

D. R. YOUNG

some aspects of public health engineering in the middle east

INTRODUCTION

General

This paper outlines problems encountered in public health engineering projects due to the prevailing conditions in the United Arab Emirates and the solutions adopted to overcome the problems.

In 1974 D Balfour & Sons were appointed by the Government of Abu Dhabi as Consulting Engineers for projects to provide facilities for water distribution, sewerage, sewage treatment and reuse of treated effluent for irrigation for the City of Al Ain. The terms of reference for the projects comprised the preparation of Master Plan reports followed by detailed designs, tender documents and supervision of construction of the necessary works recommended in the Master Plans.

Climate

Al Ain, the second city of the Emirate of Abu Dhabi, is situated some 160 kilometres inland from Abu Dhabi city near the border with the Sultanate of Oman. It is also close to the foothills of the Oman mountains with the centre of the city approximately 280 metres above sea level. Al Ain and the surrounding area being situated close to the Tropic of Cancer experience warm winters and hot summers. The mountains of Oman generally shield the area from the moist winds of the Indian Ocean and consequently rainfall is spasmodic and infrequent. These effects combine to create the desert conditions that prevail.

The mean monthly air temperature varies from 17°C in January to 36°C in August, but it is fairly common in the months of July and August for the temperature to reach 50°C. Since Al Ain is inland the humidity is lower than that of the coastal areas, being generally below 50% for most of the year, and can be as low as 15%.

PLANNING

The wealth of the state of Abu Dhabi has allowed rapid expansion of the economy and has enabled the Government to carry out an ambitious programme of development including new roads, harbours, airports, new towns and villages and all the necessary infra-structure of a modern state.

The large number of immigrants entering Abu Dhabi has imposed a pressing need for more development and the supply of essential services. A vicious spiral is caused in that much of the new development now being constructed is to house and serve people from the construction industry.

It is essential to incorporate into any design flexibility to accommodate unexpected changes in population growth rates, location or density within the limit of good engineering design. This can add to the cost of a Scheme, but having experienced problems of under-design due to unforeseen population growth the Government is prepared to meet the additional burden of cost. For example it has been fairly common for extensions to public utilities facilities such as sewage treatment works or power stations to be commenced before even the previous phases of construction were complete. Resulting from these experiences the Government now require Consultants and Planners to ensure that adequate provision is made in all projects for the maximum foreseeable populations.

WATER DISTRIBUTION

Water Consumption and Conservation

It was not possible to assess with any degree of accuracy the present water consumption and it was necessary to predict the likely future consumption on the basis of experience in other parts of the Middle East where similar conditions obtain.

The conservation aspect was considered of paramount importance in view of the limited sources of water supply. The initial source of water is well-fields tapping the aquifers fed by rainfall on the Oman mountains. No long term tests had been carried out on aquifer recharge and the safe yield of the well-fields had not yet been established. It was considered prudent to take steps to avoid unnecessary wastage and limit demand in some way, since the future alternative source or supplementary source was desalinated water from a plant on the coast. This water would be extremely expensive since to the already high cost of producing the water would have to be added the cost of pumping to Al Ain, a distance of some 140 km against a static head of the order of 280m.

Considering the above, it was decided to provide water meters to all domestic connections, as well as those for industrial and agricultural use, to promote a responsible attitude to the use of water and thereby curb excessive use and wastage. It was further decided that the pressure available to each consumer would be regulated by means of a stop tap adjacent to the meter. The Master Plan outlined methods by which the tariffs could be adjusted to encourage water conservation.

The increase in the availability of water will give encouragement to the expansion of the local agricultural activity and it was Government Policy that this should be encouraged. The allowable extent of agricultural expansion was however dependent on the safe yields of the well-fields and it was therefore difficult to assess any realistic water demand for possible future agricultural areas. This uncertainty was another factor requiring the design to be extremely flexible.

Many of the roads had, or were to have, trees planted by the sides and in the central reservations. It was considered that in future sewage effluent would be used for irrigation of the trees but, until adequate supplies of treated sewage effluent are available, provision should be made for water to be taken either from local wells or from the potable water supply.

Distribution System

The city was divided up into a suitable number of distribution zones taking into account the topography. Each zone will be fed by a pumping station situated adjacent to a ground level service reservoir, with approximately 2 days storage, and a network of water mains. The service reservoirs will be generally inter-connected and provision was made to receive water from either the well-field source or from the future desalinated water source. The ground water is of high quality and it is only necessary to incorporate chlorination equipment for the water treatment.

Due to the construction activity in the city, it was considered prudent to adopt cement lined ductile iron water mains as the most resilient pipe material.

The service pipe was polythene and the connection from the main was terminated at a meter chamber adjacent to the property.

The reinforced concrete service reservoirs were designed to be partially buried with an embankment over the roof as a means of thermal insulation. The materials and workmanship necessary to produce high quality concrete for the reservoir construction are dealt with in a subsequent section.

