Drainage problems of a South Pacific island

J G EVANS

drainage problems of a south pacific island

GENERAL

1. The kingdom

1.1 In Tonga natural resources,[1] as raw materials, are few but the Kingdom has much fertile agricultural land. Exports include copra and bananas and the principal trading partners are Australia, New Zealand, Britain and Japan - not always in that order.

1.2 Communications are good and there are regular air services to/from New Zealand, Fiji, the Samoas and elsewhere, with internal air/sea schedules connecting the outer islands with the capital, largely, by way of the international airport at Fua'amotu on Tongatapu, the main island, and the three wharves at the capital.

1.3 The ruling monarch and Head of State is H.M. King Taufa'ahau Tupou IV who ascended the throne in 1965, and who rules through the single-chamber Legislative Assembly consisting of the 7 Cabinet Ministers, 7 representatives of the 33 hereditary Nobles and 7 members elected by the Commoners. The Head of Government is H.R.H. Prince Tu'ipelehake, Prime Minister.

2. The town

2.1 Nuku'alofa lies on the north coast of Tongatapu Island, at 175° 12'W, 21° 08'S. In 1978 the population of the town was estimated to be 22 000.

2.2 During/following rainy periods parts of the town are flooded and it is common for the accumulated water to remain on the surface for days/weeks. Flooding should, however, not be confused with exposures of natural groundwater which are evident in parts of the town throughout the year, although most are reported to have eventually dried out during the drought of 1977.

[1] Unsuccessful attempts have been made to locate oil under Tongatapu. It is said that offshore drilling may be more fruitful.

2.3 Existing surface water drainage provides for Talamahu Market, Government Offices on Vuna Avenue and certain lengths of Taufa'ahau Street and Salote Avenue. The two lines serving this area discharge to the ocean.

2.4 There is no formal sewerage network and properties rely on individual wastewater disposal facilities (septic tanks or latrine pits). During rainy periods it is fairly common for septic tank effluent to be spread by the surface runoff, thus creating a health hazard in certain areas. Increased development and a rising population contribute to the dangers.

2.5 Rainfall averages 68 in (1727mm) per annum. Most of this falls in the summer period (the wet season) in January, February, and March. There are on average 167 wet days per year. The maximum daily precipitation recorded is 11 in (280mm) (in January 1952). There are no records of rainfall intensity.

2.6 The town consists of a number of drainage areas, each with its own characteristics.

2.7 Topographically, the surface slopes generally from Vuna Avenue, on the ocean front, southwards towards the lagoon. There is also a fall from west to east over much of the town area, to a trough of low ground from Vuna Avenue through Ngele'ia to the lagoon. There are other, isolated, low areas.

3. Public Health

3.1 In terms of water-borne or water-related diseases, filariasis is endemic as is typhoid but the latter is under control, largely due to an immunisation programme.

3.2 A filariasis control centre exists and dispenses tablets, free of charge, to residents and long-term visitors.

3.3 Only one species of mosquito, Culex quinquefaciatus Say,[1] is present. This species has been shown to be a vector of sub-periodic W. bancrofti[2] in Fiji.

3.4 The Kingdom appears legally well-equipped to deal with contagious and infectious diseases. Legislation provides for penalties for failure to report, and/or submit to, prescribed treatment.

3.5 The very common practice of pig breeding often results in the escape of these animals from their quarters; loose pigs/piglets are frequently encountered, even in the town centre. They constitute a traffic hazard and a health risk, and should be effectively confined.

3.6 There must be a significant risk that pigs act as vehicles for the transmission of certain micro-organisms. Little imagination is needed to picture cases where wandering pigs root about in areas frequented by children. The animals may thus become contaminated by excreta containing active pathogens which are then transferred to crops, cooking utensils, etc. when the pigs move elsewhere, or transferred to a host when the animal is handled. (The infections which pigs could transmit include typhoid, salmonellosis, cholera, and conditions associated with Escherichia coli).

3.7 Excreta is the first step in the transmission route of many diseases and any interruption to the route is a useful contribution in the fight to protect health.

---

[1] also known as C. pipiens fatigans and C. p. quinquefaciatus. The preferred name is C. fatigans (S J Miles, Systematic Entomology, 1, 263-270, 1976).

[2] Wuchereria bancrofti.

4. Land tenure

4.1 Land tenure has a traditional importance in Tonga where all land is the property of the Crown.

4.2 On reaching the age of 16, each male Tongan subject is entitled to apply to the Minister of Lands for a grant of land not exceeding $8\frac{1}{4}$ acres (3.33 ha)[1] "as a tax allotment and where any such grant is less than $8\frac{1}{4}$ acres the Minister may from time to time as land becomes available and as he deems expedient make further grants to such holder until the area .... has a total area of $8\frac{1}{4}$ acres. He shall also be entitled to receive .... an area not exceeding 1 rood 24 perches[2] in a town as a town allotment".

4.3 The local name for the allocated land is "'api", the "'api kolo" being the town plot and "'api tukuhau" the tax allotment or cultivation area, in the bush.

4.4 This method of land tenure - thought to be unique throughout the world - ignores income and social status of the occupier. It is fairly common to find a well-appointed house, with electricity/bath/septic tank, alongside a very much more modest home having no power connexion, no bath, an outdoor cooking area, and a pit latrine.

