The Asian Development Bank

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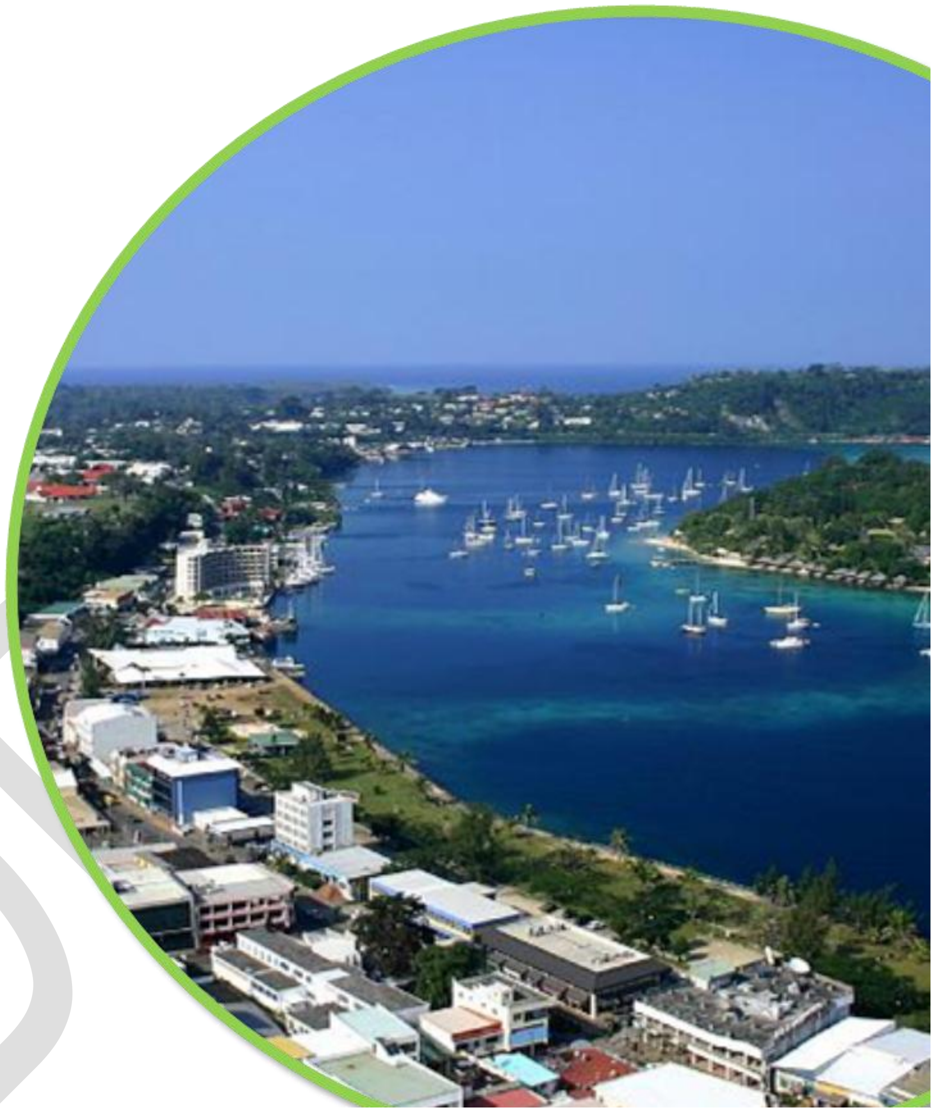
PORT VILA URBAN DEVELOPMENT PROJECT
PPTA CONSULTANT'S REPORT



PHASE 1: SITUATION ANALYSIS AND MASTER PLAN FORMULATION, VOLUME 1 SUMMARY OF MASTER PLAN AND MAIN REPORT

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ABBREVIATIONS

ADB	Asian Development Bank
AUSAID	Australian Agency for International Development
CBD	Central Business District
CBDAMPIC	Capacity Building for the Development of Adaptation Measures Project
CC	Climate Change
DCO	Development Committee of Officials
DEC	Department of Environment & Conservation
DGMWR	Department of Geology, Mines and Water Resources
DLA	Department of Local Authorities
DFEM	Department of Finance and Economic Management
DPH	Department of Ports & Harbour
EA	Executing Agency
EA	Enumeration Area
EU	European Union
FMA	Financial Management Assessment
GAP	Gender Action Plan
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GRAMP	Governance Risk Assessment and Management Plan
HIES	Household Income and Expenditure Survey, Household Income and Expenditure Survey
IA	Implementation Agency
IDF	(Rainfall) Intensity-Duration-Frequency
IEE	Initial Environmental Examination
ISPS	International Ships & Ports Security
JICA	Japanese International Cooperation Agency
LARF/LARP	Land Acquisition and Resettlement Framework and Plan
LSF	Land Sector Framework
MFEM	Ministry of Finance and Economic Management
MIA	Ministry of Internal Affairs
MIPU	Ministry of Infrastructure and Public Utilities,
MJSW	Ministry of Justice and Social Welfare, Ministry of Justice and Social Welfare, Ministry of Justice and Social Welfare
MLNR	Ministry of Lands and Natural Resources
MOH	Ministry of Health
MOL	Ministry of Lands
MOU	Memorandum of Understanding
MSL	Mean Sea Level
NACCC	National Advisory Committee on Climate Change
NLSC	National Land Steering Committee
NZAID	New Zealand's International Aid & Development Agency
O&M	Operation and Maintenance
PAA	Priorities and Action Agenda
PICCAP	Pacific Island Climate Change Project
PIEPSAP	Pacific Islands Energy Policies and Strategic Action Planning
PIGGAREP	Pacific Island Greenhouse Gas Abatement through Renewable Energy Project
PIREP	Pacific Islands Renewable Energy Programme
PMU	Project Management Unit

PPA	Physical Planning Area
PPTA	Project Preparatory Technical Assistance
PPU	Physical Planning Unit
PRIF	Pacific Regional Infrastructure Facility
PVMC	Port Vila Municipal Council
PVUDP	Port Vila Urban Development Project
PWD	Public Works Department
SPO	Shefa Planning Office
SUDS	Sustainable Drainage Systems
TA	Technical Assistance
TOR	Terms of Reference
UN	United Nations
UNDP	United Nations Development Programme
UNELCO	Union Electrique du Vanuatu Limited
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund, United Nations Children's Fund
UNIFEM	United Nations Development Fund for Women
URA	Utilities Regulatory Authority
Vt	Vatu
WHO	World Health Organization

PHASE I MAIN REPORT

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I. INTRODUCTION

A. Preamble

1. This Report is presented in 6 Volumes, this being Volume 1. Summary of Master Plan and Main Report. For each of the main sectors covered in the PPTA Study, a separate, stand alone report has been prepared, these are presented in the following Volumes:

Volume 2. Drainage

Volume 3. Sanitation

Volume 4. Institutional

Volume 5. Environment and Climate Change

Volume 6. Socio-economics

2. This Volume (Volume 1) is intended to summarise the major findings of the sectoral studies, which are elaborated in greater detail in the remaining volumes 2 to 6, in particular the sections on Drainage and Sanitation are dealt with in more detail.

3. Volume 1 also attempts to combine the strategies and recommendations referred to in Volumes 2 to 6, to form an integrated overall Master Plan for the development of sanitation and drainage infrastructure over the planning period under consideration, 2010 - 2025.

4. At a workshop held in November 2010 with the members of The Government of Vanuatu DCO (Development Committee of Officials) which was attended by directors General and Political Advisors from Government departments, it was the clear opinion of the participants that the draft Master Plan be presented in as simple, straightforward and concise a document as possible. To meet this requirement is the intention of this Volume.

5. In support of the above principle, and in the interest of conciseness, this volume, therefore does not reiterate general statements, such as introduction to the Project, Project Background, Institutional Setting etc. These statements are to be found, to some extent in the sectoral reports in Volumes 2 to 6, in the Inception Report presented at the end of June, and the First Progress Report presented in August 2010.

6. Despite the above, this document is voluminous consisting of 91 pages and the total of all 6 Volumes is more than 600 pages. Whilst all of the information contained in these pages is important to the Master Plan, such a large quantity of material is indigestible by busy executives and decision-makers. Therefore a summary volume has been prepared which is intended to present the main and most important features of The Master Plan. This Volume is entitled Executive Summary.

B. Background

7. Port Vila, a town of, within its municipal boundaries, some 44,000 residents, is the main population centre and main seat of commerce and government for Vanuatu. It has already outgrown its originally-defined urban boundaries due to substantial population increases, rapid economic development, urban in-migration and the proliferation of informal (squatter) settlements. The estimated population of the resulting ‘Greater Port Vila’ area in 2009 was 58,000 residents. These factors, coupled with the lack of an infrastructure master plan or land use plan for the city and its surrounding peri-urban areas, together with the

absence of a formal building code being followed or enforced, have resulted in ad-hoc growth, land speculation, deforestation, weak coastal management systems, and significant inadequacies in the provision of basic services, especially drainage and sanitation infrastructure, to the urban population. In turn, these conditions have caused tangible adverse impacts on the built and natural environment, public health, and the overall quality of life of Port Vila's residents.

8. The primary aims of the Port Vila Urban Development Project (PVUDP) are to (i) evaluate current and changing needs for drainage and sanitation infrastructure in the central business district (CBD) of Port Vila and the urban and peri-urban environs; (ii) facilitate improved planning processes, especially for the required urban and sanitation infrastructure, within a medium-term (15-year) planning horizon; and (iii) develop concepts for, and examine the feasibility of, different design options for drainage and sanitation infrastructure investment projects.

