miles to the fresh-water canal from Zagazig to Suez, and so gives water communication between Cairo and Suez. The connection of this great work with the maritime Canal (by the widening and deepening of the fresh-water channel, respectively to 180 and 11½ feet between Zagazig and Ismaïlieh) has been completed, and through navigation for vessels up to 400 tons burthen, paying only half the large Canal dues established between Cairo and the two seas. The new water-way will be worked under contract with the Suez Canal Company for the carriage of produce from Middle and Upper Egypt to Ismaïlieh, for shipment to Europe, in competition with Alexandria. Coals may be thus landed at Boulak direct from Cardiff or the Tyne, and return freights of cotton, sugar, wheat, or seeds be taken back in the same bottoms. (2) The Bahr-Moëz, supposed to be the old Tanitic branch,* which begins at Mit-Radi, near Benha, on the right bank of the Damietta branch, and widening through the province of Charkieh, divides near Tell-Basta (Bubastis) into two channels, which empty themselves into Lake Menzaleh. (3) The Chibin-el-koum, a fine canal nearly ninety miles long, which zigzags across the Delta from Quarnyeyn, on the Damietta to Farastaq on the Rosetta branch, throwing out, at the village from which it takes its name, a branch called the Mélig, which joins the Tabanieh canal below Sibél-Nitus, and with the latter empties itself into Lake Bourlos—a course which is almost identical with that of the old Sebenitic branch of the river. (4) The Menoufieh, which crosses the Delta a short way below its apex. And (5) the Mahmoudieh, which connects Alexandria with the Nile at Atfeh, on the Rosetta branch, about twenty-seven miles above the latter town. This last important channel, which is another of the great

* Restored to its present use by the first Fatimite Caliph, *circ.* A.D. 970.

works of Mehemet Ali, follows in a part of its course the bed of the ancient Canopic branch, and the old canal of Fooah, which the neglect of the Mamelukes allowed to finally dry up about a century ago. The present channel was begun in 1819, and during the ten months of its construction by the labour of 250,000 men, it cost 300,000*l.*, and 20,000 lives, which perished by accident, hunger, and disease. Its length from the Nile to Alexandria is about fifty miles, with an average width of one hundred feet, and it is navigable for large river craft throughout the year. Altogether, these greater canals and their navigable branches make up a system of some 1,900 miles between Farshoot and the Mediterranean. As, however, many sections of this are dry during low Nile, the water-way it would otherwise afford for the transport of local produce is broken and inefficient. But much has been done within the past dozen years to remedy this, by deepening the defective channels, and below Cairo especially the inter-communication is now fairly complete.

These main arteries, however, form little more than one-fourth of the whole canal system of the country. In Upper and Middle Egypt, from Assouan to Cairo, there are 348 minor channels which serve only for irrigation. Of these the province of Esneh reckons 9, that of Kenneh 14, Girzheh 19, Assiout 63, Minieh 71, Benisouef 52, the Fayoum in all 111, and Ghizeh 9. In the Lower provinces there are 408, of which Galioubieh has 27, Menoufieh 24, Garbieh 75, Charkieh 181, Dahkalieh 28, and Behera 73. Of this total of 756 canals—measuring in all 6,500 miles—a few in the Delta start direct from the Nile, but the great majority are subordinate ducts—capillaries, so to speak—of the larger channels, by which the vital fluid is circulated to the arable extremities of the country. Of the whole 840 canals, 112 have been constructed

during the present reign, mostly below Cairo, besides 426 bridges—150 in Upper, and 276 in Lower Egypt.

The means by which the yearly inundation is caught and distributed through this great network, over almost the whole cultivable surface of the country, are at once simple and efficient. In Upper Egypt a system of reservoirs, already mentioned, receives and stores most of the supply needed from Assouan to Assiout, below which a less complete chain of similar basins serves in part a like purpose down as far as Ghizeh, the province opposite Cairo. Thence to the Mediterranean, the whole work of storage and distribution is done by canals. Of these, both in Upper and Lower Egypt, the large primary ones tap the Nile at a higher elevation than that of the districts they are intended to inundate, and are themselves again tapped by the secondary channels, which irrigate still lower and remoter levels, and from which, in their turn, branch off yet smaller courses that are again cut, almost at will by the villagers, till the precious fluid is finally distributed as the exigencies of the various crops require. The headworks of the large canals, which issue direct from the river, consist generally of substantial stone or brick-built viaducts, with openings of from ten to fifteen feet wide, which are closable by vertical planks or sheet piling. At intervals down the canal similar dykes are placed to produce successive heads of water, as far down as the annual in-take will feed an overflow into the adjoining fields, or materially reduce the height to which the water has to be raised by manual or other labour. The secondary canals branch from the larger ones through wires similar to those described, and, like them again, are dammed at intervals to feed the smaller channels, by means of stone or brick conduits through their banks. Like the Nile itself, where necessary, the