4.5 The disparity may also have other physical manifestations. In low-lying areas prosperous householders often use soil/coral fill to raise their land/homes above flood level. The less well-off cannot afford fill and consequently, during wet periods, their sites accumulate not only the direct rainwater but also runoff from their more elevated neighbours.

5. Population

5.1 Population of the town is increasing as indicated by the following table. The 1978 population is estimated by the Government Statistician to be 22 000.

Town Area	1966	1976	% Change
Kolofo'ou	8 685	9 088	+ 4.6
Ma'ufanga	2 420	3 650	+ 50.8
Kolomotu'a	4 440	5 618	+ 26.5
Haveluloto	1 334	2 245	+ 68.3
	16 879	20 601	+ 22

5.2 Much of the population increase is said to be brought about by immigrants from other islands in the Kingdom. The attractions of Nuku'alofa include good schools and it is customary for many Tongans to leave the outer islands[3] and move to the capital for the better education of their family. They stay with relatives/friends perhaps, or erect simple homes in the 'api kolo of others; some occupy 'apis left vacant[4].

---

1 sufficient to grow a substantial stand'd of coconut/banana/taro/yam and other produce, and to rear a good number of pigs/goats/fowl, etc.

2 1 rood 24 perches = 0.4 acre = 0.16 ha.

3 the Kingdom consists of some 150 islands (although not all are inhabited.

4 possibly vacated by Tongans working/living in New Zealand/Australia/elsewhere.

5.3 From all the foregoing it can be seen that land acquisition is of much importance. An occupant can subsist from his own crops/livestock whereas a re-located person has to rely on friends/relatives for support. Fortunately, Tongans are by nature comradely people and are traditionally hospitable. They also have strong family and extended family relationships with defined duties/obligations between members.

6. Schools/Colleges

6.1 In Nuku'alofa there are 27 schools/colleges with a total of 10 687 pupils/students.

6.2 The various premises are scattered throughout the town and no good opportunity exists for any scheme of joint sewerage. Accordingly, there is no proposal to modify the drainage facilities which presently consist of septic tanks.

6.3 Effluent from the tanks percolates into the ground and is lost by absorption/evaporation. By and large the method functions well.

6.4 One might easily recommend regular emptying[1] of school tanks, in the interests of efficient working. On the other hand they cope remarkably well when ignored. No important changes are proposed but there is need for greater efforts at improved cleanliness/housekeeping/ maintenance in some cases (defective flushing cisterns seemed a fairly common fault).

7. Hotels

7.1 The Tonga Visitors Bureau list details of the 6 hotels in the town. They vary in capability from the 76-room International Dateline Hotel to the Beach House, which can take 8 guests. Total available accommodation is for about 214 persons.

8. Hospital - Vaiola

8.1 The hospital was opened in June 1971. There are 200 beds and a recently completed psychiatric ward, not yet in use.

8.2 All foul/kitchen/laundry wastes discharge by gravity to an existing treatment plant inside the hospital grounds.

8.3 The plant is said to have been originally designed to treat 12 000 gallons per day (55 000 L/d). In 1972, from 3rd January to 30th June, the Tonga Water Board recorded a consumption of 25 600 gallons per day, (117 300 l/d) average.

8.4 In July 1978 the measured amount supplied was said by the Water Board to be 1.48 mgd (6.6 mld) or about 47 740 gal/pd (218 800 l/pd) average.

8.5 The existing plant is overloaded. The compressor equipment is in operation 24 hours, in efforts to achieve some form of treatment, and it is a credit to the standard of maintenance and to the reliability of equipment that the plant copes as well as it does.

8.6 It would be easy to recommend a package treatment plant, employing one of the many oxidation methods available. This would require skilled maintenance and expenditure on electricity; there would also have to be regular sludge removal.

---

[1] This is an expression of convenience. Septic tanks should not be emptied - around 20% of the contents should remain to ensure continuation of the anaerobic action.

8.7 A plant of this type would not be satisfactory on the existing site which is relatively difficult of access. There would also be problems with maintaining the present facilities while the new units were being built.

8.8 Because of the disadvantages outlined above, it is held that any form of package plant would be inappropriate and hence this method of treatment is not recommended.

9. Miscellaneous

9.1 Tonga lies in an active seismic belt and minor earth tremors are common.

9.2 The last noteworthy earthquake was in June 1977 when the epicentre was some 138 miles (218 km) south-south-west of Tongatapu; magnitude was 7.2 Richter. The New Zealand Department of Scientific and Industrial Research has predicted[1] that disturbances of at least this magnitude may be expected on average every 13 years.

9.3 The Water Board records show that the average consumption of potable water is 13 million gallons (60 Ml) per month, say 433 300 gallons per day (1.98 Ml/d). Of this, 43 000 gallons (197 000 l) are said to be used at the Dateline Hotel and 50 000 (229 000 l) is assumed to be the daily demand at Vaiola Hospital.

9.4 Thus, 340 300 gallons (1.56 Ml) seems to be the demand, for a population of 22 000, producing a present average consumption of 15.5 gallons (71 l) per person per day. This is the demand from the mains supply; as stored rainwater[2] is also used the per capita total consumption per day must currently be somewhat in excess of 15.5 gallons (71 l).

PROJECT POLICY

1. It would be tempting to prepare sophisticated drainage proposals, with a number of stormwater pumping stations discharging into the ocean. Such a scheme may well emerge in due course but it would rely on imported plant/equipment, skilled maintenance, adequate finance and other requirements - all of which may well be readily available in other countries - but the capital/recurrent costs would be unlikely to be attractive in Tonga. Thus nothing would be achieved.