II. ENVIRONMENT AND CLIMATE CHANGE

9. Among the sectoral analyses, environmental and climate change analysis provides comprehensive background information regarding the natural and built environment of Port Vila and the surrounding area. It considers such aspects as climate, geology, water resources, coastal ecosystems, and land use (among others), but focuses more critically on urban drainage and sanitation as two key areas of concern. This summary (1) highlights significant natural features of the Port Vila coastal environment; (2) explains the importance of taking into account climate change and its possible impacts; and (3) identifies issues of concern relating to the proposed drainage and sanitation infrastructure.

A. Environmentally Sensitive Features of Port Vila

10. Occurring in the Port Vila area are several marine and coastal ecosystems of extreme importance, both from an environmental and economic standpoint. These include coral reefs, mangroves, and seagrass beds. Coral reefs provide spawning sites, nursery-grounds, feeding areas, and shelter to a vast array of fish and invertebrate species, many of which provide food for human consumption. They also provide other critical "ecosystem goods and services." They are essential in beach formation, a process that involves the breakdown of corals into calcareous sand, and indeed, provide the basis for the formation of coral islands as well. They serve as physical barriers that attenuate wave energy, thus protecting shorelines from storm surges and tsunamis. Because coral organisms produce calcium carbonate through metabolic processes, they are able to withdraw CO_2 from the atmosphere, thus helping to mitigate the effects of global climate change.

11. All the coastal ecosystems of the Port Vila area, as well as their component biodiversity, are under threat due to several causes. While the reefs of the Port Vila area have shown great resiliency to adverse impacts, increasing pressures are being felt due to pollution and siltation, overexploitation of reef resources, and climate change-related impacts. Climate change impacts affecting coral reefs include: increasing temperature which can cause 'coral bleaching'; sea level rise that leads to changes in light penetration, affecting coral growth; imbalances in populations of predator and prey species (especially the Crown of Thorns starfish); and acidification of ocean waters resulting from increasing levels of atmospheric CO_2, that inhibits further uptake of CO_2 by corals. Mangroves and seagrass beds are also being damaged due to many of these same effects, with added pressures occurring as a result of conversion (and permanent loss) of these areas to make them available for other uses (mainly fishponds and reclamation areas).

12. Cumulatively, all these effects can cause reduced resiliency of coastal ecosystems, that can lead to: reduced productivity, and reduced availability of food resources for humans; reduced structural integrity, compromising functioning of these systems as wave barriers that can protect coastlines; reduced biodiversity; and, in the case of corals, reduced activity of reef organisms in sequestering atmospheric CO_2, with consequent release of CO_2 to the atmosphere, thus exacerbating the impacts of climate change. Reduced resiliency of these ecosystems will undoubtedly also cause reduced resiliency among human populations, as well as serious economic consequences.

13. The water quality of the bays and lagoons around Port Vila is also important, as these features represent a fundamental attraction for both tourists and city dwellers. Fishing for subsistence, commerce and recreation, as well as Vanuatu's tourism industry, are all dependent upon the maintenance of good water quality.

14. Visually, the waters of Port Vila can appear crystal clear. However, despite this pristine appearance, water quality in the harbour is under severe pressure from: land-based run-off of silts and hydrocarbons; septic tank overflow and discharge; the dumping of garbage and debris; and various wastes and spills from small and large vessels using the port.

15. Water quality tests have been conducted in Port Vila over the years by the analytical laboratory of the Department of Geology, Mines and Water Resources (DGMWR). The main findings of the water quality monitoring and testing exercises conducted in the Port Vila area are as follows:

- There are significant inputs of hydrocarbons to the harbor, primarily from road and paved area runoff following heavy rains.

- Elevated levels of faecal Coliforms are observed at sampling sites in Fatumaru Bay, at the harbour seawall near the discharge from the market toilets, in Emten Channel between town and Iririki Island, and near the main wharf. Elevated bacteria counts have also been measured at the Iririki Resort sewage outlet, on the northwest side of the island. At times, bacteria levels at these sites have been measured well in excess of international public health standards.

- Seepage from inefficient septic tanks into groundwater and then into the harbour is likely to be one of the major sources of pollution, especially following rain and during spring tides.

- Leachate from poorly-sited urban and domestic rubbish dumps, storm water containing light industrial wastes, and organic wastes from piggeries and agricultural plots, as well as road runoff, are all believed to contribute to the current poor state of water quality in the lagoons.

- The reduction in water clarity in lagoons, Fatumaru Bay, and Iririki Island outlet is likely the result of elevated concentrations of plankton resulting from nutrient loading.

16. Recent water quality monitoring was conducted at several sites around Port Vila in October 2010 as part of a post-doctoral research program.[1] This monitoring effort had the advantages that (i) it included monitoring of groundwater, surface waters, and lagoon and coastal waters; and (ii) for the coastal sampling, enterococci was used as one of the

[1] By Mr. Michael Poustie, doctoral candidate at Monash University (Australia).

monitoring parameters (a more accurate indicator in this medium, than Coliforms bacteria). These recent data corroborate the general findings of earlier monitoring surveys, and give an indication that water quality standards are regularly below internationally accepted norms in the Port Vila area.

17. The data suggest that, in order to avert damage to natural and environmental resources, and avoid potential outbreaks of disease among the human population, steps urgently need to be taken to better protect groundwater, surface waters, and ocean recreational areas. The urban drainage and sanitation infrastructure being proposed under the PVUDP would represent a significant step in preventing such adverse impacts from occurring.

B. Climate Change Considerations

1. Overall considerations

18. In considering the factors that threaten the natural ecosystems and the built environment of Port Vila, it is important to take into account the possible effects of extreme weather events and climate change. Vanuatu generally, and Port Vila specifically, are highly vulnerable to natural disasters, and are exposed to a wide range of climate-related hazards that increase risk. According to one analysis[2], Vanuatu is identified as the world's most vulnerable country out of 111 countries evaluated, with high exposure to cyclones, droughts, earthquakes, volcanic eruptions, tsunamis, storm surge, coastal and river flooding, and landslides. Most of these are weather and climate related.

19. The prevalence of climate-related occurrences—and the fact that current predictions indicate that these will likely become more frequent and more intense over time as a consequence of expected effects of climate change—requires that appropriate measures be taken to improve the resiliency of the population in the face of such events. Such measures include climate-proofing of infrastructure, policy reform, and institutional capacity-building for disaster risk management. The expected impacts of a warming climate, with more frequent extreme climatic events and sea level rise are quite serious, but difficult to predict with quantitative certainty. Among the possible impacts identified are the following:

- decreased agriculture production and reduce food security;
- increased incidence of diseases such as malaria, dengue and water-borne diseases;
- water shortages;
- inundation in coastal zones and impacts on infrastructure and housing;
- coral bleaching, and other undetermined impacts on coastal ecosystems; and
- uncertain impacts on fisheries resources.

20. Based on scenarios that do not assume explicit climate policies to reduce emissions of greenhouse gas (GHG), global average temperature is projected to rise by 2°F to 11.5°F by the end of this century[3] (relative to the 1980-1999 time period). Rising temperatures, in turn, have implications for increasing frequency and intensity of extreme weather events, as well as sea level rise. For Port Vila, sea level is expected to rise by nearly 400 mm by 2060, enough

[2] Assessed according to the Commonwealth Vulnerability Index.
[3] http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/full-report/references.

to pose a serious threat to the existing footprint of buildings and infrastructure built up along the shore. It is anticipated that global warming may make tropical cyclones more frequent and more intense. Given Vanuatu's vulnerability to such events, adopting an integrated "all hazards" approach to disaster risk management will be vitally important for the future development of the nation.

21. In considering the design of the proposed urban drainage and sanitation systems for Port Vila, the likely effects of climate change have therefore been identified and taken into account.

2. Drainage

22. Flooding is a serious problem that can result in loss of human life and property, relocation of households, an increase in water-borne diseases, and other associated environmental, economic, and social costs. Natural flooding in Port Vila occurs during prolonged periods of heavy downpour, often associated with cyclones. These events cause many rivers around the town, including the Teouma, La Colle, Tagabe, and Tepwuloa rivers, to overflow their banks.

23. However, within the town's Central Business District (CBD), the reasons for flooding are largely ascribed to manmade factors. Runoff problems are most serious in the high-density development areas such as the CBD and where there are steep slopes. As the town has grown, storm water drainage structures have been added in an ad-hoc fashion. Consequently, the drains which exist are often poorly designed, prone to blockage, seldom maintained until they cause localized flooding, and generally in a state of disrepair. Reduced permeability of the land as a consequence of continuing construction and development are contributing added volumes of runoff water. In addition, trends of increasing rainfall, likely due in part to climate change, are also exacerbating the problem.

24. In work performed during the Inception stage of this project, 42 flooding 'hotspots'—existing sites where drainage is chronically constrained and flooding regularly occurs—were identified around Port Vila. The team also identified 39 catchment areas; of these, 16 catchments that have drainage problems often manifested as frequent localised flooding, and it is expected that an additional 8 catchments may be affected by drainage problems in the future due to sub-standard drainage systems and/or continued land development.

25. It should be noted that there are many factors in play that would ordinarily help to minimize flooding in Port Vila—these include: the presence of permeable limestone that underlies most of the urban land, and hilly terrain, to promote quick runoff; low- to medium-density development with relatively small proportion of paved area, also facilitating infiltration; and prevalence of rainwater collection as a drinking water supply source, reducing the volume of runoff water. Despite such conditions favouring reduced flooding, many areas of Port Vila continue to be affected by localized flooding. This suggests that drainage infrastructure is not functioning efficiently, and drainage problems need to be addressed in a planned and integrated manner. Possible climate change-related aspects also need to be taken into consideration in designing adequate drainage infrastructure.

