that no power plants other than small native affairs have yet been constructed on Celebes. The smaller islands near by probably have some potential power, but little is known concerning it.

407. *Borneo.*—The island of Borneo ranks next to New Guinea in size but contains considerably less water power. It is mountainous throughout its central part, and the rainfall is abundant. The principal rivers are the Kapuas, Barito, and Koti in the Dutch territory and the Rejang and Brunei in Sarawak, which is under British protection. Little is known of the potential power on individual streams, but the Brem-Brem Falls, on Kayan River, were explored in 1918 and are estimated to be capable of yielding several hundred thousand horsepower. The present economic value of these falls is small, however, on account of their great distance from the coast. The potential power of Dutch Borneo is placed at 2,000,000 horsepower, and an estimate based on comparative drainage areas would add about 500,000 horsepower for territory under British protection. The Dutch have examined sites having a potential capacity of 100,000 horsepower, but no plants are reported as in operation or being constructed.

408. *Sumatra.*—The island of Sumatra is more than 1,000 miles long and in its widest part is 260 miles broad. A chain of mountains extends along its western coast, so the large rivers all flow eastward. Among them are the Kampar, Indragiri, Hari (tributary to the Jambi), and Musi. The rainfall is heavy throughout the year, averaging 185 inches at Padang and even more at Palembang. Engineers of the Dutch Government have examined sites having a capacity of 325,000 horsepower on the headwaters of the Musi and in the north of the island, the streams examined including Assahan River. The Assahan drains Lake Toba, which covers 500 square miles in the crater of an old volcano high up in the mountains and is the largest lake on the island. At four sites on this river 500,000 horsepower can be developed, of which 200,000 horsepower is included in concessions already granted. The minimum potential power of Sumatra is placed at 2,000,000 horsepower, of which 8,625 horsepower is developed. The developed power is used mainly in mining, but a plant of 1,500 horsepower is operated by a Portland cement factory at Indaroeng, which has another plant of 3,000 horsepower under construction.

409. *Java.*—The population of Java is 35,000,000, and parts of this island are as densely peopled as the most thickly inhabited parts of Europe. The island is mountainous, having a mean altitude of 1,600 feet and containing several peaks that exceed 10,000 feet. The rainfall is plentiful, averaging 75 inches at Batavia and reaching 185 inches in the mountains. There are no long periods of either rain or drought, but at Batavia the period from December to March is the most rainy and July and August are the least rainy months. Rice irrigation is practiced over a large area. The rivers are numerous but comparatively small; the largest are the Solo and Brantes in the east and the Taroem and Manuk in the west. At Bandoeng, on Taroem River, there is a plant of 1,750 horsepower, and Samarang and Salatiga are supplied with electricity by a plant having a capacity of 3,000 horsepower. The total developed power on the island amounts to 12,000 horsepower, of which 6,000 horsepower is used in factories. Plants now under construction will develop a total of 44,400 horsepower. The largest plant under construction is on Anten River near Buitenzorg, where the Dutch East Indies Government is developing 28,000 horsepower. The minimum potential power of Java is estimated at 500,000 horsepower, of which 85,000 horsepower has been thoroughly studied.

410. *Hawaii.*—The Hawaiian Islands are mountainous, and the rainfall is high but not evenly distributed. At points along the coast and on the leeward (southwest) side of the islands the annual precipitation is only a few inches, but at altitudes above 2,000 feet on the windward (northeast) side of the islands it has reached 600 inches. The streams are small and are used mainly for irrigation; the power resources are scant.

GENERAL SUMMARY.

A summary of the capacity of the world's water-power plants and of the world's potential water power, representing 75 per cent of the theoretical power from flow available at least 75 per cent of the time, is given in the following tables and in graphic form on the maps (Pls. 1–8).

Summary of potential and developed water power in 1920, in horsepower.

North America.