2. The need in Nuku'alofa now is for engineering work which is comparatively inexpensive and which can be cheaply maintained. This is the ruling principle underlying the contents of this Paper.

RELATIVE LEVELS

1. In terms of drainage, ground surface elevations represent an essential item of data. Insufficient levelling detail was locally available and the first priority was seen to be the setting up of reliable datum points throughout the town, for reference later.

2. The British Admiralty soundings datum for Nuku'alofa is "9.8 ft (2.99m) below B.M. cut on W face of pedestal of Prince Wellington's monument[3]" inside the grounds of the Royal Palace.

3. This datum was used for all the levelling in the town. The effects of any earthquake, since that bench mark was established, have been ignored.

---

1 "The Tonga Chronicle", 3rd March 1978.

2 rainwater storage is a common feature in many islands - in the Caribbean, the Pacific and elsewhere.

3 from Admiralty chart 1385, (B.M. = Bench Mark)

4. A simple tide gauge was set up and observations were made during the high spring tide cycle of 23rd June 1978.

5. Measurements were also logged at the lagoon on the same day - see accompanying curves, figure 1.

6. The results show an ocean tidal range of +4.85 ft (1.48m) relative to Soundings Datum (rSD) to -0.8 ft (-0.24m) rSD while the lagoon amplitude was from +3.25 ft rSD (0.99m) to about +2.4 ft (0.73m) rSD. Mean levels were: ocean +2 ft (0.61m) and lagoon +2.8 ft (0.85m). The lagoon peaked 3 hours (theoretically, this is probably 3hrs 6mins). after the ocean.

7. There was 1.4 in (35.6mm) of rain on the 23rd June, which must have influenced the height of the lagoon peak. Accordingly, a further set of spring tide observations was recorded on the 24th July, following a dry day. The lagoon on that day peaked to +3.05 ft (0.93m) rSD or 0.2 ft (0.06m) below the level on the rain day. This result tends to support the view that surface/rainwater has a noticeable dwell period in the lagoon.

8. The lagoon outlet was visited and found to be relatively narrow and shallow[1]. Thus there can be but little opportunity for the lagoon to rapidly discharge into the ocean the precipitation falling on it, and draining into it from the catchment area. Heavy rainfall can therefore raise lagoon high water level above the observed height.

9. Whereas the observed maximum in the lagoon was +3.25 ft (0.99m) rSD, indications on adjacent walls suggest that a fairly common maximum is nearer +3.5 ft (1.07m) and it is this value which has, generally, been used for the outlet level of drainage pipes into Fanga 'Uta Lagoon.

10. At times of very heavy rain the lagoon is thought capable of rising to approximately +4 ft (1.22m). This should be regarded as unusual and is held to be within the limits of the locally acceptable flooding risk.

11. Although the lagoon mean level is higher than that of the ocean, most of the gravity surface water system must be designed to discharge into the lagoon. This is because the ocean high water peaks to a higher level than the lagoon.

12. The use of pipes to the ocean/foreshore and having flap valves was considered but abandoned as representing too high a flooding risk. Failure of such valves at a time of highest astronomical tide and a sustained on-shore wind would cause widespread flooding by seawater.

13. On the other hand, uncontrolled outlets to the lagoon, at invert levels of +3.5 ft (1.07m) rSD or higher, are thought to represent an acceptable level of risk.