26. The system being proposed as part of the PVUDP will incorporate Sustainable Drainage Systems (SUDS) principles. SUDS techniques reduce the peak flow rate and total volume of runoff by promoting infiltration to groundwater, thus reducing capital costs. These techniques also reduce pollution by promoting filtration and biological action to improve water quality at drainage outfalls, thus helping to protect aquatic and coastal environments. Implementing standard best practices such as road sweeping, sediment capture and oil separation will also improve the water quality in surface discharges, thus making these

systems fairly low-maintenance, while protecting the environment. A 'Code of Practice' for drainage infrastructure[4] has been developed by the PVUDP drainage engineers, that will help to guide the design, construction, and operation of drainage infrastructure.

(a) Overall Climate Change Considerations

27. Overall, the provision of improved drainage to alleviate flooding and related problems that are already being experienced under existing climatic conditions, can be regarded as a 'no regrets' initiative, whether or not major changes to the climate occur in the future. The possible effects of climate change have also been considered in the proposed design. For drainage it is possible to avoid potential damage costs attributable to climate change, and to do this in a cost-effective manner, by consideration of climate proofing at the design stage.

(b) Rainfall and Extreme Weather Events

28. The primary concern for drainage is that climate change will cause the design storm to occur with increasing frequency in the future. The relatively low runoff that is prevalent in Port Vila, and adopted design criteria for a minimum self-cleansing velocity of 1.5 m/s, result in drainage systems where the drains operate satisfactorily but below capacity for the design storm. This means that the systems are inherently over-designed for capacity and have additional capacity for any increase in the frequency of the design storm due to climate change.

(c) Sea Level Rise

29. Another climate-related factor that influences the design of the drainage system is the anticipated rise of seal level, which will dictate the height at which coastal outfalls will be built to avoid 'tide locking'. The project's Code of Practice for Surface Water Drainage addresses this concern, specifying that new drainage outfalls will be set with the invert above predicted highest tide level in 2060 (+1.36 m MSL), excluding waves, extreme surge, seiching or tsunami. This will minimize occurrence of tide locking.

30. Sea level rise also affects buildings and all other infrastructure along the coast; to avoid flooding of these structures in the coming decades, it is imperative to take into account the expected effects of sea level rise. In the Code of Practice, a general recommendation is made to establish a minimum platform level of +1.96 m MSL, and ground floor and crest levels[5] of +2.11 m MSL for all structures along or near the coast.

3. Sanitation

31. At present, there is no reticulated system being used to collect domestic sewage in Port Vila and there is no facility available to treat sewage effluents. Instead, the population is using on-site disposal of wastewater, either through septic tanks and soak pits in formal housing estates, or as pit latrines and natural watercourses in areas of informal housing (squatters' settlements). In general, blackwater[6] is either diverted to septic tanks or to pit latrines, while greywater[7] is sent either to septic tanks, or to open areas where it infiltrates into the ground. Sludge in septic tanks is periodically pumped by one of several commercial operators in the area who offer this service. The sludge material is taken to the Bouffa landfill

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[4] Code Of Practice for Surface Water Drainage. ADB Port Vila Urban Development Project. ADB TA 7345-VAN.
[5] Crest level refers to the top of any structure (e.g., berm, basement threshold) that serves as a barrier to water entry.
[6] Toilet waste containing fecal material
[7] Wastewater from such sources as kitchens and laundries, with no fecal content

site for disposal. Unfortunately, no regular protocol for handling the sludge at the landfill site is followed, with the result that sludge materials are often intermingled with other wastes, and not properly dried. Discharges thus disposed to pit may still contain high fractions of fecal material[8].

32. These poor sanitation conditions cause several environmental problems, and pose potential health risks. Effluents with high nutrient levels can cause eutrophication in the nearshore environment, resulting in algal blooms and die-off of corals. High counts of coliform bacteria along swimming beaches and in rivers indicate that other disease-causing pathogens may be present, which can cause intestinal disorders and more serious health problems. These problems can in turn result in additional economic costs, in terms of lost tourism revenue, lost productivity and added health care costs.

33. While large-volume commercial or institutional water users have dedicated, on-site wastewater treatment systems, these facilities have generally not been well maintained or properly operated. Also, water quality monitoring data are difficult to obtain for treatment plants, and for many of them, it is suspected that the effluents being discharged do not comply with recognized standards.

34. Collectively, these factors strongly indicate the need to improve the delivery of sanitation services in Port Vila. The PPTA consultant team has considered several planning and design alternatives for a system to address the current and projected needs. Ideally, such a system would include the following elements: (i) a piped, common reticulated wastewater collection system, in areas of intensive urban development (mainly the CBD); (ii) a wastewater treatment plant that would process water to an internationally-accepted standard, with treated effluent to be discharged either through an ocean outfall, or to surface waters (river); (iii) improved construction, maintenance and operation of septic tanks in those areas not served by the reticulated collection system; (iv) improved handling and processing of sludge at the solid landfill site; (v) processing of sludge from both WWTP and septic tanks through an anaerobic digester to produce organic compost and methane gas that could be used for energy production.

35. If a new wastewater treatment plant is established, a decision may be made to further treat potentially hazardous effluents (i.e., those from the slaughterhouse and the hospital) at the new facility. In this case, additional pre-treatment may be required to destroy pathogens, prior to introduction of wastewater from these facilities into the treatment plant waste stream.

36. It is not yet known with certainty which of the design options identified will be selected for Port Vila—this is still to be determined, based on further consideration of technical feasibility, social acceptance, land availability, costs, and other factors.

(a) Climate Change Considerations

37. While the final design option for a wastewater system for Port Vila has not yet been decided upon, it is not too early to consider the possible impacts of climate change, since these may have implications for the design of the new system. The most important factors relating to climate change are discussed below.

[8] Other waste streams, such as runoff from piggeries, may be contributing untreated fecal material to surface waters that are ultimately being discharged into coastal receiving waters.

(b) Rainfall

38. Long term records indicate a decline in annual rainfall consistent with El Niño Southern Oscillation (ENSO) increasing periods of drought in Vanuatu. But conversely there is a trend towards more frequent heavy rainfall events and this is also the pattern predicted by climate change models. Such changes could have an impact upon a reticulated sewage collection system, particularly if under certain conditions it causes increases in the amount of water infiltrating into the collection pipes. Therefore, allowance will be made for a 20% greater wet-weather flow which is judged adequate 'climate-proofing' to compensate for this effect.

(c) Temperature

39. An increase in temperature, as predicted by climate change models, could have both positive and negative effects for a wastewater treatment system. Positive effects are related to the fact that with higher temperatures, biological activity of bacteria within the waste stream would speed up. Within the wastewater treatment plant, and within oxidation ponds, more rapid biological action would facilitate quicker breakdown of wastes. On the other hand, higher temperatures would cause more rapid releases of hydrogen sulphide (H_2S) gas within the collector pipes. Pipe gradients that ensure sewage flow velocity between accepted minima and maxima of 0.90 m/s and 3.00 m/s, respectively, would mitigate this effect[9].

(d) Sea Level Rise

40. A total rise in sea level of about half a meter would be expected by the year 2060 at Port Vila. For sanitation infrastructure, two possible impacts of such a rise would need to be considered: (i) potential flooding of wastewater treatment facilities, if they were to be built at a low elevation near the coast, and (ii) the need to design the depth and alignment of an ocean outfall appropriately (if an ocean outfall is included as part of the system). The potential effects of sea level rise will be taken into account in selecting the final design alternative for the sanitation system.

41. One additional factor relating to the design of the wastewater system has interesting implications relating to climate change. High electricity costs for operating the WWTP can be significantly offset by incorporating facilities for on-site electricity generation, based on digestion of methane gas from the waste. Such an option can help to reduce the release of greenhouse gases, thus contributing to the mitigation of climate change. The design proposals being considered incorporate this feature as an integral element.

C. Recommendations

42. The Phase I findings suggest that improvements to the drainage and sanitation infrastructure of Port Vila will, in balance, provide much-needed services within the main population and business centre, and, at the same time, offer significant environmental, social and economic benefits. The maintenance of environmental quality in Port Vila is closely tied to the health and vitality of the tourism industry, one of the municipality's—and nation's—most important economic drivers. Thus it is evident that maintaining environmental quality in the Port Vila area should be of utmost concern to government decision-makers, both at the local and national level.

[9] As discussed above, increasing rainfall could lead to increased infiltration of water into the collector pipes. By itself, this is an adverse effect, but it could dilute sewage and increase flow rates, thus attenuating the formation and accumulation of H_2S gas in the collector system.

43. Several recommendations are presented that are intended to help to ensure that the overall environmental objectives of the project will be met. These are divided into two categories: (i) 'core' targeted recommendations for strengthening environmental compliance and results of the proposed PUVDP infrastructure development activities; and (ii) broader 'supplementary' recommendations, many of which would require additional technical assistance. These latter sets of recommendations are not only germane to the proposed infrastructure development activities, but would also serve to enhance environmental values within Port Vila generally. The recommendations are summarized in Table 1.

1. Targeted Recommendations for Improving Environmental Outcomes

44. **Cost-effective design and implementation**: In order to minimize the adverse environmental and economic impacts of construction of both the drainage and sanitation infrastructure, and to reduce the costs involved, it makes sense to coordinate these activities as much as possible. Further combining the development of these two infrastructure systems with any planned improvements to roadways within Port Vila, could further extend the environmental and cost benefits.