	Developed.	Potential.
Mexico	400,000	6,000,000
United States	9,243,000	28,000,000
Alaska	40,000	2,500,000
Newfoundland	60,000	400,000
Canada	2,418,000	20,000,000
Costa Rica	15,000	1,000,000
Guatemala	4,000	1,500,000
Honduras	3,000	1,000,000
Nicaragua	400	800,000
Salvador	2,700	200,000
Panama	13,300	500,000
West Indies	12,500	150,000
Approximate total	12,210,000	62,000,000

South America.

	Developed.	Potential.
Argentina	25,000	5,000,000
Bolivia	12,000	2,500,000
Brazil	250,000	25,000,000
British Guiana		2,500,000
Dutch Guiana		800,000
French Guiana		500,000
Chile	60,000	2,500,000
Colombia	25,000	4,000,000
Ecuador	2,500	1,000,000
Paraguay	200	2,000,000
Peru	36,500	4,500,000
Uruguay		300,000
Venezuela	12,500	3,000,000
Approximate total	424,000	54,000,000

Summary of potential and developed water power in 1920—Continued.

Europe.

	Developed.	Potential.
Sweden	1,200,000	4,500,000
Norway	1,350,000	5,500,000
Finland	185,000	1,500,000
Russia	100,000	2,000,000
Esthonia, Latvia, Lithuania	20,000	200,000
Poland	80,000	200,000
Ukraine	40,000	425,000
Region of the Caucasus	5,000	5,000,000
Hungary	30,000	150,000
Czecho-Slovakia	50,000	420,000
Jugo-Slavia	125,000	2,600,000
Austria	205,000	3,000,000
Rumania	30,000	1,100,000
Bulgaria	8,000	1,200,000
Greece	6,000	250,000
Turkey		Small
Albania	1,000	500,000
Italy	1,150,000	[a]3,800,000
Switzerland	1,070,000	[b]1,400,000
Germany	1,000,000	1,350,000
France	1,400,000	4,700,000
British Isles	210,000	585,000
Belgium	700	Small.
Denmark	1,500	2,000
Netherlands		
Spain	600,000	4,000,000
Portugal	10,000	300,000
Iceland		500,000
Approximate total	8,877,000	45,000,000

[a] Ordinary flow. Ordinary low flow estimated at 2,700,000 horsepower.
[b] Ordinary low water 900,000. For 9 months, 1,374,000 horsepower, and for 6 months, 2,504,000.

Asia.

	Developed.	Potential.
Chinese Republic	1,650	20,000,000
India	150,000	27,000,000
Asia Minor	500	500,000
Arabia		
Persia		200,000
Afghanistan	2,000	500,000
Siberia		8,000,000
French Indo-China		4,000,000
Siam and Malay States	4,500	4,000,000
Chosen	2,620	500,000
Japan	1,000,000	[a]6,000,000
Approximate total	1,160,000	71 000,000

[a] Total power developed, under lease, and available at low flow.

Africa.

	Developed.	Potential.
Tangier		50,000
Morocco		250,000
Algeria	130	200,000
Tunis		30,000
Tripoli		Small.
Eritrea		Small.
British Somali		Small.
Italian Somali		Small.
Gold Coast and British mandate in Togo		1,450,000
Liberia		4,000,000
Sierra Leone		1,700,000
Senegal		250,000
Rio de Oro		Small.
Gambia		Small.
Portuguese Guinea		Small.
Union of South Africa	5,000	1,600,000
Angola	4,000	4,000,000
Southwest Africa (Union of South Africa mandate)		150,000
Belgian Kongo and Belgian mandate	250	90,000,000
French Kongo		35,000,000
French mandate in Kamerun		13,000,000
Nigeria and British mandate in Kamerun		9,000,000
Rhodesia		2,500,000

Africa—Continued.

