in 1873 after plans of H. M. Covert, taking the supply from the San Diego River, which drains 40 square miles, and pumping it 220 ft. by a Hooker steam pump of 8-in. bore and 42-in. stroke, into two reservoirs, one holding 100,000 gallons 100 ft. above the town, the other holding 850,000 gallons 200 ft. above the town.

Distribution is by 6 miles of 5-in. riveted wrought-iron pipe, asphalted. The pipe is made of No. 14 sheet iron. There are 5 fire hydrants, 11 gates and 300 taps, and 51 meters. The town does not pay for use of hydrants. Service pipes are of wrought iron, coated.

The population in 1880 was 2,700. The daily consumption is 80,000 gallons.

The capital stock of the company is $250,000. The works have cost $79,000. There is no debt.

The expenses in 1881 were $14,828,08, and the receipts $17,975,57.

E. J. Buell is the Superintendent.

CCCXLI—SANTA BARBARA.

Santa Barbara, California, in lat. 34° 26′ N., long. 119° 43′ W., is at the southeast end of a valley 2 miles wide and 5 miles long between a range of hills along the Pacific coast and the Santa Inez range of mountains. Missouri Creek, a stream of ten square miles water-shed, in which the water runs only during the rainy season, passes through the city.

Settled by the Jesuit missionaries about 1780, it was incorporated as a city in 1874.

A reservoir was constructed by the Franciscan monks about 50 years ago, by a stone dam laid in cement, across Mission Creek, 100 ft. long, 16 ft. thick and 16 ft. high, with both sides vertical. From this basin the water was conveyed 10,000 ft. by an open conduit lined with stone and cemented, to a reservoir 110 ft. square and 10 ft. deep. The walls of cemented stone are vertical on the inner face, 15 ft. thick for 4 ft. from the bottom and 3 ft. thick at top. Its surface is 300 ft. above the city.

In 1873 the conduit being much obstructed by breaks from land slides and growth of roots, a wooden flume, V-shaped, with sides 12 in. wide, and laid on a grade of 2½ ft. per 100, was substituted, and distributing pipes were laid in the city, after plans of Hermann Schuessler, C. E., and under the superintendence of R. B. & A. W. Canfield. The pipes were of No. 16 wrought iron, with riveted joints, and coated with asphalt and coal tar. In the business part of the town, where the pressure at night frequently was over 90 lbs., the riveted pipe leaked greatly and has been replaced by cast-iron pipe. There are 4½ miles of pipe, of from 6 to 2-in. diameter. The 6-in. and 5-in. are of wrought iron, riveted, the 4-in. of cast iron and the 3-in. and 2-in. and some 4-in. of wrought iron, welded. There are 14 fire hydrants, 19 gates and 220 taps. Service pipes are of iron, some galvanized and some coated with asphalt and tar.

The population in 1880 was 3,600, and the daily consumption 180,000 gallons.

The works are owned by a private company, with a capital stock of $120,000. They have cost $30,586, besides $20,000 paid for the old works. The gross receipts to December, 1881, have been $55,548.20. There is no debt. Further financial statements are not furnished. R. B. Canfield is the President, and A. W. Canfield the Secretary and Superintendent.

CCCXLII.—LANCASTER, O.

Lancaster, Ohio, in lat. 39° 42′ N., long. 83° 35′ W., is on the Hock Hocking River. The ground rises from the river and the Hocking canal to a hill 263 ft. above the canal.

Settled in 1800 and then called New Lancaster, the prefix was dropped in 1805.

Water-works were built by the city in 1877, after plans of A. Bauman. The first works were for fire protection only and consisted of a small pumping engine and a single line of pipe, taking water from the Hocking canal. In 1878 a stand-pipe 18 ft. in diameter and 69 ft. high was erected. In 1880 the boiler proving too small, steam was brought 200 ft. to the engine from an iron works. Permanent works were then built. A well 20 ft. in diameter and 18 ft. deep, sunk in water-bearing gravel, receives the water from a gallery 270 ft. long, which is built of brick, is 4 ft. wide and 4½ ft. high, arched at top and taking its water from the bottom. It is to be made 500 ft. long. The water now rises to the surface of the ground and wastes over the top of the well.