45. **Meeting current service demands**: It is important that the drainage and sanitation systems for Port Vila prioritize the handling of drainage and wastewater streams to benefit the greatest number of user-beneficiaries. However, effluent streams and discharges from other sources, that may entail special requirements, should not be overlooked. One problem that may require special attention relates to large-volume wastewater generators (e.g., hotels, abbatoir, brewery, and hospital). While these users have their own wastewater treatment facilities, their adherence to accepted water quality standards for effluent discharges has not been verified. As a safeguard, it will be desirable to ensure that effluent streams from these facilities can be accommodated for further treatment through the proposed sanitation system as necessary. Disinfection of wastewater, separation of hydrocarbons from water runoff, and other special treatment need to be considered, both for large-volume generators such as the hospital and abattoir, and for certain small-volume generators such as gas filling stations and butcher shops.

46. **Meeting future service demands**: Municipal master planning for Port Vila's infrastructure must take into account the municipality's expanding population and rapid economic growth as projected for the full term of the planning period (15-year planning horizon). Planning well in advance to provide adequate sanitation and drainage infrastructure for peri-urban growth areas, will help to ensure the greatest cost-effectiveness, and will also minimize potential adverse social, economic and environmental impacts and conflicting land uses.

47. **Applying environmental safeguards**: Assuming that the Government approves the PVUDP for financing through the ADB, the Bank's environmental and social safeguards will continue to apply. This will require further detailed assessment and development of a more detailed EMP that will form part of the contractor's obligations for compliance under the official contract documents and work order. In addition, it is recommended that ADB include loan covenants that will obligate the Government to take necessary steps to strengthen their own environmental compliance policies, regulations, and procedures.

48. **Mainstreaming climate change:** The considerations for climate-proofing of sanitation and drainage infrastructure need to be taken into consideration when the detailed engineering design of these systems is initiated.

Table 1 Summary of Environmental and Climate Change Recommendations

	Action	Principal Actor(s)	Expected Benefits
	"CORE" RECOMMENDATIONS		
1	• Coordinate construction activities to develop sanitation and drainage infrastructure (and road improvements) simultaneously	• PWD • Engineering team	• Avoid redundancy • Save on costs • Minimize environmental impacts of construction
2	• Meeting current service demands for general (small-scale) and specialized (large-scale) water users	• PWD • Engineering team • Large scale users (e.g., hospital, resorts, abattoir) • Department of Environment and Conservation	• Environmental protection • Pollution avoidance
3	• Meeting future service demands	• PWD • Department of Lands • Port Vila Municipal Council	• Cost savings • Minimize environmental impacts
4	• Applying environmental safeguards	• Department of Environment and Conservation • ADB • Contractors • PWD	• Avoid, minimize environmental impacts
5	• Mainstreaming climate change	• Engineering team • PWD • Vanuatu Meteorological Service	• Protect infrastructure investments
	"SUPPLEMENTARY" RECOMMENDATIONS		
6	• Integrating climate change into long-term planning	• Donors • PWD • Department of Lands • Port Vila Municipal Council • Vanuatu Meteorological Service	• Protecting human life and property • Promoting resiliency
7	• Economic valuation studies	• Donors • Department of Tourism • Department of Environment and Conservation	• Providing economic rationale for allocating funding to strengthen of environmental protection
8	• Strengthening capacity for environmental monitoring	• Donors • Department of Environment and Conservation • Department of Geology, Mines and Water Resources	• Provide improved capacity for implementing environmental protection measures
9	• Extending monitoring in marine environment	• Donors (GEF) • Department of Fisheries • NGOs	• Enabling more accurate evaluation of climate change and impacts to biodiversity within marine ecosystems

2. Technical Assistance to Complement Infrastructure Improvements

49. **Economic valuation studies**: A detailed and comprehensive economic valuation study of 'environmental goods and services', focusing especially on tourism-related aspects, could help to present a compelling argument for decision-makers to take stronger steps to

protect Port Vila's environment and its natural resources. The underlying logic is that, without necessary expenditures being shouldered by government and/or the private sector for maintaining a clean and healthy environment in Port Vila, the tourism industry, so vital to the local economy (and other related enterprises as well), will be severely affected. Such analytical work could provide decision-makers with the rationale that they need to justify approval of budget allocations to develop programs for improving environmental management, thus providing a foundation for sustainable tourism development.

III. PLANNING

A. Introduction

50. To address the need to estimate the requirement for new infrastructure in an urban or peri urban area the PPTA Team require to know, or to be able to estimate three major pieces of information.

- The first is to clearly define the area under consideration.
- The second is to define the period of time under consideration, the life of the Plan.
- The third is to estimate the likely growth of the area under consideration during the Plan period in terms of population increase and spatial development.

B. Planning Area

51. Following on from the Inception stage further discussions were held with the Zoning Team in the Ministry of Lands during August and September 2010. During these discussions the Zoning Team requested that the PPTA Team re-consider the Planning Area to be covered by the Study, in order to be more fully consistent with the area currently under consideration by the Zoning Team.

52. Essentially this involved extending the area, originally proposed by the PPTA Team, to the North West to include areas adjacent to the newly reconstructed Efate Ring Road, which is an area likely to attract future growth and development due to the presence of improved infrastructure.

53. The second recommended expansion was to include the area to the east of Emten Lagoon to include the newly emerging settlement known as Teoumaville. This large area already has some new sub-divisions within it, which have been provided with basic infrastructure (roads, electricity, water) and where occupation has commenced. In the opinion of the Zoning Team this area which also borders on the recently rehabilitated Efate Ring Road, is most likely to provide a focus for the future expansion of Port Vila over the Planning Period under consideration (2010-2025).

54. A slight reduction in the Planning Area will be noted with the removal of part of the area known as Erangorango to the north of Bauerfield Airport.

55. The main concern of the Zoning Team is to define those Peri-Urban areas, with the greatest likelihood of rapid growth and bring these under development control as soon as possible. This would be achieved by boundary revision and the promulgation of new legislation introducing stricter development controls.

56. The PPTA Team have agreed to adopt the modified Planning Area as recommended by the Zoning Team. Figure 1 shows the original (as per Inception Report) and the revised Planning Area.

C. Population and expansion

57. Two of the dynamics of urban planning and urban growth, are of vital importance to preparing an appropriate Master Plan for sanitation and drainage in Port Vila.

58. The first is to estimate the number of people residing within the planning area at present and into the future. This is because in the context of sanitation, the volume of wastewater produced, which has to be conveyed, treated and disposed of is entirely dependent upon the number of water consumers generating that wastewater.

59. The second, particularly important in the context of storm drainage, is the spatial area to become occupied during the period of the Plan. Storm drainage is not dependent primarily on people but on nature, i.e. rainfall. If a particular catchment area is unoccupied, drainage can be allowed to take its own natural course, without inconveniencing anyone. It is only when an area of land becomes occupied that drainage is required, to protect people and their property from the elements. Therefore having made projections of overall population growth, and understanding that, that increasing population will need to settle in new development areas the planner needs to make, hopefully informed projections of which areas are most likely to be developed.

60. Each new catchment which comes under development, regardless of the pace of that development and the number of persons residing there, will require as a minimum the identification of the natural point at which storm water will exit the area, and the sizing of an appropriate outlet structure to enable that exit. Further networks upstream can be developed in line with the pace of settlement of the area.

61. These issues are addressed by the considerations below.

D. Census Data

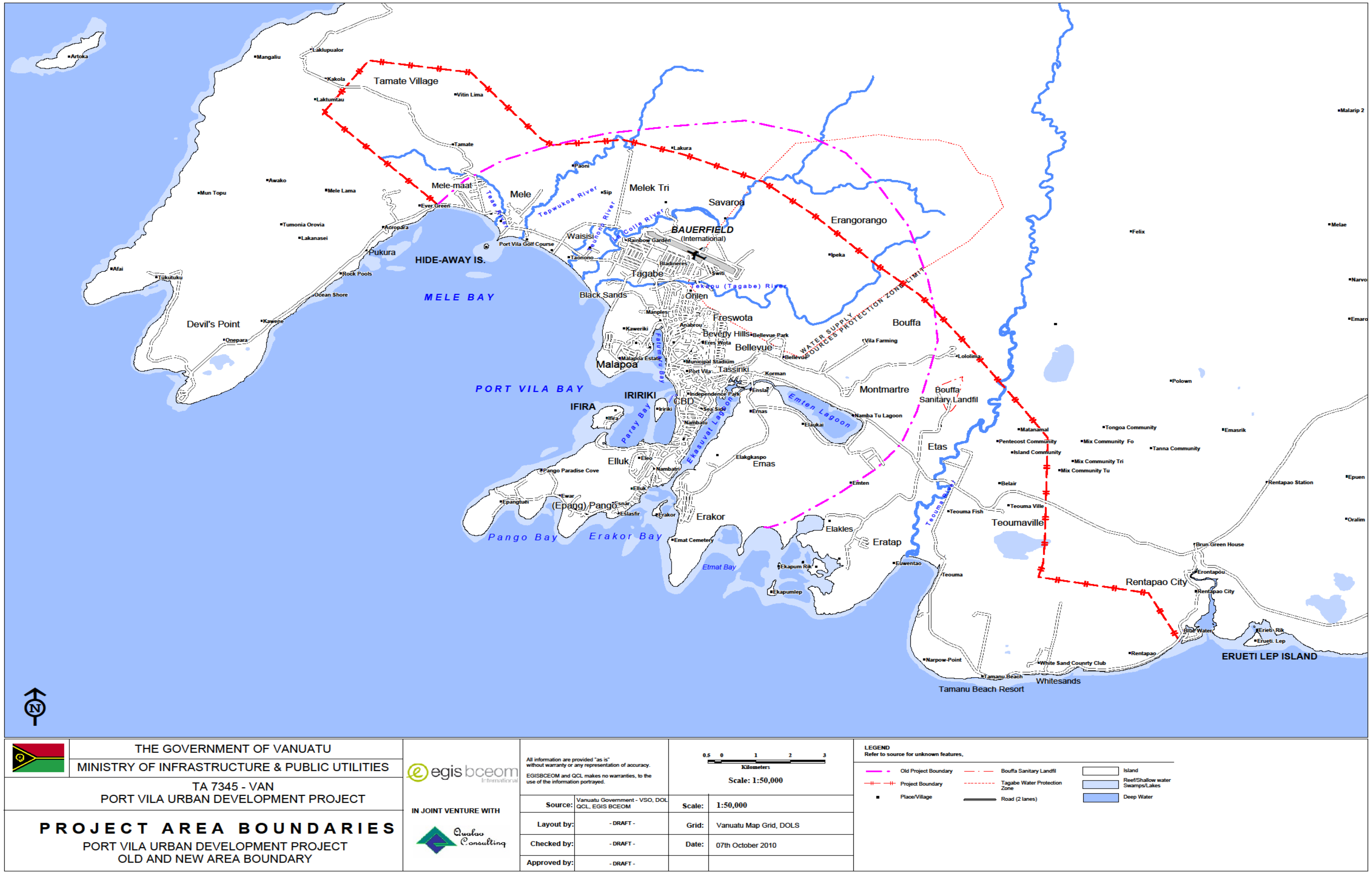
62. During August 2010 partial results of the 2009 Population and Housing Survey were made available by the Vanuatu National Statistics Office. These timely results have been essential in enabling the PPTA Team to make better informed projections of future growth from the perspectives of a) the likely overall rate of growth, and b) those areas likely to become the focus of future growth.