	Developed.	Potential.
Tanganyika (British mandate)	800	2,700,000
British Central Africa		1,200,000
British East Africa	900	4,700,000
Portuguese East Africa		3,700,000
Bechuanaland		20,000
Abyssinia		4,000,000
Egypt		600,000
Ivory Coast, Dahomey, and French mandate in Togo		2,850,000
French Guinea		2,000,000
French Sudan		1,000,000
Madagascar	100	5,000,000
Approximate total	11,000	190,000,000

Oceanica.[a]

	Developed.	Potential.
Australia		620,000
New Zealand	45,000	3,800,000
Philippine Islands		1,500,000
Sumatra	[b]11,600	2,000,000
Java	[b]56,500	500,000
Borneo		2,500,000
New Guinea		5,000,000
Tasmania	34,500	400,000
Celebes		1,000,000
Approximate total	147,000	17,000,000

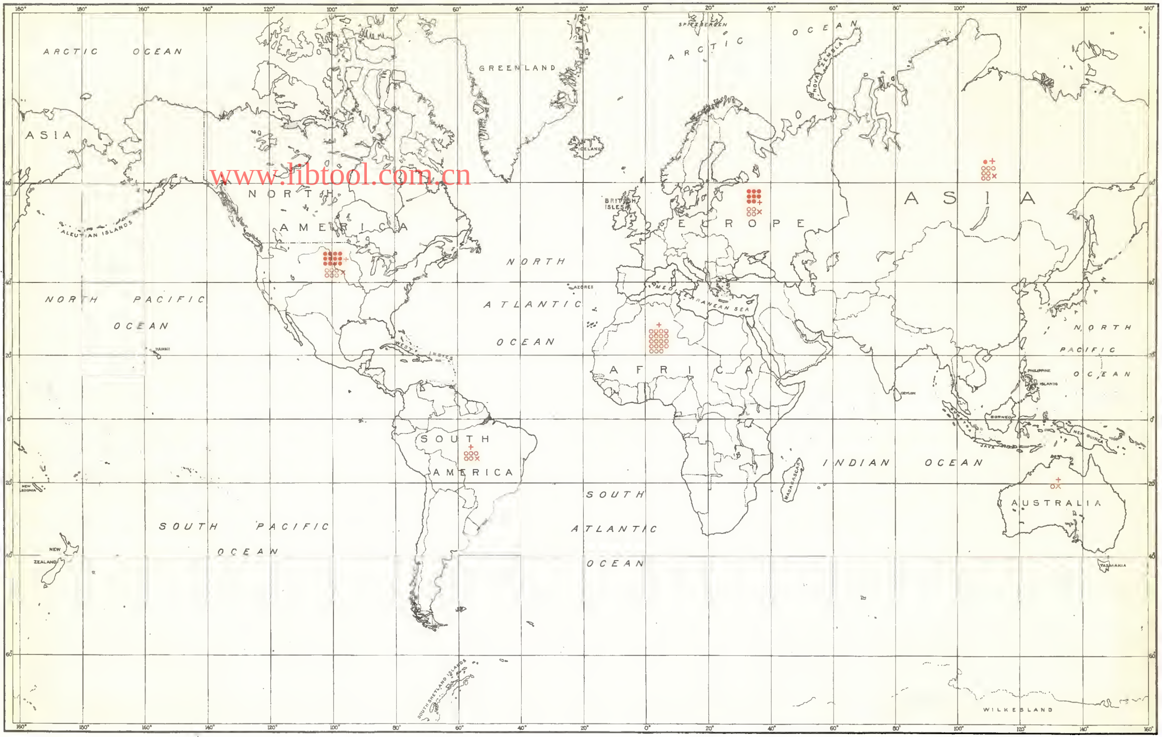
[a] All these estimates except those for the Philippines and New Guinea assume the use of storage.
[b] Installed or under construction, November, 1920.

Recapitulation.