A Worthington pumping engine with 20-in. steam and 12-in. water cylinder of 15 in. stroke, lifts the water 133 ft. into the stand-pipe which is on ground 64 ft. above the pump.

The construction of a reservoir on Pleasant Hill, 263 ft. above the city is contemplated.

Distribution is by 6 miles of cast-iron pipe of from 12 to 4-in. diameter, with 61 fire hydrants, 25 gates and 100 taps. Service pipes are of lead.

The population in 1880 was 8,000. The daily consumption is not known.

The works have cost $46,801.46 to March 20, 1882, for construction, and $2,397.60 for operating. The bonded debt is $25,000.

The expenses in 1881 were $1,854.58, and the receipts, $1,196.55.

The works are managed by three Trustees. A. Bauman is the Secretary and Superintendent.

CCCXLIII—MALDEN.

Malden, Massachusetts, in lat. 42° 25′ N., long. 71° 3′ W., on Malden River, a stream tributary to the Mystic River, is on level ground in the southerly part of the town and hilly to the northward. It was settled in 1634.

Water-works were built for the town in 1870 by G. H. Norman after plans of A. F. Sargent, C. E., taking the supply from Spot Pond, which also supplies Medford and Melrose. It has a water-shed of about 2 square miles and an area of 296 acres at 139 ft. above tide water. The supply is by gravity.

The distribution is by 36.8 miles of wrought-iron and cement pipe, of from 16 to 4-in. diameter, with 198 fire hydrants, 317 gates and 2,468 taps. There are 29 meters in use. The town pays $3,000 per annum for public hydrants and drinking fountains. Lead service pipes are used.

The distributing pipes are made by the water board, which is found to cost about 25 per cent. less and to insure better pipe than purchasing from manufacturers. Prior to 1875 considerable trouble was had with the freezing of pipes. In that year more than a mile of main was frozen at one time and thawed out by use of steam. Since then pipes have been laid deeper. The population in 1880 was 12,017, and the daily consumption 480,000 gallons.

The cost of the works has been as follows, to December 31, 1881 : For construction, $362,101.58 ; for maintenance, $69,518.49 ; for interest, $198,092.79. The receipts have been $290,883.09. The bonded debt is $350,000, at 6 per cent. The expenses in 1881 were : For extensions, $6,792.05 ; for maintenance, $4,325.66, and for interest, $21,000. The receipts were $34,801.11.

The works are managed by three commissioners, one being elected each year. W. W. Hawkes is the Superintendent.

(TO BE CONTINUED.)

The receipt of statistics, as follows, is acknowledged with thanks : From W. W. Hawkes, Superintendent, statistics and water-works of Malden, Mass., and full set of reports from 1873 to 1881. From A. Bauman, Secretary, statistics and report of the water-works of Lancaster, O. From R. B. Canfield, President Mission Water Co., statistics and water rates of the water-works of Santa Barbara, Cal. From E. J. Buell, Secretary and Superintendent, statistics and water rates of the water-works of San Diego, Cal. From Alexander L. Archibald, Engineer, report and statistics and water rates of the water-works of Truro, Nova Scotia. From M. A. Hale, statistics of the water-works of Columbus, Miss. From E. W. Harman, Superintendent, reports, statistics and water rates of the water-works of Staunton, Va.

BAR OF RIO GRANDE.

From *The Rio News* of Rio de Janeiro, Brazil, we clip the following :

For many years past there has been considerable conflict of opinion as to the cause of the bar at the entrance to the port of Rio Grande. The prevailing idea, however, has hitherto been that the silt and alluvial matter brought down by the water from the interior was deposited at the entrance of the estuary and formed the bar. This notion has been so elaborated that calculations have been put forward of the actual quantity in cubic meters of sand which have been thus deposited. But a careful examination of what actually takes place during the prevalence of northeast and east winds clearly shows that this supposed deposit from the upland waters does not now take place to any appreciable extent, and hence is insufficient to account for the present state of the bar.

Another theory for the formation of the bar is that it results from the meeting of the fresh water and the northeast swell. The concussion produced is presumed to cause the suspended earthy matter to fall to the bottom. A third theory is that the action of the southwest swell has been such as to drive the sand towards the entrance and thus cut off the scouring action of the outflowing current.