63. The Census results indicate an overall growth in the population of Port Vila of some 4.1% per annum, between 1999 and 2009. During the same period in Shefa Province (main island of Efate excluding the outlying islands) the population grew at 4.5%.

64. Using the information available from the census data, the PPTA Team's first task was to determine the existing population residing within the selected Planning Area. Two pieces of information were essential to this process, as follows:

1. the total population of those Enumeration Areas (EAs) which were 100% inside the boundary of the Planning Area, plus

Figure 1 - Original and revised Planning Areas



2. a proportion of the population of those EAs not wholly lying within the Planning Area. This proportion was taken to be equal, in percentage terms, to the area of the EA lying within the Planning Area, i.e. if 50% of the EA was within the Planning Area, 50% of it's population were deemed to be residing inside the Planning Area.

65. By this means the PPTA Team estimate that at the time of the census in 2009 there were 57,962 persons residing within the extended Planning Area. This compares with the population within the Municipal Boundary of Port Vila itself which the census reveals to be 44,040.

E. Population Projections

66. To prepare a time bound Master Plan particularly for sanitation, which is sensitive to the number of users to be served; the PPTA Team require not only the existing population, but also to estimate the future population growth or regression within the Master Plan time-frame. Therefore from the base 2009 figure of 57,962, projections have been made for the likely population in the years 2015, 2020 and 2025, the planning horizons agreed for the Project.

67. From studying the Census results it is clear that the whole of the Greater Port Vila area has not grown at the same rate over the inter-censal period between 1999 and 2009. Some areas have increased in population terms, very quickly, at above the average rate of growth, but others have stagnated in population growth terms or in a number of cases population has declined.

68. The reasons behind this are complex. Greater Port Vila has a number of different land-uses within it. These can be summarised as follows:

- it is the capital city of Vanuatu, the seat of Government and the main focus for Government Ministries and administrative headquarters;
- it is also the major commercial centre for the whole of Vanuatu;
- it contains relatively large residential areas; and
- It is also a focus for tourism and a holiday resort.

69. These differing land uses result in differing growth characteristics, the first three tending to promote densification as populations increase, the fourth, however, having the opposite effect where sea front land, previously occupied by indigenous inhabitants is converted to tourist accommodation with very few permanent residents.

70. The above explains, in part, the discrepancies in growth rates between the various EAs. A further explanation is that some EAs become 'saturated' and are practically unable to absorb further population growth. In this case new populations have to seek dwelling places in less densely populated areas.

71. To understand the growth and spatial dynamics of a City, in the abbreviated time frame of a PPTA, requires intense local knowledge of the historical development of the city and therefore its likely dynamics in the future. Fortunately the PPTA Team has the services within it of ten, well and diversely qualified Ni-Vanuatu professionals all of whom are long-term residents of Port Vila and are fully familiar with the history of its spatial growth. By tapping into this resource the PPTA Team has been able to rapidly assimilate the historical growth and

from this identify and to some extent, quantify the potential future growth of the city in terms of magnitude and direction.

72. From discussion the PPTA Team were able to define as follows:

1. Those EAs most likely to grow in population terms at above the average rate.
2. Those EAs which were saturated or almost saturated and were likely to grow at below the average rate.
3. All other EAs were assumed to grow at the average rate.

73. A consensus was reached, shown in Table 2 where:

- EAs expected to grow at higher than the average rate are shaded brown;
- EAs expected to grow at below the average rate are shaded green; and
- EAs unshaded are expected to grow at the average rate.

74. It was further agreed that a conservative figure of 10% was a fair estimate at how much above or below the average rate the estimated growth rate might be.

75. In addition where an EA does not lie wholly within the Planning Area, the percentage of that EA observed to lie within the Planning Area (and therefore the percentage of its population residing within the Planning Area) is shown in the second column.

76. From the above exercise the PPTA Team estimate that the population within the Planning Area at the end of the next three five-year periods will be:

- Year 2015: 72,582
- Year 2020: 89,725
- Year 2025: 108,585

77. From a spatial planning point of view, almost more important than the increase in population is the increase in the number of households created. This increase in households gives us an indication of the amount of extra land required to house the increasing population, as each new household, or family is deemed to require a new plot of land on which to establish a home.

78. An attempt has been made to assess this requirement for additional development land. This estimate is based on the assumption that each new household or family unit will occupy an area of 500 m^2. This figure has been arrived at after discussions with experienced Ni-Vanuatu technicians and sociologists and is only a best estimate, but does give some dimension to the area of new residential land which may be required over the Planning Period of PVUDP.

79. The 2009 census report informs us that between 1999 and 2009 the average household size fell from 5.1 persons per household to 4.8 persons per household. So for the purpose of projection we take this to be a prediction of the average household size over the complete PVUDP time horizon 2010 to 2025.

Table 2 – Population projections by enumeration area

		Actual Population			Projected Population		
EA No	EA Name	Pop19'89	Pop 1999	Pop 2009	Pop 2015	Pop 2020	Pop 2025
708	Blue Water Resort 708 (??%)	n/a	n/a	n/a	n/a	n/a	n/a
710	Devil's Point 710 (20%)	82	77	15	19	24	29
711	Hideaway Island 711	566	1176	806	1024	1265	1531
712	Mele Bay 712 (70%)	626	456	1441	1830	2262	2738
713	Mele 713	491	676	763	969	1198	1450
714	Melektree 714 (15%)	42	38	106	122	149	181
715	Chris Soles 715 (90%)	617	1118	3420	4778	5906	7148
716	Erakor 716	616	1128	2413	3371	4167	5043
717	Erakor 717	796	985	1892	2403	2970	3595
718	Bellevue 718 (50%)	200	130	698	975	1205	1459
719	Pango 719	452	992	1806	2064	2552	3088
720	Worauloa 720	58	0	0	0	0	0
721	Pango 721	306	417	440	559	691	836
722	Pango 722	0	6	138	175	217	262
801	Bauerfield 801	841	3239	6609	7554	9339	11301
802	Tagabe Central 802	411	378	460	584	722	874
803	Tagabe north 803	242	598	881	1119	1383	1674
804	Agathis East 804	156	777	825	1048	1295	1568
805	Tagabe South 805	277	356	287	364	451	545
806	Malapoa college 806	573	495	709	900	1113	1347
807	Agathis West 807	675	1012	1243	1579	1952	2362
808	Tebakor pressing 808	305	374	204	259	320	388
809	Namburu north 809	888	889	1511	1919	2372	2871
810	Namburu south 810	357	227	555	634	784	949
811	Melcofe 811	90	12	77	98	121	146
812	Stade 812	442	587	637	809	1000	1210
813	Georges Pompidou 813	399	452	604	767	948	1148
814	Bouganville north 814	483	234	425	540	667	808
815	Post Office 815	44	17	19	24	30	36
816	Bouganville south 816	94	86	43	55	68	82
817	Court house 817	326	266	347	441	545	659
818	Burns Philp 818	121	134	102	130	160	194
819	Independence park 819	329	484	285	362	447	542
820	Vila East 820	397	185	539	616	762	922
821	Ex British prison 821	384	440	155	197	243	295
822	Vila central hospital 822	461	337	505	641	793	960
823	Tongoa/Futuna 823	673	903	713	906	1119	1355
824	Seaside Paama 824	572	608	655	832	1028	1245
825	Colardeau 825	348	158	282	358	443	536
826	Nambatu West 826	368	165	359	410	507	614
827	Nambatu East 827	597	728	604	767	948	1148
828	Piblic Works 828	363	496	287	364	451	545
829	Nambatri West 829	402	706	359	456	564	682
830	Honda farm 830	405	413	512	650	804	973
831	Nambatri East 831	489	660	420	533	659	798
832	Hotel Le Lagon 832	182	49	69	88	108	131
835	Blacksands 835	2320	4818	7111	9031	11164	13511
836	Seven star 836	353	571	1010	1283	1586	1919
837	Ohlen 837	258	936	1180	1499	1853	2242
838	Namburu central (Simbolo) 838	613	1659	1464	1859	2298	2782
839	Jack fong 839	422	319	292	371	458	555
840	Freswota 840	831	2715	6475	7401	9149	11072
841	USP 841	355	424	864	988	1221	1477
842	Le meridien 842	122	239	229	291	360	435
843	Teouma Road 843	406	646	2805	3919	4844	5862
844	Pango Road 844	233	335	541	687	849	1028
845	Nambatri North 845	379	219	427	542	670	811
846	Malapoa Point 846	106	30	136	155	192	233
847	Malapoa Estate 847	219	351	208	264	327	395
				57962	72582	89725	108585

No shading	Indicates areas likely to grow over the Planning Period at the "flat" rate of 4.1% p.a.
Ochre shading	Indicates areas where higher growth is expected thus 10% added to the 5 year totals
Green shading	Indicates areas where expected growth will be lower than average, 10% is deducted from the 5 yearly totals

80. Using the above-mentioned household size and from the figures produced by the PPTA Team's population projections, the number of new households appearing during each of the five year periods will be as follows:

- 2009-2015: increase in population 14,620, equivalent to 3,046 new households.
- 2016-2020: increase in population 17,143, equivalent to 3,571 new households.
- 2021-2025: increase in population 18,860, equivalent to 3,929 new households.