In designing the pumps for pressurizing the pipe system care was taken to limit the range of capacities to be provided such that interchangeability of pumps could easily be achieved. It was also considered prudent to provide a full range of spare pumps and spares for pumps in the Contract. Additionally sufficient standby capacity was provided to ensure the continued full operation of the system in the event of pump or motor failure. This is important since the spares will inevitably need to be imported and this can involve delays.

At least 3 months storage capacity for chlorine has been provided since this material will also need to be imported and adequate stocks should always be maintained. The pumping station sub-structure and buildings were designed to provide adequate space for any future pumps required to cover increased demand due to changes in population, density, etc., as outlined previously. There will therefore be space for any future pumps required to cover increased demand or to service an additional pressure zone.

SEWERAGE AND SEWAGE TREATMENT

Special Problems in a Desert Climate

In hot desert areas movement of fine sand, usually known as dune sand, presents many problems and could cause difficulties with the operation of the sewerage and sewage treatment system. Sand may find its way into the system from the washing of clothes, through manhole and chamber covers where these are not properly sealed and many other ways. Sand can cause filtration problems, excessive wear in pumps and mechanical equipment and difficulties with sludge withdrawal from treatment processes.

Sand entering via the domestic connection could not be prevented, but the main sewerage system was designed to be sealed as far as possible against the ingress of wind-blown sand. In the sewers good cleansing velocities are important to maintain the fine sand in suspension or at least to move any deposition at high rates of flow. Grit extraction equipment at the sewage treatment works is essential, and the regular cleansing of wet wells at pumping stations is very necessary.

In hot climates sewage will rapidly become septic if it is devoid of oxygen for even a short period, and under such conditions strong odours and a corrosive atmosphere in the sewers and manholes will occur. The formation of sulphides can be minimised by reducing the retention period in the sewerage system as far as possible. It was therefore imperative to ensure high velocities in the sewers and it was decided that, normally, a minimum velocity of 1 metre per second at ultimate maximum rates of flow should be achieved. In addition checks were made to ensure that the minimum velocity in the early stages of the development would be of the order of 0.7 metres per second. Where sewers are to be laid with only minor development connected in the early stages, sewer flushing will be carried out at regular intervals.

Good ventilation of the sewer system is essential, but the use of ventilated manhole covers was ruled out due to the possible ingress of fine sand. It was not considered wise to adopt ventilating columns at regular intervals on the main sewers since odour problems are often experienced when temperature inversion conditions prevail. The only means of ventilation acceptable was via the stack pipe at the domestic connection.

It could not be expected that the above measures would be completely effective and therefore there would still be a build-up of hydrogen sulphide in the wet wells of the pumping stations. It was considered that the above proposals would keep the sulphides generated in the gravity sewers feeding the pumping stations to a reasonably low level. Nevertheless it is necessary to maintain an acceptable working environment in the pumping stations and it was decided to adopt a forced ventilation system with ozone treatment of the air discharged to the atmosphere to control odours. Small scale ozone production units, which have a low power consumption, are relatively inexpensive and will be provided at each pumping station for the treatment of the air discharged to the atmosphere via the ventilation system.

The potential for sulphide formation is greatest in rising mains as natural aeration of the sewage cannot occur. The addition of chemicals to the sewage to prevent sulphide formation is feasible but would need to be continuous resulting in high chemical costs. It was considered essential to adopt some method to reduce the sulphide in the pumping main especially in an effort to reduce the offensive odours that would occur at the discharge point of the pumping main discharging to the sewage treatment works. Facilities for the injection of oxygen downstream of the pumping station and at intermediate points along the pumping main are to be provided.

Sewage Treatment System

Bearing in mind that the pumped sewage has had some pre-treatment, by virtue of injected oxygen, it was considered that problems of corrosion and odours would be minimal at the inlet to the works. Thus no special treatment at the inlet works was provided and this consists of screens, macerators, detritors and flow measurement.

As the sewage should be well oxygenated on reaching the works it was considered unwise to provide primary sedimentation tanks since this could result in septic conditions reoccurring. It was therefore decided to adopt the extended aeration system of treatment. Concrete tanks with surface aerators are to be used with an approximate retention period of 20 hours at dry weather flow. Final settlement is provided in circular concrete tanks, from which the activated sludge will be removed and returned to the inlet to the aeration tanks. In order to produce an effluent of suitable quality for re-use for irrigation, tertiary treatment in the form of rapid gravity sand filters has been provided. After sand filtration the effluent will be chlorinated prior to reuse.

The surplus sludge will be treated by aerobic digestion in simple rectangular tanks with floating aerators. Odours from this process should be minimal since the surplus sludge should be relatively stable by virtue of the long sludge age (ca. 20 days) in the aeration tanks. A period of consolidation will be allowed in the digestion tanks and after removal of the top water the sludge will be delivered to open lagoons where final reduction of the moisture content will be achieved by natural drying.