whole of these canals are embanked, and the maintenance of their earthworks is a rigorous duty of the adjoining villagers. The depth of water in the navigable canals averages about three feet at low Nile; but, as the beds of the smaller channels are considerably above the ebb level of the river, these latter are, of course, dry during the greater part of the year. Soon after the annual rise begins—about July—the head dams of the larger canals are opened, and the rising volume of water is admitted into the first sections till their banks are overflowed, and the adjoining land flooded; the dykes lower down are then in turn similarly opened, as also those which feed the secondary channels, till the inundation is complete. As in "low" years the supply is insufficient for the whole area to be irrigated, so in over-high Niles there is more water than is required, and the excess is more or less destructive of all the crops near the river. Another class of canals accordingly serves to catch this surplus water, and discharge it into the river lower down. But the existing provision for this method of drainage is still inadequate, and three times during the past ten years great damage has been done by overflows that could not be thus diverted in time. The great annual inundation, which is controlled and distributed in the manner now described, is further supplemented by numerous wells, by many thousands of *sakkias* and *shadoofs*, and a yearly increasing multitude of steam and other pumps, the operation and uses of which will be more conveniently described in our chapter on agriculture.

Extensive as is this great system of canalisation, it is still not only insufficient to water all the land that might be reclaimed to cultivation in Lower Egypt, but it provides imperfectly for even the existing area during the eight months of ebb. To irrigate this adequately would re-

quire a constant supply all the year round in the main canals at the same height, and in the same quantity as when the river has risen from twelve to fifteen feet; and to obtain this desideratum the engineers of the French expedition first projected, and Mehemet Ali, nearly fifty years later constructed, the great work known as the Barrage of the Nile, immediately below the apex of the Delta. After experiment of the principle on one of the larger canals, the plans prepared by M. Mougel, a French engineer in the service of the Viceroy, were adopted, and in 1847 the structure, on a much grander and costlier scale than had been suggested to Napoleon, was begun. The scheme consisted of a vast double bridge or viaduct, the western section of which was to span, and by a system of sluices dam back, the Rosetta branch, and the eastern the Damietta. It was estimated that the great work and its necessary complement of new canals would provide for the efficient irrigation of nearly 4,000,000 acres of ground, and by dispensing with more than 25,000 *sakkias* and *shadoofs* would set free for other labour the many thousands of men and oxen employed in working these antiquated machines—a result which, if accomplished, would have been commercially well worth its cost. During the next couple of years the work was vigorously pushed on, with a vast expenditure of money and labour, but soon after the accession of Abbas Pasha it was suspended, and has not since been resumed. The section over the Rosetta branch is, however, nearly complete, and is a structure of fine architectural effect. The river—at this point 506 yards wide—is spanned by a bridge of sixty-one arches of sixteen-feet span, with a sluice-gate in each opening, and the whole capped by a line of crenellated turrets corresponding in design with loftier towers over the entrance gateways and in the centre of the

work. A similar but longer structure bridges the Damietta branch, which is 592 yards wide, but the sluice arrangement is here incomplete; and, except during high Nile, the only water that passes through this section is conveyed by a canal from the other side, and rushes through two or three arches only, the rest remaining dry. It was originally intended to back up the river by this structure about fifteen feet, but owing to the defective foundations it has not been deemed prudent to submit the work to a greater strain than that due to a head of from three to five feet of water, a level which is sufficient for the lands of Lower Egypt without the costly supplement of steam or other pumping.*

The urgent want, therefore, of more efficient irrigation than this incomplete work affords, has recalled attention to the necessity of complementing it by other means of supply; and, in considering these, the choice has lain between a system of high-level canals, and the completion and extension of the present Barrage. The view of the Government was at first favourable to the former plan, according to which the Nile would have been tapped either at Queremate, on its right bank about fifty miles above Cairo, or on the left bank at Echment three miles higher up, and, by means of a flatter fall than that of the river, a head of water would have been provided sufficient to supply a regulated irrigation to nearly 3,000,000 feddans of land below the capital all the year round, thus rendering the greater part of Lower Egypt practically independent of a good or bad Nile. The great cost, however, of either of these schemes led to their abandonment, and it was then decided to utilise Mougel Bey's great

* At present, navigation is carried on through locks at the Delta end of each section, where a toll of 60 paras (about 1½d.) per *ardeb* is levied on passing craft.

work. In 1875, therefore, Mr. Fowler was instructed to exhaustively examine the condition of this structure, and to submit estimates and plans for its completion. This was done early in the following year, and, as the result showed that for an outlay of about 1,000,000*l.* the work could be made to realise its original purpose, and so supply nearly all the additional irrigation required, it has been decided that this shall be done. Mr. Fowler's scheme is to complete the sluices of the existing Barrage, and to construct a new set on deep and very massive foundations immediately below the down-stream edge of the present work, which, while limiting the pressure on the old foundation to less than five feet, will raise the whole hydraulic head to the required level originally designed. The entire structure will be further strengthened by a broad mass of rubble, incorporated with two lines of béton blocks, traversing the river-bed immediately below the new sluices, and so forming a solid abutment to the whole. When these additions to this great work have been carried out, vast tracts of new land may be at once brought under cultivation, and with the aid of a few additional canals to distribute the precious fluid over the extended area, the complete irrigation of Lower Egypt will have been provided for, with an immense economy of labour and money, as compared with the costly and inefficient system now in use. The result will be an enduring monument for both the sovereign and the engineer to whose joint energy and skill its achievement will be due.