	Developed.	Potential.
North America	12,210,000	62,000,000
South America	424,000	54,000,000
Europe	8,877,000	45,000,000
Asia	1,160,000	71,000,000
Africa	11,000	190,000,000
Oceanica	147,000	17,000,000
Approximate total	23,000,000	439,000,000

DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

WORLD ATLAS
OF COMMERCIAL GEOLOGY
PART II PLATE 1



Mercator's projection

EXPLANATION

Developed water power in 1920

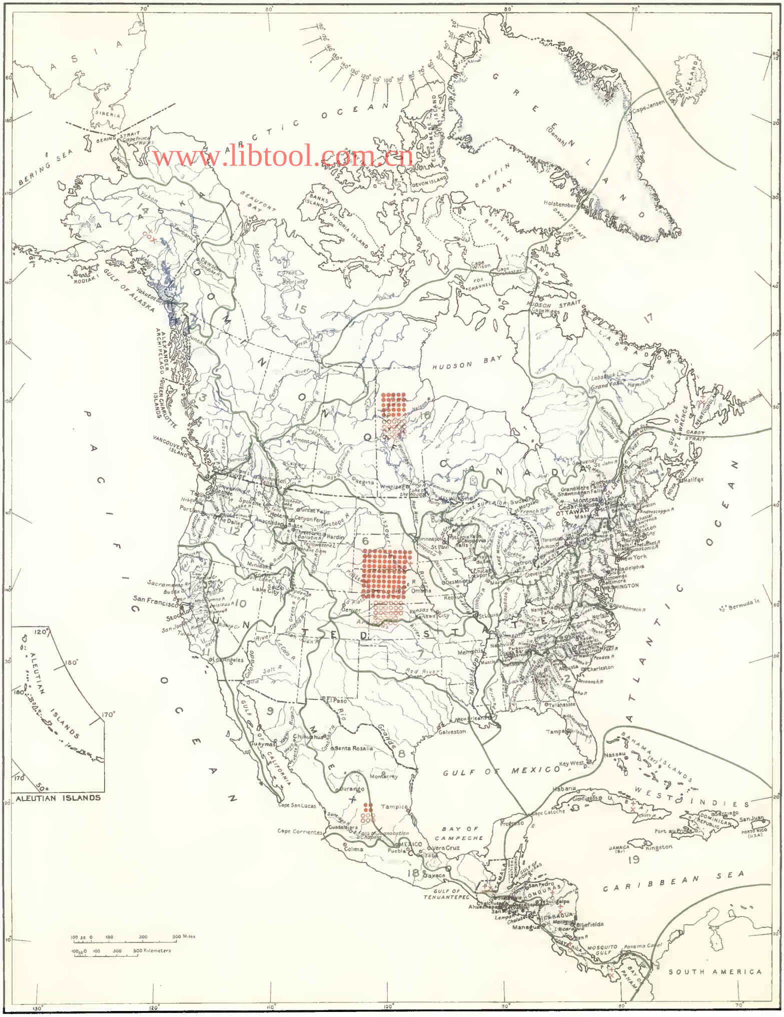
Each dot (●) represents 1,000,000 horsepower and each cross (+) less than 1,000,000 horsepower of installed capacity

Water-power resources (developed and undeveloped)

Each circle (○) represents 10,000,000 and each cross (×) less than 10,000,000 continuous potential horsepower at low-water stage

WATER POWER OF THE WORLD BY CONTINENTS

(SYMBOL FOR AUSTRALIA REPRESENTS ALL OCEANICA)



WATER POWER IN NORTH AMERICA BY COUNTRIES

EXPLANATION

Developed water power in 1920

Each dot (•) represents 100,000 horsepower and each cross (+) less than 100,000 horsepower of installed capacity

Water-power resources (developed and undeveloped)

Each circle (o) represents 1,000,000 and each cross (×) less than 1,000,000 continuous potential horsepower at low-water stage

