TWO WATER FLOW MAPS OF CALIFORNIA

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Maps showing volume of movement have became familiar geographic tools in such cases as highway traffic and ocean trade. Indeed, their value prompts inquiry into other kinds of movements which might usefully be shown on flow maps. Water, logically enough, is one of these, and it is a matter of curiosity that water flow maps for water-conscious California should be so few to date.[1] In view of data available from public agencies,[2] it is suggested here that California's water resources might be portrayed for our students and the general public in a more revealing way by greater use of flow maps.

For example, in place of the usual river map which shows little difference in river size, there might be offered instead a map on which river width is drawn in proportion to actual volume of flow. Figure 1 shows all rivers having an average annual natural runoff of at least 100,000 acre-feet, with line thickness proportional to runoffs exceeding 500,000 acre-feet.

As a teaching device, the map makes tangible the idea that river flows from the San Joaquin Valley and North Coast are oriented away from the parts of California where they are most needed at present. Plainly indicated are the importance of the Delta area as a natural distribution point for man's diversions,[3] and the significance of the relatively gigantic Colorado River to the southern part of the state. The map further suggests the substantial exhange of waters between California and its neighbors, and the resulting political and economic implications of a shared water supply. A glance at this sort of map may prompt basic questions and inspire progress toward their answers; for example: What balance of climate and ground conditions accounts for the runoff pattern? To what degree have river volume and spacing been related to usability? Why did the state select one, and only one, river as a political boundary?

For many parts of California, the larger water flows tend to be the manufactured ones, particularly urban aqueducts and irrigation canals. These cannot be overlooked in making an accurate accounting of California water flow. In contrast to existing maps which show only the direction of river diversions, Figure 2 indicates the relative annual volume of the larger diversions. To permit presentation at this scale, the map is limited

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[1] Perhaps most notable is the map of Central Valley streamflow published by U. S. Bureau of Reclamation, in *Central Valley Basin,* 1949, Plate 10. Average annual runoffs for the larger rivers of California, 1889-1929, compiled originally in the Calif. Div. Water Res. *Bulletin* 25, were reported conveniently in the *Geog. Rev.*, 1939, p. 253.

[2] Outstanding sources of flow data used in compiling the two maps here were: (1) Calif. State Water Resources Board, *Bulletin* 1, 1951, and *Bulletin* 2, Vol. I, 1955; (2) Calif. Div. Water Res., *Reports of Sacramento-San Joaquin Supervision* for 1953 and 1954; and (3) U.S. Geological Survey, *Water Supply Papers* for the Colorado River Basin and Pacific Slope Basins in California. In addition, certain canal data were kindly furnished in a letter from Irvin M. Ingerson, Principal Hydraulic Engineer, Calif. Dept. of Water Resouces, November 13, 1957.

[3] Average annual natural runoff about 30 million acre-feet per year.