81. Therefore over the 15 year period some 10,546 new households would require accommodation. In turn using the average of 500 m^2 per new household a total area of 5,273,000 m^2 for new development. This would represent the area of the building plots alone. If we make allowance for the requirement for common services such as roads, footpaths, parking areas, shops, churches, schools and the like the total requirement for new development lad would be 30-50% more than this, therefore requiring:

- 5,273,000 x 1.5 = 7,909,500 m^2

82. This equates to a single piece of land almost 3 kilometres by 3 kilometres, which is equivalent to about half the extent of the present Central Business District.

IV. DRAINAGE

A. Introduction

83. Detailed description of the Drainage studies is presented in Volume 2, Drainage Report. The remainder of this section is a condensed version of Volume 2 which draws attention to the most import findings of the studies.

1. Phase I Activities

84. During the Inception Stage a rapid review and analysis was completed of the current situation for drainage. The focus was on identifying the key issues and constraints to be addressed by the Master Plan and Investment Project. The Review included:

- Assessment of the adequacy, condition and capacity of the drainage systems and their operation and maintenance.
- Existing policies, legislation and regulations governing the drainage sector, including the Building Code and an assessment of the scope for amendments to ensure effective, more cost-efficient and sustainable delivery of drainage services for Port Vila.
- Consideration of the impacts of climate variability and change on drainage, and the risks this could pose to the drainage master plan as well as the proposed investment project.

85. The focus then moved to appropriate solutions for drainage and to selecting recommended design criteria and methods appropriate to the Investment Project. Rainfall data was obtained and analysed to provide a robust understanding of the historical characteristics, variations and trends in rainfall. This was used in combination with data on sea level rise to determine the approach for climate proofing necessary to achieve sustainable drainage solutions.

86. Port Vila is a hilly town always close to the sea so there are very many small drainage catchments draining directly to the Bay and Lagoons. In addition there are a number of large sinkholes characteristic of the karstic limestone geology which drain to the groundwater table. Each catchment has different issues and different solutions. The Master Plan for drainage has identified the individual catchments and the solutions for each.

87. For the investment project a long-list of high-priority projects has been identified, including approximate cost estimates. The long-list includes subprojects for the 'hot-spot' areas with flooding problems reported at the Inception Stage. Projects have also been chosen because of the importance of the location and the complexity of the problems, the rationale being that the investment project will be a well resourced opportunity to complete the most difficult and expensive projects

2. Solutions

88. Observations and calculations demonstrate that the actual percentage runoff for most of the town is low. The exceptions are the high density development in the Central Business District (CBD) and the steep hill slopes. Across the town most problems occur when storm water gets onto the roads. It then flows down the slope until it comes to an outfall or spreads and infiltrates on adjacent land. In low areas where there is nowhere else for water to go it collects and becomes a flooding problem. The situation will become worse with more development. First as vacant plots are built upon there will be less land along the roads where water can soak away. Secondly, the fraction of runoff will increase.

89. Clearly positive drainage provision is required. This will not require large size or extensive drainage networks, although there will be a number of site specific difficulties and no solution will be maintenance free. Because the town can be served by a number of relatively small and independent drainage networks it is anticipated that a well considered and maintained system will be sufficient and that there will be no additional cost in meeting climate proofing and sustainability requirements.

90. Solutions can also employ Sustainable Drainage Systems (SUDS) techniques. These reduce the peak flow rate and total volume of runoff by promoting infiltration to groundwater, this reduces capital cost. These techniques also reduce pollution by promoting filtration and biological action to improve the water quality at drainage outfalls, this helps protect the environment. Traditional methods of road sweeping, sediment capture and oil separation will also improve the water quality of surface water discharge, these make the systems maintainable and also helps protect the environment.

91. The requirement for better policies and regulations governing the drainage sector has been addressed by the drafting of a Code of Practice for Surface Water Drainage. This covers public and private sector requirements for drainage infrastructure between the point where roof drainage meets the ground and the drainage outfall at the point of discharge to a waterbody or groundwater.

B. Design

1. Design Methods

92. Consideration has been given to the design methods to be employed for the Port Vila urban area. It has been concluded that the Rational Method is suitable and appropriate for all developed and developing areas which require drainage. Catchments do not exceed 5 km^2 and outfall pipes will not generally be larger than 600 mm diameter or equivalent which are the upper limits generally applied to the Rational Method for urban storm water drainage design.

Importantly, adoption of the Rational Method avoids the need for special computer software and will be easy to use for both public and private sector engineers undertaking drainage design in the future. It is noted that the Rational Method is not suitable for rural catchments larger than 1 km^2.

93. Consideration was given to various published Codes of Practice, in particular the Queensland Urban Drainage Manual which represents the 'state of the art' guide within the region. But such guides are targeted at much larger and more complex drainage areas and require procedures beyond what is necessary for Port Vila. Instead a basic set of guidelines has been written for application of the Rational Method incorporating some simple tables and methods to determine parameters taken from the Queensland Manual which are in turn based on recommendations in the *Australian Rainfall and Runoff* series of publications, and are therefore well respected and tested methods.

94. The Rational Method has been used for preliminary calculations for the long-list of high-priority projects. Spreadsheets are used for the calculations. The calculations are informative on several issues.

- The small runoff, particularly at the head of the systems in residential districts means that for the design discharge pipe drains do not run full. With the Rational Method it is usual to assume that pipes run full because it simplifies the calculations. But for Port Vila it is necessary to calculate the part full flow to ensure self cleansing velocity can be achieved. The spreadsheet automatically checks and shows the adjustment.

- Achieving constant or increasing self cleansing velocities may require some deep drain excavation, which is potentially expensive and slow if the excavation is into unweathered Limestone. The excavation can be reduced by using shallow open channel type drains at the head of the system, or better still grass swales or infiltration trenches if the land slope is not too steep.

- Even so, self cleaning velocities cannot be achieved in the head of some systems and there will be a need for an enhanced maintenance regime and in these locations open channels can be favoured over pipes.

- The grid pattern of streets in hilly districts (e.g. CBD) produces situations where breaks in drainage slope are unavoidable, the designs will mitigate this as far as is possible and include appropriate provision for maintenance such as catchpits for removal of silt.

2. Policies, Regulations and Codes of Practice

95. There are currently no effective policies, regulations or codes of practice which adequately cover drainage. The National Building Code, as the title indicates, only deals with buildings and their immediate environs. The only drainage issue addressed is roof drain, the sizing of gutters and downpipes but not the disposal of the water.

96. It is customary to have separate codes of practice for the infrastructure component of drainage. This requirement has been addressed by drafting a Code of Practice for Surface Water Drainage. This is for use by the public and private sectors. It sets out the design criteria and methods which will be used for development of the Investment Project. It has been tested for technical content during the outline design of the high-priority projects in the long-list.

3. Standards of Service

97. Drainage systems will be designed to the standards of service consistent with international practice. Therefore most drainage will be designed for a 1 in 2 years return period rainfall. The exception will be the CBD and high density residential development with more than 20 dwellings per hectare where design will be for the 1 in 10 year return period rainfall. Further explanation is provided at section IIC and by Table 1 of the Phase I Drainage Report.

C. Rainfall and Climate

1. Rainfall data and analyses

98. Daily (24 hour) rain gauge data has been provided by the Department of Meteorology for two stations:

- Port Vila for the period 1975 to June 2010, gauge elevation about 23 m MSL at the Vanuatu Meteorological Service establishment, Nambatu.
- Bauerfield (airport) for the period 1985 to May 2010, gauge elevation about 19 m MSL near the airport buildings.

99. There are daily rain gauge records from 1953 for Port Vila and 1972 for Bauerfield, but at this time only monthly summaries are available and the daily data has not been traced.

100. The average annual rainfall for Port Vila since 1953 is 2,140 mm, and for Bauerfield since 1972 it is 2,226 mm. Overall Bauerfield tends to be wetter than Port Vila, probably influenced by the proximity of the higher ground inland. The records also indicate that the rainfall at each location can be quite different on the same day. This is normal for the tropics where convective thunderstorms have a small footprint and can track through an area such that whilst one location may be drenched a short distance away it can remain dry. Another characteristic of the tropics is that rainfall is extremely variable year on year; at Port Vila it ranges between 1,091 and 3,579 mm. Annual variations show correlation with the El Niño Southern Oscillation (ENSO); for Vanuatu El Niño years are drier and La Niña years are wetter. However, there is no correlation between high 24-hour rainfalls and the ENSO. This is because high daily rainfalls mostly arise from seasonal convective thunderstorms independent of the ENSO, albeit that some of the heavy rainfall events on record will be associated with tropical cyclones for which the frequency is affected by the ENSO.