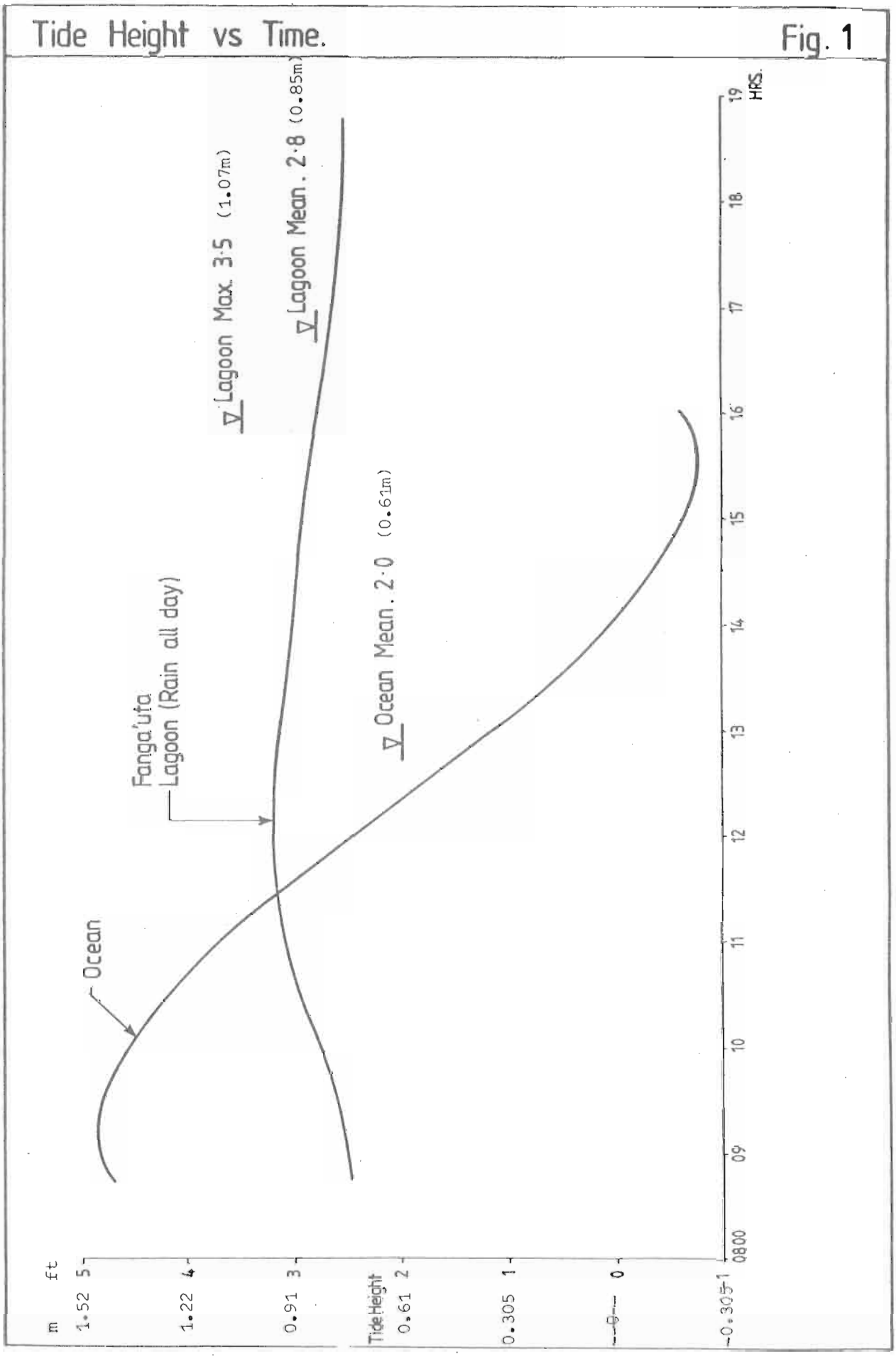
SURFACE WATER DRAINAGE

1. There are no natural watercourses in Nuku'alofa and no network of surface water drains. During heavy rain the water gravitates to low points, a number of which remain inundated for days/weeks.

2. In due course these accumulations percolate/evaporate exposing, in some low areas, the natural groundwater which may form a permanent feature (except during drought, as in 1977, when even the groundwater evaporated to below surface level).

---

[1] the visit coincided with high water in the Ocean.


Tide Height vs Time.
Fig. 1
Ocean
Fanga'ufa
Lagoon (Rain all day)
∇ Lagoon Max. 3·5 (1.07m)
∇ Lagoon Mean. 2·8 (0.85m)
∇ Ocean Mean. 2·0 (0.61m)
m ft
1.52 5
1.22 4
0.91 3
Tide Height
0.61 2
0.305 1
0 0
-0.305 -1
0800 09 10 11 12 13 14 15 16 17 18 19 HRS.

3. The rise of the lagoon to about 3.5 ft (1.07m) rSD regulates groundwater level in these low areas. The underlying/surrounding coral is pervious but not sufficiently open-textured to permit the groundwater to at once follow the lagoon tidal fluctuation. Accordingly, groundwater is exposed where surface levels are around 3.5 ft (1.07m) or below.

4. This level must be maintained and any attempts to depress it must, for the present, be strictly prohibited.

5. In this context one should not lightly consider any proposals to reclaim land from the lagoon which involve lowering the groundwater level, without adequate investigations/review by an experienced hydrogeologist.

6. Interference with the groundwater would result in the depression of the water table level throughout the catchment area, including points appreciable distances from the seat of abstraction. It is doubtful if the drop in water level could be followed sufficiently rapidly by the roots of plants/trees, many of which might be put at risk.

7. Furthermore, knowing that the ocean peaks to +4.85 ft (1.48m) it is possible for any interference with groundwater to cause saline intrusion, another danger to vegetation. What effects there might be on the island's underground water resources are unknown.

8. For these reasons there must be no interference whatever with the level of natural groundwater. In those areas where it is almost permanently exposed the means of its "removal" is to fill, and to drain off any rainwater which seeks to rise above the critical level of 3.5 ft (1.07m) rSD.

9. Under normal conditions, the engineering design of storm drains requires pipes of adequate diameters to accept the flow. Thus a gravity-only drainage system usually commences at its apex with comparatively small pipes while at the point of discharge the conduits are at their largest in that system.

10. In much of Nuku'alofa such customary practice would not be possible. The ground in some areas has very little fall and, over large pipes, there would be insufficient or no cover to allow discharge at the recommended minimum level of 3.5 ft (1.07m) rSD. To cross roads, pipes larger than about 9 in (225mm) diameter would need local humps in the carriageway - an unacceptable solution from traffic and drainage viewpoints.

11. To meet the special needs, it would be necessary to use a number of comparatively small pipes laid side-by-side. Also, because of the poor available cover such pipes should have thick walls, in efforts to avoid the concrete surround normally provided for physical protection. The pipeline should have no formal joints so that water may enter freely - another reason why standard concrete surrounds cannot be used.

12. (Thick-wall concrete pipes, imported, would be prohibitively expensive. The MoW[1] now make concrete pipes for their own use, but the existing production facilities/output would be inadequate for the amount of pipework necessitated by the proposals herein - whichever method of drainage is selected).