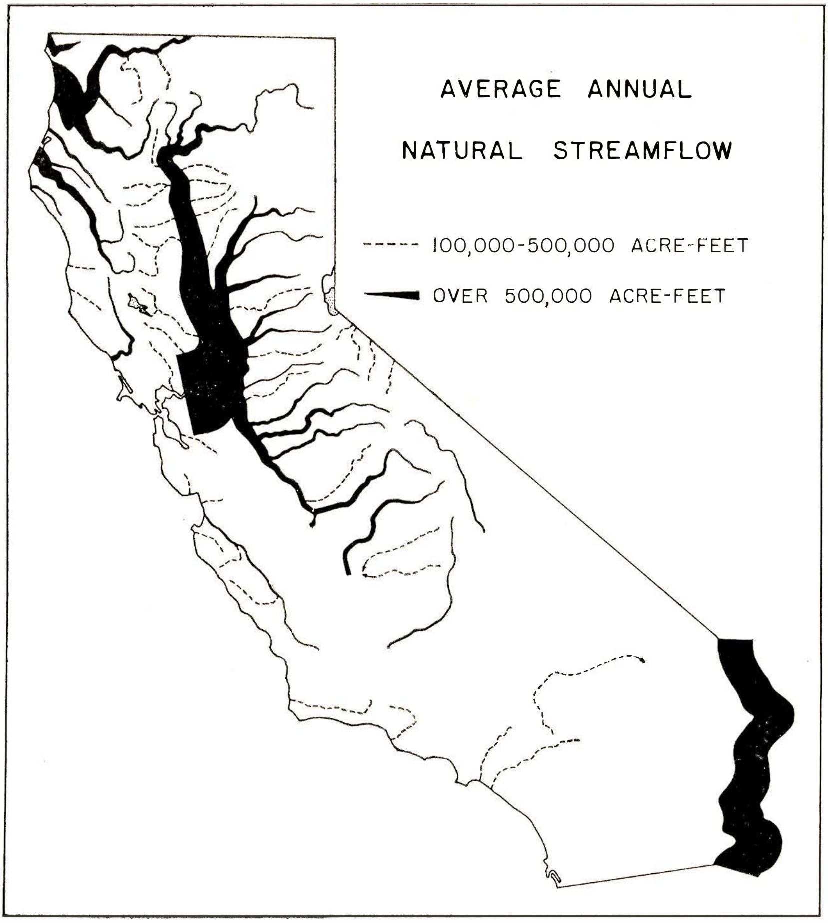

Fig. 1

to major diversions terminating outside the original watershed.[4] These man-made rivers are comparatively new and in many cases are variable; where average annual flow is obviously increasing, recent one-year data were used in place of the historic average annual flow.

[4] Definitions of diversion "outside the watershed" were made here arbitarily, and in part for convenience in presentation. Thus, among the borderline cases included were the All-American Canal and the Glenn-Colusa Canal-Back Borrow Pit-Yolo Bypass system. Excluded were the Sutter Bypass (over 3 million acre-feet annually) and the Delta Cross Channel (over 2 million acre feet annually). Also excluded were numerous short interbasin diversions, none accounting for as much as 50,000 acre-feet annually. These are, in north-south order: Pit River watershed to Madeline Plains, Mad River to Eureka, Little Truckee River to Sierra Valley, Echo Lake to American River, Cosumnes River to American River, Cache Slough to Vallejo, Contra Costa Canal, Mono Craters Tunnel, Salinas River to San Luis Obispo, Santa Ynez River to Santa Barbara area, and Cottonwood Creek to San Diego area. Possibly also

