FOREIGN EXPERIENCE AND TECHNIQUES

WATER RESOURCES OF PERU AND POSSIBILITIES OF THEIR UTILIZATION

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UDC 627.1(83)

Hydrographic Net. The insufficient streamflow of the Pacific Coast (Costa), difficult natural conditions of the Peruvian upland (Sierra) and the tropical forest zone (Selva), and the poor accessibility of the majority of river basins have long retarded investigation and utilization of the country's water resources. To a considerable extent this was due also to the level of development of government enterprises for utilization of natural resources. Nor was the uncontrolled monopoly by capitalist firms of mining and industrial construction conducive to proper development of water resources. The indicated conditions have been and, as a grave heritage, still are the reason for insufficient knowledge of the country's rivers.

Peru's hydrographic net comprises the basins of the Pacific and Atlantic (Amazon) Oceans and of inland lakes. Fifty-two rivers* with a total mean annual flow of 32-35 km³ are of importance. The majority of them are small, and with the exceptionally dry climate of the western slope of the Andes and of the coast, their waters do not always reach the ocean.† When intense rains of short duration do occur, they are subject to catastrophic floods with volumes amounting to 80% of the annual flow. The length of these rivers does not exceed 200 km and the mean annual flow of most of them ranges from 100 to 1500 million m³. The rivers with highest flows are the Tumbes with 4.35 km³, the Santa with 3.88, the Chira with 3.83, and the Ocanya with 1.83 km³. All rivers have quite sharply fluctuating discharges. Only 10 rivers, originating deep in the mountains among eternal snow, flow to the ocean the year round. The first stream flows from the upland appear in October or November. Floods occur from December to March, and by June-July the discharges begin to diminish rapidly. From August to November most of the river channels remain dry.

All Atlantic rivers in Peru are in the Amazon river system, originating on the eastern slopes of the Peruvian Andes in Lake Huaycash at about 5000 m; under the name Marañon (about 1380 km long) and flowing to the confluence with Ucayali where the Amazon proper begins (Fig. 1). The area of the Amazon basin in Peru (including the tributaries originating in the Ecuadorian Andes), which is 1,058,000 km², and the mean annual runoff of 355 km³ constitute 15 and 11% of those at the mouth. A number of large tributaries enter the Amazon within Peru's boundaries. The largest are Huallaga (1100 km) and Ucayali (1960 km). High water on the tributaries lasts here from January to mid-April. Low flow begins in June and lasts till September-October. Water-level fluctuations in the rivers are quite considerable.

In the north three large left tributaries of the Marañon, the Tigre, Napo, and Putumayo Rivers, originate in the Ecuadorian Andes. Their regime has its peculiarities: the flood occurs in the summer months of the Northern Hemisphere since they originate near the equator where most of the precipitation comes from May to September. The lack of coincidence of floods in the left and right tributaries reduces to some extent the Amazon's water level fluctuations in its upper reaches. In the south of the Peruvian Selva the swift Madre de Dios River, full of rapids in its upper reaches, flows eastward into Bolivia. The catchment of the high mountain lake Titicaca (A = 8340 km², depth = 355 m) lies in the extreme south of the country at 3812 m above sea level. Five rivers flow into the lake and one flows out. It is of great fishing and transport importance.

The study of stream flow and regime of many rivers, especially in the mountain zone, is still insufficient, and in the tropical zone it has only begun. Thus the lower reaches of such large rivers as the Marañon, Ucayali,

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*There are 80 rivers on the coast but the flow of 28 of them is so small and they dry up so frequently that they are of no interest for utilization; they are intermittent water courses.
†The coastal zone is distinguished by a stable arid climate where precipitation does not exceed 30-50 mm. The Andean slopes facing the coast are also very dry. At 1500-2000 m above sea level annual precipitation does not exceed 250 mm.

TABLE 1

<table>
<thead>
<tr>
<th>Zone</th>
<th>Length of observations (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal</td>
<td>77 19 23 12 9 9 5</td>
</tr>
<tr>
<td>Mountain</td>
<td>119 83 30 6</td>
</tr>
<tr>
<td>Tropical</td>
<td>17 17</td>
</tr>
</tbody>
</table>

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Utilization of Water Resources for Irrigation.

Peru's water resources are utilized mainly for irrigation and to a lesser degree as yet for hydropower and water transport (the Ucayali River and the lower reaches of the Marañón and Huallaga Rivers). The inadequate precipitation and arid climate make irrigation of prime importance in a considerable area of the country, particularly in the coastal zone (Costa). There is now a little more than 2.8 million ha under cultivation, of which 1.1 million are irrigated. The main irrigated area is in the Costa. Here 726,000 ha were irrigated in 1969 in the 30 river basins. The largest irrigation systems are in the northern part of the country. With the locally established irrigation quantities, the flow of the coastal rivers would be sufficient for doubling the irrigated area, but this would require seasonal and longer stream flow regulation (only 8 km$^3$ their flow is now being utilized).

Eighteen reservoirs with a total capacity of 1.3 km$^3$, some of which are multipurpose, have been constructed in watercourses of the Andes' western (Pacific) slope. The largest of them are the 360 million m$^3$ Tinajones on the Chancay River, the 260 million m$^3$ San Lorenzo on the Chipilico River, and the 200 million m$^3$ El Fraile on the Tambo River. Smaller reservoirs, high mountain lakes, and lagoons, 15 of which are dammed up and have spillway structures, also play a role in stream flow regulation. The construction of nine larger reservoirs with a total capacity in excess of 3 km$^3$, aimed at multipurpose use of water resources in the mountain zone and on the rivers of the Andes' western slope, is being contemplated in the near future. In view of the difficulty of regulating the flow of western-slope rivers (lack of favorable storage sites and the need of building high dams), flow from the eastern slope of Andes is being diverted to the coastal zone. At present this diversion amounts to 0.8 km$^3$/year. In spite of considerable difficulty (the need to construct long tunnels and canals high in the mountains), transmountain diversion is becoming increasingly more important.

No less important in satisfying the increasing water demand in the coastal zone is ground water, of which 1.2 km$^3$ are now being used. Realizing the great importance of investigating the ground water supply, a special commission for its study and for devising means of its utilization was established when the national program of irrigation development was promulgated in 1965. Extensive investigations are planned, the results of which are expected by 1974-75. Irrigation plays an important role also in the mountain zone (Sierra), although here the dependence of agriculture on irrigation is not as great as in the coastal zone. However, with an optimal irrigation water supply, climatic and edaphic conditions in individual provinces (oases) make it possible to obtain two crops per year. In the mountain zone, 323,000 ha are now irrigated. It is possible to increase the irrigated area by 120-150,000 ha and to improve existing systems at relatively small direct cost. This construction will, however,