HARBOUR WORKS.

Alexandria.—The modern harbour of Alexandria in which the trade of the port is now carried on lies, as already described, within the upper curve of a bay formed

by the two projecting headlands of Ras-el-Teen, on the NE., and Cape Adjemi and Marabout Island on the SW., and measuring six miles in length by an average of two in width. It is landlocked on every side except one, the SW.; the wind from this direction is, however, the prevailing one during eight or nine months of the year, and from time immemorial the "sea" thus occasioned has seriously impeded the loading and discharge of vessels in the roadstead by stone lighters, as the custom has hitherto been. The importance of remedying this great drawback on the convenience of his chief port had been felt by the Khedive from soon after his accession, but it was not till the threatened rivalry of the Suez Canal had emphasised the necessity that he finally decided on carrying out a work of such magnitude and cost. Accordingly, in 1870, a contract was entered into with Messrs. Greenfield and Co., an eminent English firm, for the construction of a great breakwater, an inner harbour mole, and a line of quays, which should, together, afford the requisite shelter and increased accommodation needed by the growing trade of the port. After some months spent in the necessary preparations the work was begun in the spring of 1871, when the Khedive in person laid the foundation stone. Since then the original plan has been considerably modified, but it will be sufficient to mention its ultimate lines as now in great part carried out. Commencing at a point fifty metres SW. of the Ras-el-Teen lighthouse, the outer breakwater extends first in this latter direction for nearly 1,000 metres, and then, curving to SSW., runs in a straight line 2,350 metres further, or, in all, above two miles across the mouth of the harbour, enclosing an area of more than 1,400 acres of still water, deep enough for vessels of the largest class. The principal entrance to the port is now, therefore, round the south-western end of the

breakwater, which is 1,500 metres from the shore, while the narrow passage off Ras-el-Teen affords ingress and egress only to small craft and shore boats. As in the case of the great moles at Port Saïd, this outer sea-wall has been constructed, up to the water-level, of huge blocks of concrete, manufactured at the neighbouring Mex quarries, of sand and Theil lime, and deposited pell-mell on the sea side, with an inner front of rubble. The upper portion of the work, which is of solid masonry, rises ten feet above the lowest, or seven above the highest sea-level,* and is of a uniform surface width of twenty feet. In all, about 25,000 concrete blocks, weighing twenty tons each, and 130,000 tons of large and small rubble stones, have been sunk in the foundations of this great work. Shorewards the scheme comprises a broad mole, stretching out 900 metres from the mouth of the Mahmoudieh Canal and the harbour terminus of the Cairo railway, towards Ras-el-Teen; and a line of quays, 1,240 metres long, extending from the same point along the Marina to close upon the Admiralty Dock. Like the inner mole, these quays are based on a deep rubble foundation, with a superstructure of solid masonry, and when completed will have abutting iron jetties, alongside which ships may load and discharge in all weathers. A branch railway will connect the mole and quays with the Alexandria and Cairo line, and thus with the whole railway system of the interior; so that when the line now in advanced progress to Khartoum is completed, the abundant produce of the Soudan—which is at present all but wholly shut out from the Western markets—will be

* The maximum rise of tide here is twelve inches, but the level of high Mediterranean, when the water is forced up the Levant by westerly gales, is three feet above the level of low Mediterranean, caused by gales from the eastward.

carried to the Mediterranean almost in fewer days than it has hitherto taken months by the slow transport of river and caravan.

The necessary complement of this undertaking—the total cost of which will exceed 2,000,000*l.* sterling—will be the removal of the ledge of rock in the mouth of the harbour known as the Three Fathoms Shoal. Dangerous even in daylight, this obstruction practically closes the port between sunset and sunrise; and as the increased power of modern cannon has deprived it of all strategical value as a protection against hostile shipping, its removal has now become, so to speak, a corollary of Messrs. Greenfield's great work. Already the harbour dues of 4*d.* a ton on vessels with cargo, and 2*d.* on those in ballast,* levied since the completion of the breakwater, yield about 130,000*l.* a year, and it is estimated that little more than a twelvemonth's receipts of these would cover the cost of blasting and clearing away this now sole impediment to safe and easy entrance to the port at any hour or in any weather.

Suez.—The works at this port, though less extensive and costly than those at Alexandria, are still only second to these latter in magnitude and importance. The idea of them was originally limited to a dry dock, the want of which was soon felt by the Peninsular and Oriental Company after beginning, in 1842, the mail and passenger service between England and India, *viâ* Egypt. There was at that time no accommodation for repairing vessels south of the Isthmus nearer than Bombay, and the Company therefore strongly urged the Egyptian Government to erect either a gridiron or a floating dock at Suez to supply the want. The application was how-

* Coasting steamers pay only half rates, and sailing coasters only 2*d.* per ton once a month.