Green lines bound numbered drainage units described in the text

WATER POWER IN SOUTH AMERICA BY COUNTRIES

EXPLANATION

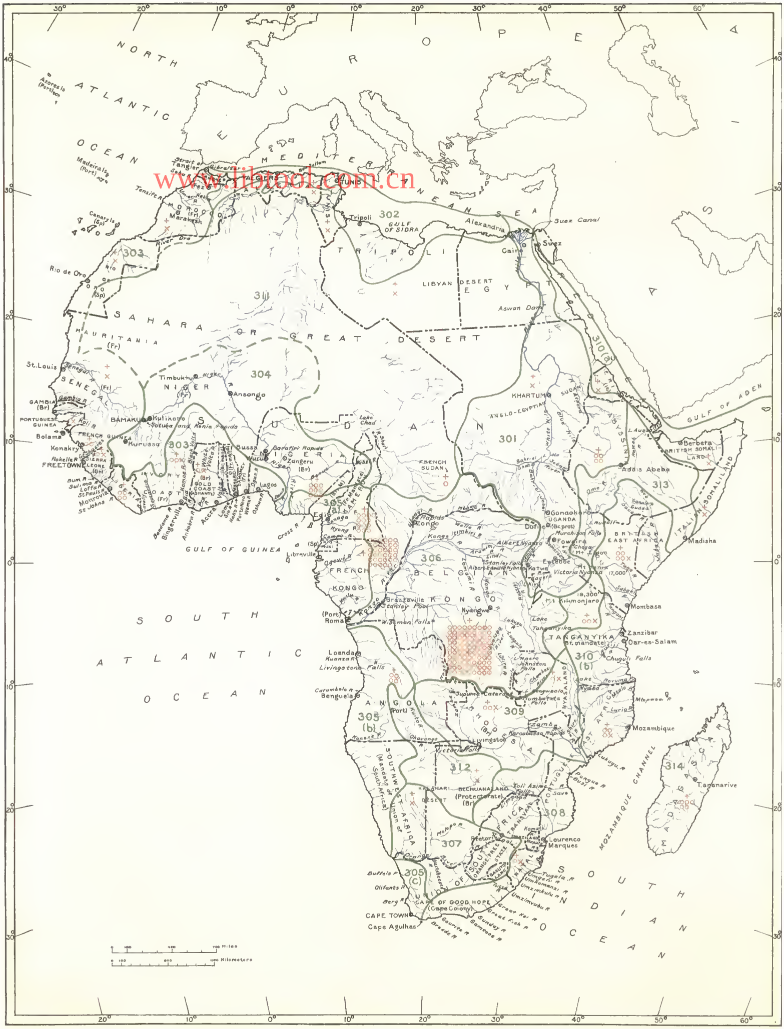
Developed water power in 1920

Each dot (•) represents 10,000 horsepower and each cross (+) less than 10,000 horsepower of installed capacity

Water-power resources
(developed and undeveloped)

Each circle (o) represents 1,000,000 and each cross (×) less than 1,000,000 continuous potential horsepower at low-water stage