13. Where pipes would be in road verges there is of course a risk of fracture/displacement; vehicles are frequently driven and parked on verges. Such risk will be accepted. In any event, thick-wall pipes would be better able to accept loads than conventional pipes.

---

[1] MoW = Ministry of Works

14. Another limiting factor is the roadside space available for pipes/pipelaying. If side-by-side "small" pipes were used then there is a physical limit to the number which could be accommodated in the road margins, and hence a limit on the rate of removal of runoff. (This last remark ignores existing services such as water lines, overhead cable supports and underground telephone cables - two other constraints on land availability).

15. On most roads gulleys would presently be totally useless. There are, generally, no kerbs/channels to confine rainwater and the carriageway is often above the ground alongside, onto which it sheds its runoff flow.

16. Coral fill above and around the pipeline would delay the time of entry of flow into the pipe, especially if its upper levels were obstructed by soil/vegetation. The immediate dissipation of flooding would therefore be unlikely, with an all-pipe system of drainage.

17. Furthermore, because of the poor gradients large diameter pipes would be necessary to ensure no-flood conditions. But, as explained, large pipes could not be used.

18. In some respects this could, curiously, be fortuitous. A highly effective gravity drainage network could be designed to prevent all flooding - at least within a stated statistical return frequency. At the same time it would introduce, very rapidly, a considerable volume of fresh water into the lagoon. This would be in addition to the rainwater directly entering the lagoon, the level of which would thus rise by reason of the two forms of inflow.

19. As argued elsewhere, under present conditions lagoon level can rise to around 4 ft (1.22m) rSD during heavy rain. The rapid addition of rainwater from a catchment area of some 700 acres (285 ha)[1] would certainly raise the level higher, having regard to the two somewhat confined channels connecting the lagoon to the ocean.

20. To assist in the overall drainage difficulty the proposals allow for the subdivision of the large urban catchment into constituent areas, requiring smaller pipes (or channels, as appropriate) and giving a greater number and spread of outlets into the lagoon.

21. Subdivision is by drains alongside the north-south aligned roads. These drains alone will give useful relief in as much as they will remove the pools commonly seen besides many roads after rain.

22. This interception of runoff will reduce the opportunities which now exist for septic tank effluent to be spread by surface runoff. Accordingly, the needs of public health will be met by the installation of storm drainage.

23. In certain critical areas surface levels are around 3.5 ft (1.07m) rSD, or groundwater level. If it is accepted that there must be no lowering of this water, then the only way for its "removal" is to fill; a common enough step already in many an 'api kolo[2] in Nuku'alofa.

24. Only the minimum depth of fill should be used, the governing criterion being that depth necessary to (just) accommodate 6 in (150mm) thick-wall concrete pipes. In practice, this means fill to a level of 4.2 ft (1.28m) rSD.

25. The ultimate in floodwater removal would require watertight[3]

---

1 estimated from the 1:25000 series of maps of Tongatapu.

2 'api kolo = town dwelling plot.

3 to secure watertightness and protection against earth movements "plastic" pipes would be useful but in large diameters they would be very costly, in Tonga.

pipes under carriageways, laid to adequate gradients and discharging to suitable pumps.

26. An alternative to the piped drainage referred to in the foregoing sections is a method employing channels as the main conduits for floodwater removal (to the lagoon).

27. The alternative is more effective in that it would remove flooding more rapidly (but with greater risk to lagoon life). It is also, generally, less expensive in capital cost and maintenance will be cheaper. Thus the alternatives become self-selective insofar as channels are seen to be more attractive. However, in some cases drainage will require channels and pipes.

28. In terms of effects on lagoon life, channel drainage will have the greater impact. Accordingly, an ecological study[1] should include a careful review of the final proposals.

29. One very useful feature of channel drainage would be the opportunity to provide a kerb, for any adjoining road, merely by extending the sidewall of the channel above carriageway level. Simple openings in this extension would admit run-off from the highway and there would also be useful mechanical support for the highway material/traffic.

30. For satisfactory detailed designs further site study will be essential. Nonetheless, the present alternatives are thought to be a good guide to the requirements.

FANGA 'UTA LAGOON

1. As argued elsewhere most of the surface water discharges will enter the lagoon. This is unfortunate. The shallow depth - adults often ford the lagoon on foot to reach Kanatea Island - coupled with its poor circulation provide little dispersal of any pollutants. In this context readers should note that, to certain forms of lagoon life, even fresh rainwater is a pollutant.

2. It might be thought that the shallow depth and large surface area would encourage useful photosynthesis and good oxygen transfer. However, it is likely that the turbidity of the water militates against the former and temperature effects influence the latter.

3. A report[2] published in January 1978 suggests that the lagoon ".... is and will continue to be a significant environmental management problem ...." and continues " .... it will be necessary to be extremely careful with further development around it if the situation is not to deteriorate further".

4. The report includes the results of bacteriological tests of the ocean water and of the lagoon. It is significant that the highest levels of coliform bacteria appear in the lagoon.

5. Much of the pollution must originate from properties on the lagoon shore, a number of which have no septic tank - the occupants freely discharge crude sewage directly into the water.

6. Because of the low-lying level of the lagoon shore - in its natural state this land was mangrove swamp - water is encountered above, at, or at best only a few inches below, the surface (depending on the lagoon level). Accordingly, even if septic tanks were in use

---

[1] an ecologist has now been appointed.