101. The relatively long daily rainfall records for Port Vila and Bauerfield have provided a good basis for generation of synthetic rainfall intensity-duration-frequency (IDF) curves. The method is explained at section IIIA of Volume 2 Drainage Report. The derived curves are typical for the prevailing climatic type, the Port Vila 1-hour 1 in 10 year rainfall intensity is 76 mm/h, for Bauerfield it is 103 mm/h. For design purposes the Bauerfield curves will be used for catchments north of the Municipal Stadium, the Port Vila curves for catchments to the south. The derived tables and curves are incorporated into the Code of Practice for Surface Water Drainage.

2. Climate Proofing

102. For drainage it is possible to avoid potential damage costs attributable to climate change, and to do this in a cost-effective manner, by consideration of climate proofing at the design stage. The concern for drainage is that climate change will cause the design storm to occur with increasing frequency in the future.

103. Trial calculations have demonstrated that for Port Vila the low runoff and adopted design criteria for a minimum self cleansing velocity of 1.5 m/s result in drainage systems where the drains operate satisfactorily but below capacity for the design storm. This means that the systems are inherently over-designed for capacity and have additional capacity for any increase in the frequency of the design storm due to climate change. This will be considered during the design by sizing the drains for the required return period based on the current statistically derived design storm, thereby satisfying operational criteria for the existing rainfall variability. The design will then be checked for the same return period rainfall projected for 2060. Should the drainage flow then exceed the capacity of any part of the system consideration will be given whether it is necessary to change the design. This procedure has been included in the Code of Practice for Surface Water Drainage together with the corresponding IDF curves derived for 2060.

104. It should be noted that the consequences of a reduction rather than an increase in the frequency of the design storm would be an increase in the requirement for flushing and cleaning drains.

105. Overall the provision of improved drainage to alleviate problems and flooding which occur with the existing climate can be regarded as a ‘no regrets’ initiative whether or not there are major changes to the climate in the future.

D. Detailed Drainage Master Plan

1. Drainage Strategy

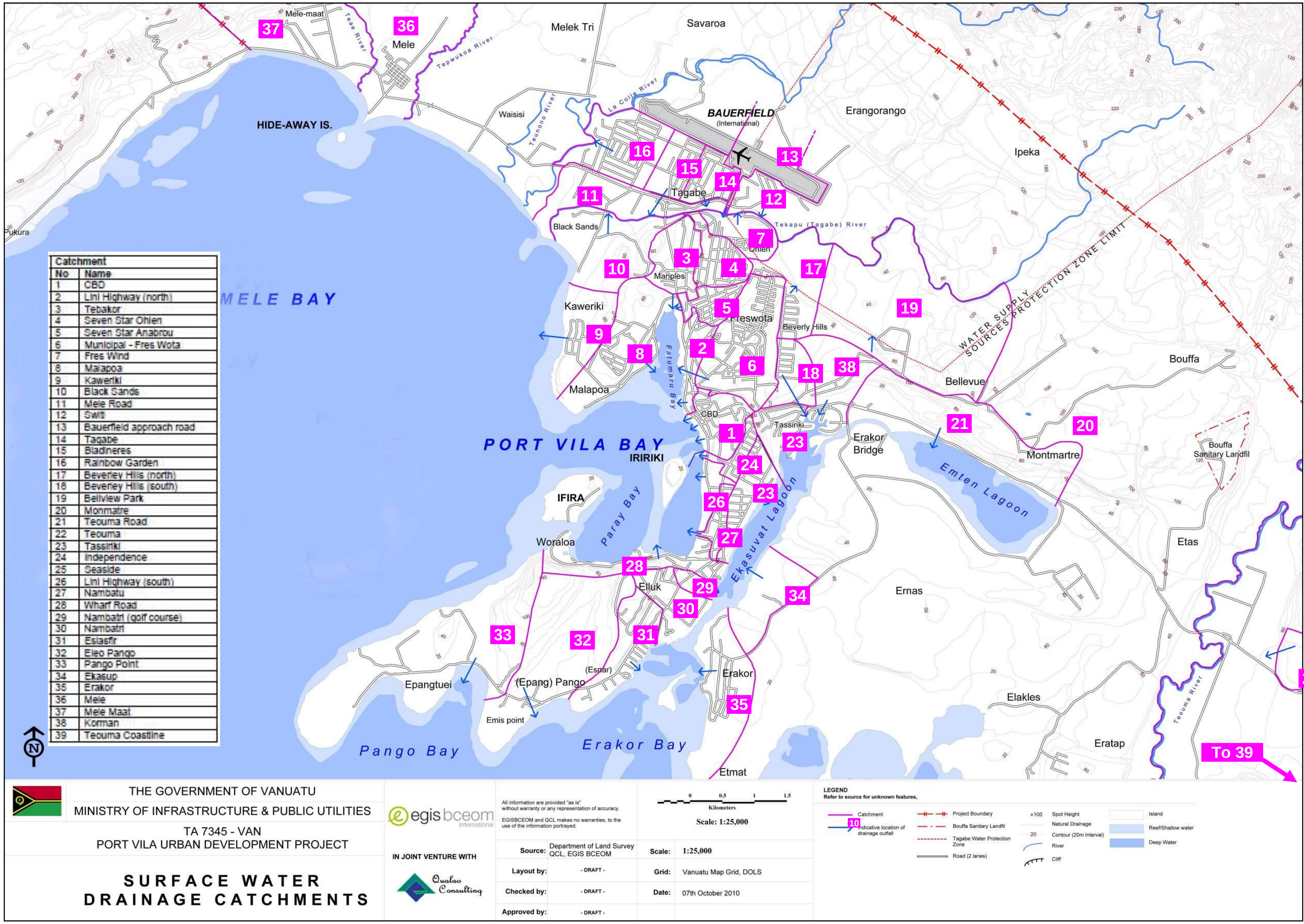
106. The Drainage Strategy considers drainage solutions for all developed or projected developed areas of Port Vila, within the period of the Master Plan.. It allows for new development as well as the filling of existing growth areas. The Master Plan will allow the Drainage Strategy to be implemented selectively and over time.

107. For considerations of drainage Port Vila is divided into topographic catchments. This is logical because of the hilly terrain and proximity of the bays, lagoons and watercourses. This is also convenient because works packages can be implemented on a catchment basis according to priority, independent from neighbouring catchments and according to availability of funds. Figure 2 shows the drainage catchments, general location of outfalls and a tabulation of the catchments. The strategy is presented at Annex 1: Summary of master plan drainage strategy by catchment, this lists the catchments and gives summary information about known drainage problems and the recommended drainage solutions.

2. Demand Forecasts

108. Demand forecasts are required for the next 5, 10 and 15 years. Surface water drainage is somewhat different to other services such as sanitation because surface water drainage occurs in a catchment area without human occupation whereas sanitation only becomes necessary when people move into the catchment. There is also a difference between a completely natural catchment and one affected by man’s activities, e.g. forest cleared for pasture.

Figure 2: Surface water drainage catchments



109. In most situations the natural drainage will cope with a low density of human settlement without apparent impact. In practical terms built drainage can be considered to become necessary when an area is sub-divided and roads are built. The requirement will increase as plots are built upon, and further increase if high density development occurs, or if warehouses, retail space and parking lots are added. The extent and nature of the drainage works required is specific to the natural drainage catchment and not necessarily directly linked to population in the way it is for sanitation.

110. Accepted best practice is to provide, or at least make provision for, the basic drainage system at the time of sub-division. Historically, this has not been the case in Port Vila and sub-divisions develop without a drainage plan. Inevitably problems arise such as a building on one plot causes a neighbouring plot to flood or water stands at low spots on unmade roads. In terms of demand forecasts this means drainage within Port Vila is already in a 'catch-up' situation with a legacy of unsatisfied demand for drainage. This is the baseline situation.

111. Growth forecasts based upon the enumeration areas (EA) of the 2009 census indicate that growth will be almost entirely within existing sub-divisions. This is because the newest sub-divisions presently have a large number of un-built plots. Growth will also occur within informal housing areas by expansion or an increasing density of occupation within the defined EA. The table at Annex 2: Demand forecasts for drainage, indicates how EA projected growth correlates by drainage catchment and where there is an immediate or future requirement for drainage.

112. Any drainage that is built must be large enough to accommodate the discharge for the fully developed catchment irrespective of whether plots remain empty. This does not preclude the phased construction of drainage within a catchment but the phasing must follow a logical sequence:

E. Problems and Constraints

1. Impact of flooding

113. The flooding in Port Vila is localised and occurs in locations where there is ineffective drainage or no positive drainage at all. There are no locations with significant or frequent fluvial (river) or coastal flooding problems. This localised flooding is not directly life threatening. Although much of the time flooding could be considered mostly an inconvenience it nevertheless has numerous and potentially significant impacts including:

- direct damage to infrastructure and property;
- disruption of road traffic;
- obstruction of access to residential property and businesses;
- safety risks for vehicles and pedestrians;
- amenity risk leaving the flooded areas polluted and covered with sediments;
- health risk from dirty water, pools where mosquitoes can breed and wind blown dust when sediment has dried out; and
- financial and economic impacts on business and commerce.

114. The existing poorly developed urban drainage has another visible impact which is erosion of road shoulders and sealed pavement edges (fretting).

2. Origin of sediments

115. Sediments in the existing drains originate mainly from within the road reserve. In many places the fretting of the pavement and erosion of the shoulder is a significant source of sediment. But general road use, dirt falling from vehicles, etc is also everywhere contributing to the sediments.