It is possible that a combination of these influences has considerably increased the tendency to forms and banks at or near the present bar, but close observation shows that its present state is entirely due to the breaking of the ocean waves on the shallow bottom. During the prevalence of the east and northeast winds the sand-banks are surrounded by a heavy surf. Every broken wave tears up sand from the bottom. This sand is carried forward by the water, and is eventually deposited by the total dispersion of the wave. The sand thus deposited forms in course of time a shoal on which in turn more waves break, and it assumes under their action a ridge with deeper water on either side. Now this action, under which the bar was in a state of continuous though possibly very slow growth, would not be prevented by any increase of velocity or scouring action of the outflowing current. It is true that in favorable seasons and strong gales from the west and northwest some counter action would be set up, and the outflowing current would remove a part of the recent deposit; but the first gale from the east and northeast would re-establish the conditions and the ridge would be reformed higher and broader than before. That this is the case at the bar of Rio Grande is demonstrated beyond question by the experience of the last ten months.

The only remedy for this action of the ocean wave is by dividing this belt of surf and compelling it to break at a distance from the entrance to the navigable channel; or, in other words, to construct some artificial obstruction so as to prevent the waves of translation from acting upon the bar, when the sand now forming it is removed either by dredging or any other mechanical agency. But it must be borne in mind that no amount of dredging applied in the present state of the bar can be of the slightest avail, because the conditions necessary to secure success do not exist. It must also be distinctly understood that a breakwater will not remove the present bar, but it will prevent the formation of another when the present one is removed, and it will enable the outflowing current to keep the navigable channel open by facilitating the scour into deep water.

It is believed that the great error which has hitherto been committed in dealing with the harbor of Rio Grande has been the constant interference with the bed of the estuary inside the bar, while no attention was paid to the formation of the bar itself. Dredging has been carried on at intervals inside the entrance and this has formed so many holes or hollows by which the declivity of the channel has been altered and the uniform scouring action of the outflowing currents interfered with if not partially destroyed, for it is obvious that all scouring action must be due to the lower stratum of water and not to the surface currents. Soundings recently taken show that the bed of the present channel is higher at its entrance from the sea than at the anchorage opposite Sao José do Norte, clearly proving the cause of the retardation of the scour. All observations tend to confirm the opinion that any permanent and effective improvement to the harbor must commence outside the entrance.

The grand obstacle to these improvements, and more especially the construction of breakwaters, is the probable expense. The estimate presented by Sir John Hawkshaw in 1875 put the cost of efficient, permanent breakwaters for the improvements at Rio Grande at £2,000,000 sterling. If such an outlay were absolutely necessary, then it is questionable if such works are possible ; but on the other hand it may be asked if it is not practicable to construct an efficient breakwater at a much less cost. The experience of other similar works shows that breakwaters have been erected in very exposed situations which have proved effective, the costs of which were scarcely a sixth of that stated by Sir John Hawkshaw. At Rio Grande the absence of all suitable material in the shape of stone, shingle, etc., precludes the idea of having recourse to the modern system of concrete blocks, or large masses of stone ; but the province to the north of Porto Alegere would furnish an abundant supply of excellent timber as well as any quantity of rubble stone. With these a breakwater could be constructed which would insure immediate means for improving the entrance to the harbor.

The use of timber may be objected to as not being sufficiently durable, but if an effective breakwater could be constructed to last say 50 years, it is to be expected that long before that time the immense advantages which would accrue to the port, would furnish ample resources to maintain such a structure or on the same site gradually to construct one of more durable material. The urgency of the case is such that any means should be resorted to that would insure a speedy removal of the present obstructions; and objections on the score of durability should not weigh against the certain ruin of the trade of Rio Grande, if not of the whole of the south of the province, by delay.

It is confidently believed that with an expenditure of £300,000 the necessary works could be carried out, including the eastern breakwater and the removal of the present bar by a special system of dredging, and that a permanent channel could be opened for vessels drawing 12 ft. 6 in. at all seasons of the year.

Designs have been prepared for a breakwater combining some novel features in the adaptation of piled structures to sandy bottoms. But before presenting these plans to the authorities, the author of them suggests that they should be submitted to the best authorities on harbor engineering for revision, so as to avoid as far as possible the expenditure of money upon mere empirical schemes.