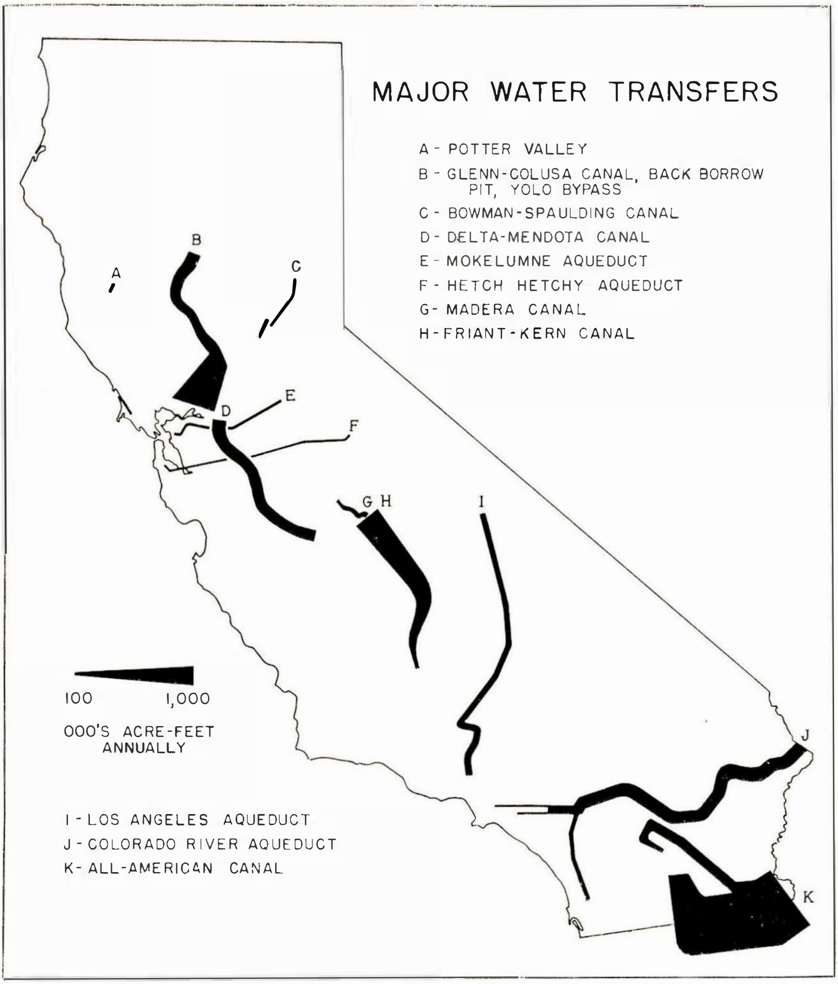

Fig. 2

The largest water diversion shown on Figure 2—one not especially publicized in California—is the All-American Canal flow to Imperial Valley,[5] beside which the South Coast imports from the Colorado River

qualifying for the foregoing list would be flow from Cache to Putah Creeks and from the Kings to the San Joaquin River. It is revealing to note that despite the greater publicity given certain more recent diversions such as the Contra Costa Canal or the Cachuma Tunnel, two of the older and little-publicized diversions—primarily for hydroelectric purpose—actually transfer far greater water volume: the Potter Valley diversion from the Eel River to the Russian River watershed, and the Bowman-Spaulding canal system linking the Yuba and America Rivers (letters A and C, respectively, on Figure 2).

[5] About 3 million acre-feet per year, excluding the Coachella Branch.

and Owens Valley look all but insignificant. In fact, it is somewhat misleading to say that the Colorado River no longer flows into the Salton Basin! Other basic conditions illustrated by Figure 2 include: (1) the near-absence of exports from the North Coast watershed as yet; (2) the magnitude of Owens River diversion, considering dependence on facilities constructed under engineering and financial limitations of an earlier day; (3) the relatively small use as yet of Sierra Nevada water by the Bay Area; (4) the recharge of groundwater reservoirs in the Los Angeles area with imported water, as represented on the map by two prongs extending westward from the terminus of the Colorado River Aqueduct; (5) the complex, but integrated, flow of irrigation, irrigation drainage, and floodwaters along the west side of the Sacramento Valley, and (6) the well-publicized southward water transfers in the San Joaquin Valley.

Certain problems are inherent in constructing water flow maps. The very fact that these maps have far-reaching utility and that source data for them are readily obtained makes it desirable to anticipate such problems. Perhaps chief among them is the matter of scale. The range of flows even within a local area is often so large as to prevent complete portrayal. One alternative is to prepare separate maps of individual kinds of water flow, such as Figures 1 and 2 above. Likewise, there is frequent difficulty in accurately representing both volume and route of flow within a limited space. The use of color permits overlapping of flows to some extent. Where color fails, the technique of "stylizing" the routes of flow is usually successful, so long as there is no attempt to combine stylized flow data with accurate base data, such as city location, on the same map.

More important than the problems are the possibilities of drawing many more and better water flow maps than the two demonstrated here. It is entirely feasible, for example, to create maps to illustrate: (1) interstate water flows, especially complex situations involving the Klamath River, Lake Tahoe, or the Colorado River; (2) integrated schemes of natural and man-made flows, especially in heavily-irrigated valleys,[6] (3) seasonal patterns of water flow, where such matters as wastage, storage, and hydroelectric generation are pertinent. The teacher is urged to consider the advantages of such flow maps, wherein students may visualize both the "where" and the "how much" in one glance.

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[6] Due to scale limitations, it was not deemed practical to show local (intrabasin) diversions on Figure 2, despite their huge volume and local importance. Largest of these, according to the author's information, is the Palo Verde Canal, which diverts over 800,000 acre-feet annually. In descending order of annual volume are: Turlock Canal, Merced Canal, South San Joaquin Canal, Sutter Butte Canal, Almanor-Butt Tunnel, Ward Tunnel, Modesto Canal, and Fresno Canal. All of these carry an annual average flow exceeding 300,000 acre feet.