[2] Environmental and Ecological Report on Tonga Part 1 - Tongatapu, Dr A L Dahl, South Pacific Commission.

the effluent therefrom would have little or no dry soil into which to percolate.

7. One remedy involves the eventual removal of buildings in the vicinity of the lagoon, particularly in the area from and including Haveluloto to near Ngele'ia Avenue, a length of some 1.2 miles (1.93 km).

8. Land vacated should be restored to its original condition as a mangrove strip. Mangroves are the natural habitat of various life-forms and tend to act as protection during hurricanes. (This latter aspect was discussed with a consultant on Natural Disasters who fully upheld the principle). The law also recognizes the situation - Sec. 7 of The Birds and Fish Preservation (Amemdment) Act, 1974, makes it an offence to "cut, damage, remove or destroy any mangrove".

9. The above remarks represent one solution. Another might involve the construction of a wall edging the lagoon and the use of coral fill to raise the ground to a suitable level.

10. Sufficient detailed study was made of the lagoon margins to show that the situation requires much further review, and a clear evaluation of alternative courses of action.

11. It is recommended that a careful investigation be carried out by an ecologist (recently appointed).

12. Meanwhile, it would be prudent to prohibit all further development along the lagoon shore, in the length described and in a strip of at least 50 ft (15.2m) from lagoon high water mark.

13. The possibility will always exist that waste sump oil, for example, might enter the drainage system and thus reach the lagoon. Only public awareness can frustrate such an event, although in a dry period the dangers will be much reduced.

14. Furthermore, at times of rain there will be suspended matter in the discharge, from the coral roads, and some of this will also enter the lagoon. The low velocities in the system should restrict its distribution to the vicinity of the various outfalls. In addition, catchpits will be included to intercept some suspended particles.

15. In efforts to reduce the impact of any pollutants, surface water pipes could be bifurcated at the lagoon and extended along its bed. They will also be perforated along their length, to present a number of outlets, to benefit as much as possible from the dilution factor and to lessen any shocks to lagoon life. (Such practice should be considered for existing discharges to the lagoon).

16. These remarks relate to the piped system of drainage. The preferred alternative of pipes/channels will have appreciably more impact on lagoon life because the rate of removal of floodwater will be greater and there will be little opportunity to separate suspended matter from the run-off.

17. As with a piped system, the channel drainage scheme will include the attendant risk of admitting pollution into the lagoon from leakages of septic tank effluent, oil spillages, leaching of domestic wastes, etc. At storm times such pollution will be diluted and the dangers will be thus reduced. If pollution enters the channels in dry periods it can at least, with a measure of routine inspection, be detected and its source traced.

18. Accumulations of rubbish in the channels will tend to hold back water, giving opportunities for insect breeding. In storm periods any small accumulations of rubbish will be swept into the lagoon. Both these dangers may be largely prevented by routine maintenance.

19. On balance, it is considered that occasional entry into the lagoon of diluted pollutional loads can be better handled by the natural agencies than the steady and concentrated pollution - in wet and dry seasons - from the present development along the lagoon bank. No doubt the ecological study will throw further light on this aspect of the situation.

WASTEWATER

1. Sewerage

1.1 In Tonga as a whole there are no planning laws and development is permitted/tolerated without control. In Nuku'alofa, plans/drawings of new buildings are submitted to the Ministry of Health where they are examined/approved. The developer is required to indicate the location of the septic tank and he is handed a detail of the tank which is thought to be appropriate to the accommodation.

1.2 (Standard tank designs embrace 1 - 50 persons served and the range includes 10 tank sizes varying linearly from 325 to 2 400 gallons capacity - 1 500 to 12 000 litres).

1.3 In the absence of formal building/development planning it would be some years premature to propose a conventional sewerage network for the town. Nonetheless, it would be wrong to dismiss the subject. There is little doubt that Nuku'alofa will emerge as a planned and structured community and it is thought right to consider formal sewerage facilities for the central, commercial, area of the town. This includes a modern bank, post office, government buildings, shops, offices, market, cinemas and other publicly-used premises. These buildings should not be permanently committed to the use of septic tanks but should be adequately drained by a piped system.

1.4 The argument for this suggestion rests mainly on the changing pattern of tourist/visitor traffic. Formerly, outsiders could arrive only by sea and the duration of the journey - having regard to the relative isolation of Tonga - would generally overlap the incubation period of most diseases. Thus, infected persons would in most cases be identified, probably, even before arrival (except disease "carriers").

1.5 An attempt is being made to encourage the tourist industry, with noticeable success, and hence efforts to improve health conditions and/or to safeguard health should also be encouraged.

ARRIVALS/YEAR	1972	1973	1974	1975	1976	1977
By Air	4430	6356	6403	6770	9312	11023
By Cruise Ship				44968	33024	28000

(Visitors by cruise ship do not generally stopover for longer than 1 night whereas the average stay for airline passengers is 5-7 days: source, Government Statistician).

1.6 Airline passengers from long distances can arrive in Tonga very rapidly, unwittingly carrying diseases to which the islanders, and others, would be exposed possibly without warning. (The 1977 cholera outbreak in the Gilbert Islands caused some concern in Tonga, and elsewhere in Polynesia).

1.7 Since many of the visitors will frequent various parts of the centre of Nuku'alofa, it is held that there must be a case for securing that area in terms of public health - notably by removing the risks created by the spread of septic tank contents during flood periods.