Green lines bound numbered drainage units described in the text



EXPLANATION

Developed water power in 1920

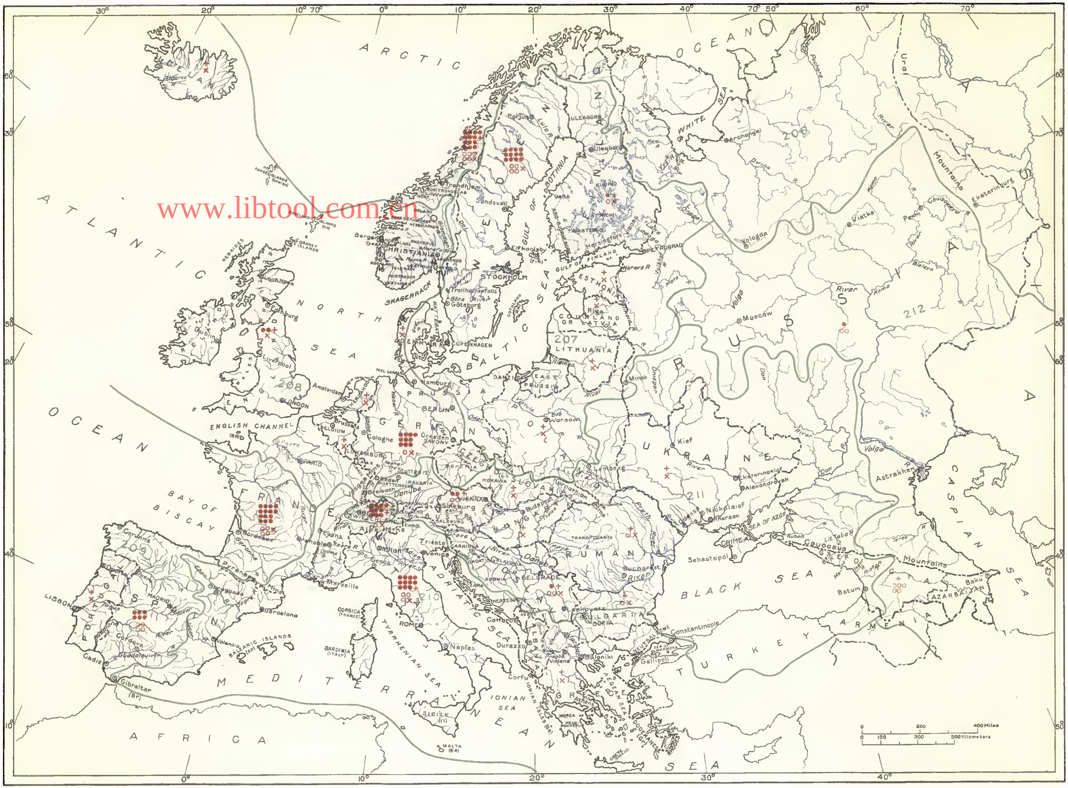
Each dot (•) represents 10,000 horsepower and each cross (+) less than 10,000 horsepower of installed capacity

Water-power resources
(developed and undeveloped)

Each circle (○) represents 1,000,000 and each cross (×) less than 1,000,000 continuous potential horsepower at low-water stage

Green lines bound numbered drainage units described in the text

WATER POWER IN AFRICA BY COUNTRIES



EXPLANATION

Developed water power in 1920

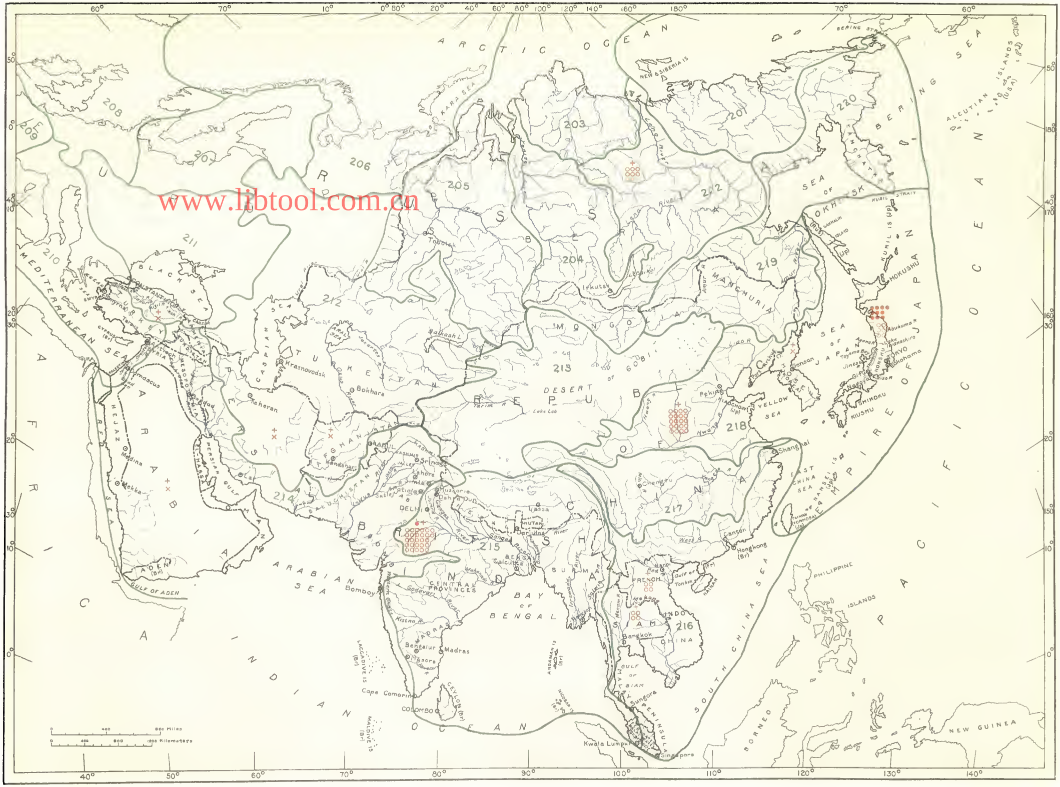
Each dot (•) represents 100,000 horsepower and each cross (+) less than 100,000 horsepower of installed capacity