With the effluent being used for irrigation and the dried sludge for the conditioning of sandy soils it can be seen that treated sewage represents a valuable contribution to water and agricultural resources.

Sewerage System

Due to the topography of Al Ain it is possible to drain the central area of the city (with a few exceptions) into a trunk sewer gravitating to within a short distance of the sewage treatment works. At this point a major pumping station is to be constructed from which the sewage will be discharged into a 3 km long pumping main. Oxygen will be injected into the main as described previously.

The outlying areas of the city were sub-divided into smaller drainage areas, in which sewage pumping stations of various capacities are located. From these pumping stations, sewage will be pumped into a pumping main system which ultimately discharges to the trunk sewer.

In addition to the ozone equipment mentioned earlier, which is to be installed to reduce odour, it is necessary also to protect the stations from corrosion. In the wet well all surfaces are to be lined with PVC sheeting bonded to the walls and any remaining exposed concrete surfaces will be protected by acid-resistant mortar.

The manholes on the sewerage system have been designed such that the concrete walls will be constructed with a glass reinforced plastic (GRP) liner which is left in after completion. Further, the underside of the top slab will be lined with GRP and a GRP plate placed beneath the lid of the manhole cover. Again acid resistant mortars will be used where surfaces are unavoidably exposed to the corrosive atmosphere i.e. at the roof slab joint and the benching.

The sewer pipe material generally adopted will be vitrified clay for all diameters up to 600mm. Above this diameter GRP pipes will be used. In the past, in the Middle East, vitrified clay has been used somewhat cautiously due to excessive breakages in shipment which caused their cost to be prohibitive. However, the exporters of these pipes have recently managed to reduce this loss to something less than 1% by using single cargo ships, by palleting pipes and giving careful supervision to the unloading operations. The corrosion resistance of vitrified clay makes this material ideal for use in the Middle East. The cost of vitrified clay, however, above 600mm diameter becomes prohibitive and GRP would at present seem to represent the best solution, taking into account its corrosion resistant qualities and its cost. It does, however, need special care during pipe-laying as its strength, as a pipeline, depends on the backfill material and the way in which it is placed. The material adopted for the pumping mains will be ductile iron because of its known durability and strength.

The minimum size of pipe will be 150mm (including the house connections) to minimise the risk of blockages. House connections will generally not be made to the main sewer by angle branch connections, but through a manhole. The gradients required to achieve the minimum velocities mentioned previously mean that the drainage areas in relatively low density housing developments are quite small, but it is desirable that the number of pumping stations should be kept to a minimum. However, it was considered that in this situation the higher sewage velocities in the pipes were the more important factor.

Effluent re-use

The re-use of the sewage effluent for irrigation purposes is of great importance in Al Ain since there is a major tree planting programme in progress. It is highly desirable to use sewage effluent for irrigation to avoid, where possible the use of more valuable potable water sources. Although the system necessary to distribute the sewage effluent throughout the city is an expensive one it represents a case where the wealth of the country can be used to achieve a considerable long term benefit. It was considered necessary to chlorinate the effluent from the sewage works, since, however many precautions are taken, it is possible that irrigation workers and members of the public may inadvertently drink irrigation water.

CONCRETE

In the Middle East salt-laden aggregates can be one of the most likely causes of the problems in concrete manufacture but with fresh water being at a premium, the washing of aggregate is an extremely expensive item. The use of saline water in the concrete mix could be another cause of poor concrete, and it was considered that the specification for concrete should, whilst limiting the overall chloride and sulphate levels, take into account the problems of the salt content of both aggregates and water. A limit was therefore placed on each individual component as regards chloride and sulphate levels as well as an overall limitation.

The dust content of the aggregates in the Middle East is frequently high and its variability from one batch to another is often a cause for widely varying test cube results. Good sieving of aggregate should avoid this problem, but in an area where dust storms are frequent it was considered that aggregates should be stored in hoppers, bins or closed sheds. There would therefore also be some control over the temperature of the materials which when standing in the direct sun could reach a temperature as high as 80°C. The use of aggregates at high temperature causes a 'flash set', and to help to avoid this in the mixer it has also been specified that the concrete mixing plant should be painted white, since it has been established that a temperature reduction of the metalwork of the order of 10 deg.C can be achieved. Provisions were made in the specification for the addition of ice where necessary to cool materials and in addition, a strict limitation regarding the time from mixing to placing has been imposed.

CONCLUSION

It is important to remember that problems arising with and the solutions adopted for the Al Ain water distribution and sewerage systems are particular ones and applicable to one part of the Middle East. In some cases they may also apply to other areas in the Middle East, but it should be remembered that there are often many solutions to an engineering problem. In this instance, it is indeed fortunate that the relative wealth of Abu Dhabi permits the adoption of the optimum engineering and environmental solutions to the problems arising from geographical location.