1.8 (Elsewhere in this Paper will be found proposals for increasing the number of septic tanks, in/out of the town centre. A by-product of this step will be an increase in sludge volumes and the consequent overloading of the existing sludge disposal facilities at Tukutonga, facilities which are already inadequate. Thus, there will be a need for improved sludge treatment. Disposal units, which are proposed herein, create an opportunity to include enlarged facilities and adequate means to treat town sewage, in addition to sludge. Whether or not sewerage is to be provided, the proposed sea outfall will be necessary for the expanded/improved sludge units as an alternative to the present unsatisfactory method of sludge disposal).

1.9 The weakness in the foregoing argument is that the International Dateline Hotel, where most visitors will doubtless stay, is omitted from the future sewerage scheme. This is intentional and is supported by the following points -

(a) as shown elsewhere, the hotel represents a high hydraulic load[1]; it contributes a comparatively low pollution load,

(b) the present arrangements - including chlorination[2] - are seen to be reasonably satisfactory, at least for the foreseeable future,

(c) there would be practical difficulties in pumping the hotel flow into the proposed rising main alongside Vuna Avenue (and the alternative of double pumping with storage/balancing capacity would be inappropriate).

1.10 For the above reasons, then, the hotel is excluded from the first-stage sewerage proposals. A later programme should provide formal facilities, but it is difficult to justify adequate provisions at the present state of conditions.

1.11 Existing flush toilets in the town centre use mains water and doubtless a case could be made for the continuation of this practice. However, if the proposed embryo sewerage system is seen as a realistic scheme then the future would see an extension thereof, in due course. Thus there would be an increasing use of mains water.

1.12 Now the treated water supply relies on groundwater sources, which in Tonga are finite. Clearly it is undesirable to use this supply for the water-carriage method of drainage. Clean, treated water for flushing would be a misuse of a valuable natural resource and its use would perhaps jeopardize development in future years and endanger the supply for the increasing population.

1.13 Thus any water-carriage drainage scheme should look elsewhere for its supply.

1.14 The use of seawater is proposed[3] although this practice entails certain dangers. The most noteworthy is the risk of cross-connexion with the potable water system. On the other hand, this will be a limited hazard since any unauthorised access to a water main is illegal, although connexions elsewhere would be possible.

---

[1] most of this originates from baths/showers and housekeeping, not from toilets.

[2] the effluent from the hotel septic tanks is chlorinated before discharge to the ocean.

[3] a similar proposal is currently being implemented in Betio, Gilbert Islands, by the Australian Govt Dept of Housing and Construction.

1.15 In any event it is proposed to incorporate the flushing network into the Tonga Water Board undertaking thereby reducing the risk of cross-connexion and misuse.

1.16 Seawater flushing will require a pumping station for abstraction from the ocean, a rising main, storage reservoir and distribution network.

1.17 To balance supply and demand, storage of seawater will be required and the proposals include a service reservoir, either on Mount Zion, maximum height 53 ft (16m) rSD, or alternatively an elevated tank.

1.18 A network of seawater distribution pipes will be included. These will follow closely the lines[1] of potable water mains and branches. For ease of maintenance, proper identification and co-ordinated pipelaying, the whole seawater system must become the responsibility of the Tonga Water Board.

1.19 Sewers will be laid to serve the selected area, draining to a central point whence the flow will be pumped to a site at Tukutonga for treatment - sedimentation and gravity discharge to the ocean. The site will also contain sludge digestion facilities sufficiently large to accept septic tank contents.

1.20 Sewage treatment will consist of sedimentation, for the removal of most of the suspended matter. The effluent will be admitted to the ocean, by means of an outfall pipe discharging into deep water at the edge of the reef.

1.21 Sludge removed will enter a digestion stage, designed to accept also septic tank contents from the town. Processed sludge will be released to drying beds where the separated liquor will be removed for re-treatment, the dried sludge being used for landfill on site and elsewhere as required.

1.22 The foregoing outlines the nucleus of a formal drainage system for the central area of the town. It has certain shortcomings, notably its lack of flexibility, although this is caused by the poor available surface gradients.

1.23 The present proposal for seawater flushing could be criticized on, inter alia, installation and running costs vis-a-vis availability of freshwater. Tonga Water Board officers confirm that adequate water resources are now available and can be made available for an increased population for some time. Indeed, investigations are in hand for developing new groundwater sources and there is no reason to suspect that sufficient resources do not exist.

1.24 Vaiola Hospital has its own wastewater treatment plant. The site is too far from the town centre to permit a gravity connexion to the sewerage system as proposed.

1.25 It would be possible to pump the hospital discharge to the town centre, whence it could be re-pumped to Tukutonga. This would be the wrong step; the disposal of hospital wastes in that way would have to rely on the implementation of the town sewerage scheme. Whereas this scheme is desirable, it is not essential at present while improvements at the hospital have a higher priority rating.

2. Septic tanks

2.1 Outside the central area of Nuku'alofa it would not now be realistic to prepare sewerage proposals.

2.2 It is recommended that all premises, excluding those which may be served by sewers, in the town as defined should be equipped with adequate

---

[1] where possible, the seawater pipes should be laid in the same trench as the sewers.

septic tanks of suitable size and of approved construction. (Pit latrines should be forbidden except, possibly, for temporary purposes). The Government should so legislate, and provide funds for the supply of tanks to the public, free of charge.