Water-power resources (developed and undeveloped)

Each circle (○) represents 1,000,000 and each cross (×) less than 1,000,000 continuous potential horsepower at low-water stage

Green lines bound numbered drainage units described in the text

WATER POWER IN EUROPE BY COUNTRIES



EXPLANATION

Developed water power in 1920

Each dot (●) represents 100,000 horsepower and each cross (+) less than 100,000 horsepower of installed capacity

Water-power resources
(developed and undeveloped)

Each circle (○) represents 1,000,000 and each cross (×) less than 1,000,000 continuous potential horsepower at low-water stage

Green lines bound numbered drainage units described in the text

WATER POWER IN ASIA BY COUNTRIES
EXCLUSIVE OF MALAY ARCHIPELAGO

EXPLANATION

Developed water power in 1920

Each dot (•) represents 10,000 horsepower and each cross (+) less than 10,000 horsepower of installed capacity

Water-power resources (developed and undeveloped)

Each circle (○) represents 1,000,000 and each cross (×) less than 1,000,000 continuous potential horsepower at low-water stage

Green lines bound numbered drainage units described in the text

WATER POWER IN OCEANICA AND MALAY ARCHIPELAGO BY COUNTRIES

EXPLANATION

Developed water power in 1920

Each dot (•) represents 100,000 horsepower and each cross (+) less than 100,000 horsepower of installed capacity

Water-power resources
(developed and undeveloped)

Each circle (○) represents 200,000 and each cross (×) less than 200,000 continuous potential horsepower at low-water stage

Scales
100 0 100 200 300 400 500 600 Miles

WATER POWER IN THE UNITED STATES BY STATES

THE WORLD ATLAS OF COMMERCIAL GEOLOGY.

The study of the world's resources of its essential minerals was begun during the World War as a part of the task of keeping American industries supplied with raw material. A preliminary world atlas of commercial geology was prepared in manuscript form for the use of the State Department and the Peace Commission and was subsequently revised and issued as Part I of a World Atlas of Commercial Geology, in the belief that it would be helpful in directing both the mineral industry and the commerce of the United States.

Part II of the World Atlas—this work—which represents the results of a continuation of commercial world study, shows the world's potential water power and the extent to which it has been utilized at home and in other countries the products of whose mineral and other industries may compete in the world's markets with those of the United States.

Part I includes 72 pages of text and 72 plates and is sold for $2.

Part II includes 39 pages of text and 8 plates and is sold for $1.

Orders should be sent to the Director of the United States Geological Survey at Washington. Payment may be made by money order or in cash, sent preferably in a registered letter.