2.3 It is recommended that the provision of tanks should be made obligatory, for all buildings not otherwise drained, and that the cost of the tanks should be borne by Government - thus ensuring that correct materials and workmanship are used, and that all households benefit, regardless of the occupant's income. This step would be a significant contribution to public health safeguards in the town.

2.4 The supply of septic tanks alone would, however, not fulfil the needs of public health. It would also be necessary to provide surface water drains, as detailed elsewhere, to ensure that floodwaters do not distribute tank effluents - a common occurrence under existing conditions.

2.5 The census of 1976 showed that there were 3043 households in the town (each with an average of 6.77 persons) - it is estimated that there may now be some 3180.

2.6 A sample survey of a characteristic town area, containing 47 dwellings, gave the following results -

Septic Tanks	20
Pit Latrines	3
Pour-Flush Toilets[1]	11

2.7 If these figures are any guide it seems that about 1826 septic tanks are required, if "households" means dwellings, to equip all homes in Nuku'alofa.

2.8 In reality, the figure is likely to be rather less than 1826 because of the likelihood that some families are in shared accommodation. A better estimate would perhaps lie around 1700 - 1750. (The latter figure has been used herein).

2.9 In general, schools/colleges are already adequately served and no significant demand for septic tanks should arise from such premises.

2.10 The tank empyting service of the MoW removed the following loads of septic tank contents in 1977, from -

Talamahu Market	544
Police Department	87
Public Toilets	200
Hospital	214
Government Quarters	104
Private Premises	563
	1712 loads

2.11 Each load represents 750 gallons (3400 l) and so the total volume removed was about 1.28 million gallons (6 Ml).

2.12 The danger with the use of septic tanks lies in the reliance placed upon this type of sanitation system. Septic tanks are useful where sufficient suitable land is available to accept the effluent; such circumstances exist in rural communities, of course, which was the apt description for Nuku'alofa until fairly recently. Now, the town is becoming urbanized with the increase in population and density of development and, in principle, it is wrong to recommend septic tanks as a continuing means of wastewater disposal.

2.13 Nonetheless, in practice there is little alternative to tanks, at the present time, but the authorities must constantly review the situation, as the community develops. In due course, there will come a time when formal sewerage facilities will be required (and can be justified). At that stage septic tanks will no longer be the appropriate method of disposal.

2.14 Whether the full value of the tanks already installed will be realized by then is, at this moment, conjectural. On balance, it is thought that - for some years - there is no real alternative to septic tanks for wastewater disposal, unacceptable as this may perhaps seem to those accustomed to more sophisticated methods.

ACKNOWLEDGEMENTS

This paper is presented by permission of the Ministry of Overseas Development, London, and with the consent of The Government of Tonga. The Author is grateful for the co-operation extended to him by these authorities, and for the assistance given by individuals in London and in Nuku'alofa. Opinions/views contained in this Paper are those of the Author alone and do not necessarily reflect any official standpoint or policy.

BIBLIOGRAPHY

(1) KENNEDY. Report on the Planning and Development of Nuku'alofa, 1969.

(2) CASTRILLON, S. Findings and Observations made during the Second Inspection of Sewage Treatment Plant at Vaiola Hospital, Nuku'alofa, Tonga, 1972.

(3) LUYENDYK. Report on Land Reclamation, UNDP, 1973.

(4) MUNRO, A M. Outline Master Plan - Town Planning, Foreign & Commonwealth Office, London 1973.

(5) SHORES (Babbage & Partners). Engineering Report, 3rd Five Year Development Plan, 1975

(6) Third Development Plan, 1975 - 1980, Central Planning Office[1], 1976.

(7) Sir Alexander Gibb & Partners Australia. Road Improvement and Maintenance Study, Final Report, Vol.1, UNDP - ADB, 1976.

(8) MANNIO, P & AMIN, V C. Consultant's Report on the Small Industries Center Project in Tonga, 1977.

(9) FEACHEM, McGARRY, MARA, eds. Water, Wastes and Health in Hot Climates, Wiley, 1977.

(10) DAHL, A L. Environmental and Ecological Report on Tonga, Part 1: Tongatapu, South Pacific Commission, Noumea, New Caledonia, 1978.

(11) Land Act, Chap. 63.

(12) Land (Amendment) Act, 1973.

(13) Public Health Act, Chap.48.

(14) Roads Act, Chap.98.

(15) Water Board Act, Chap.47.

(16) Birds and Fish Preservation Act, Chap.75.

[1] now Central Planning Department

(17) Birds and Fish Preservation (Amendment) Act, 1974.

(18) Parks and Reserves Act, 1976.

(19) Harbours Act, Chap.102 (see Sec.17)

(20) Public Works Bill, 1975

(21) The Institution of Engineers, Australia, Australian Rainfall and Run-Off, 1958

(22) Ditto, 1977 edition (S I METRIC)

(23) COLYER & PETHICK. Storm Drainage Design Methods - A Literature Review, Hydraulics Research Station, 1977.

(24) FEACHEM & CAIRNCROSS. Small Excreta Disposal Systems, The Ross Institue of Tropical Hygiene, 1978.

(25) Health Aspects of Excreta and Wastewater Management, IBRD/World Bank, 1978

(26) Report on Surface Water Drainage and Wastewater Facilities at Nuku'alofa, Richards & Dumbleton International, for The Government of Tonga, 1978.