116. In contrast widespread soil erosion of the landscape is not a significant problem. This is because the climates favours good vegetation cover to bind the soils and within the municipal area the steepest Limestone hill slopes are generally stable and resistant to erosion.

3. Constraints

117. There are several key constraints to drainage:

- Lack of effective planning and regulation of private and public sector works which require drainage.
- No Code of Practice for Surface Water Drainage.
- The receiving surface waterbodies which are the bays and lagoons are environmentally sensitive and already under stress and degraded by the proximity of the urban area and port. Care must be exercised that changes to surface water do not cause further decline.
- There are a number of large sinkholes which have no outfall and runoff which flows to the low-point created by the sinkhole will stay there until it infiltrates or evaporates.
- There is little or no maintenance of existing drainage systems and interventions are reactive not planned.

4. Positives

118. There are some strong positive cultural and physical factors to the benefit of surface water drainage in Port Vila:

- The majority of the houses collect roof drainage water for drinking because they prefer the tastes to the treated water supply.
- Most houses have gardens so that rain can infiltrate the ground where it falls.
- The town overlies very permeable Limestone with a high natural infiltration rate and therefore the capacity to absorb all but the heaviest and longest rainfalls.
- The urban area is hilly; this works against infiltration but causes water to runoff down the slope. This is to advantage when the flow is towards the coast, but it is a problem when flow is towards a sinkhole.
- There are few really low-lying areas or wetlands where urban population might encroach.

F. Sustainable Drainage Systems (SUDS)

119. Traditional drainage systems are designed to quickly transport surface water from the drainage area to the outfall. This has disadvantages in that it concentrates runoff and increases flow rate over that of the natural drainage regime.

120. Also runoff from the urban or built environment can be highly polluting. The runoff may carry a mixture of polluting substances, such as toxic metals, pesticides, oils and hydrocarbons, sediments and oxygen-depleting substances which can lead to poor water quality and ecological damage in the receiving waterbodies.

121. The concept of more sustainable management of this run-off can be promoted by installing 'softer' engineering systems, such as grassed swales and wetlands, as a means of controlling the rate of flow and treating or absorbing pollutants. These techniques, known collective as Sustainable Drainage Systems (SUDS), can make a significant contribution to the reduction of pollution and flood risks.

G. Solutions for Drainage Problems and Constraints

122. Considering the constraints but building on the positives the solutions considered have broadly followed SUDS principals.

- The foundation of the solutions is a 'toolkit' of guidelines and generic measures to address the various problems and constraints which differ between drainage catchment. These are provided by the proposed Code of Practice for Surface Water Drainage (Phase I Drainage Report, Appendix 3). This is intended for use on all future public and private sector drainage works. The Code of Practice documents the criteria to be applied to the design of solutions.
- SUDS methods to control diffuse pollution at source e.g. grass swales, infiltration drains, soakaways, and possibly artificial wet treatment ponds. With these techniques pollution is reduced by capture of sediment, biological action of the plants and the soil, and promotion of infiltration. Also runoff is reduced.
- Traditional methods are used to manage residual sediments and pollution, these include:
    - Routine road sweeping to remove the sediment before it enters the drains.
    - Gully pots with sediment traps at drain inlets and catchpits to trap sediments further down the system, particularly at breaks of slope.
    - Oil separators at recognised high risk locations e.g. filling stations, vehicle washes, workshops, delivery areas and car parks.
- Gravity drainage is favoured over pumped drainage because of lower operation and maintenance requirements.
- At sinkholes positive drainage is favoured over infiltration methods because of uncertainty for sustainability of this method of disposal for large catchments (it is assumed SUDS principles are maintained in the catchment).

123. These solutions are summarised below:

Problem	Solution
No practice standards for drainage and outside the scope of National Building Code.	• Introduce Code of Practice for Surface Water Drainage incorporating SUDS.
Poorly engineered roads frequently without kerbs or channels to control and convey runoff to outfall.	• Construct roads to standard cross-sections choosing from a suite of cross-sections to suit circumstances. • Maximise use of SUDS for road drainage.
Ineffective and poorly located road gullies and drainage turnouts, too few in numbers with significant surface water flow on roads and places with standing water.	• In urban situations with sidewalks provide standard gullies with a silt sump. • In areas without sidewalks or kerbs use roadside swales, ditches or channels with inlets at sags or other locations with potential for ponding on road.
Sediment washed onto and standing on the road: which is unsightly and a health hazard particularly from wind blown dust; washes into drains and causes blockage; significant factor in point pollution at outfall.	• Maximise use of SUDS to reduce quantities of sediment washed onto road. • Regular street cleaning with vacuum street sweeper.
Sediment washed into drains (street cleaning significantly reduces but does not eliminate the problem of silt).	• Road gully pots with sump to trap silt, regular programme of clearing sumps with vacuum tanker. • Catchpit chambers, particularly at locations prone to settlement of sediment e.g. break of slope; regularly cleared with vacuum tanker.
Hydrocarbon pollution at filling stations, car washes, workshops, parking lots, warehouses and delivery bays, etc.	• Introduce regulations requiring full retention and bypass type oil separators.
Sinkholes which are large plan area depressions caused by solution of carbonate rock. These form basins within topographic valleys without a path to convey runoff towards a watercourse or the sea. The floor of a sinkhole generally has impeded infiltration due to cumulated sediment. Increasing runoff from urbanisation collects and ponds in sinkholes and spreads to flood roads and property.	• Piped gravity drainage (but requires deep trenches or small bore pipe tunnels in some locations); or • Pumped drainage (with ongoing O&M requirement); or • Designed soakaways in combination with SUDS in catchment, (but probably not sustainable in medium to long-term for larger catchments).

Problem	Solution
Blockage of existing drainage, prevalence to blockage for reasons above but neither is the problem currently addressed because there are no records of drains or active programme of inspection and maintenance.	• Locate drains and clear where feasible (Rapid Works programme). • Instigate regular programme of inspection and maintenance. • Programme of improvement or replacement of drains to improve performance for water volume and water quality and facilitate maintenance.

124. It should be noted that in circumstances where drainage is installed, particularly where road gullies are required, it will be necessary to ensure that roads are of adequate standard. Where roads are not of adequate standard roadworks will be required over and above that to reinstate consequent on drainage works.

Implementation scenario

Do Nothing	Baseline case, carry out no maintenance and make no improvements: will result is progressively deteriorating conditions for surface water drainage, nuisance flooding, small flood damage and erosion of roads, increasing pollution of waterbodies.
Do minimum	Carry out regular inspection and maintenance of existing drainage systems. Implement Code of Practice for Surface Water Drainage to be a statutory requirement for all new developments.
Drainage only in high-priority catchments	As 'do minimum' but improve or provide new drainage systems in catchments with a recent history of flooding problems.
Drainage of all catchments	As 'drainage only in high priority catchments' but with programme of works and street adoption for all urban and peri-urban catchments.

H. Long-List High-Priority Sub-Projects

125. During Phase I it is required to identify high-priority 'climate-proofed' drainage subprojects for detailed study during Phase II of the PPTA, including the identification of adaptation measures intended to reduce disaster risks and vulnerability to climate variability.

1. Climate Proofing

126. The Phase I studies have identified two issues for drainage that require climate proofing:

- the concern for drainage systems is that climate change will cause more frequent occurrence of the 'design storm' and that in the future the systems will have insufficient capacity; and
- sea level rise may cause tide-locking by submergence of outfalls.

The second of these concerns also affects planned elevation levels for infrastructure and buildings along the shore.

127. The concern for capacity is easily addressed in Port Vila provided that drainage systems are designed to international standard hydraulic criteria. If this is done the drains will inherently have additional capacity for any increase in the frequency of the design storm due to climate change. There are several reasons for this including the small size of the catchment (the largest single catchment is only 2.3 km2), the permeable sub-strata and capture of roof drainage, achieving self cleansing velocities in drains, all of which combine to reduce flow in the drains.

128. The design procedure in the Code of Practice for Surface Water Drainage specifically addresses climate proofing as follows:

- Design for the required return period based on the current statistically derived design storm, thereby satisfying operational criteria for the existing situation (e.g. self cleansing velocity is achieved).
- The design is then checked for the estimated design storm of the same return period predicted in 2060. Should the drainage flow then exceed the capacity of any part of the system consideration is given to whether it is necessary to change the design.

129. It should be noted that the consequences of a reduction rather than an increase in the frequency of the design storm would be an increase in the requirement for flushing and cleaning drains.

130. Overall the provision of improved drainage to alleviate problems and flooding which occur with the existing climate variation can be regarded as a 'no regrets' initiative whether or not there are major long-term changes to the climate in the future.

131. Sea level rise is addressed in the Code of Practice for Surface Water Drainage as follows:

- New drainage outfalls to be set with the invert above predicted highest tide level in 2060 (+1.36 m MSL), excluding waves, extreme surge, seiching or tsunami. This will minimise occurrence of tide locking.
- Requirements for minimum platform (+1.96 m MSL), ground floor and crest levels (+2.11 m MSL); for infrastructure and building development along the coast.

132. Predicted levels for 2060 referred to in the Code of Practice need to be kept under review and adjusted if observed sea level rise departs from the predictions. The year 2060 has been chosen because a 50 year horizon exceeds the design life of infrastructure projects.

2. Rapid Works Programme

133. The rapid works programme is being implemented during the PPTA to address immediate requirements for surface water drainage. It can be considered a 'prelude' to any high-priority sub-projects which follow. The rapid works programme was conceived at the Inception Report stage with two principal objectives:

- demonstrate that The Government and the funding agencies are making visible and tangible efforts to solve storm water drainage problems; and
- to take early action clearing blocked drains to alleviate some of the most obvious and pressing problems.

134. Irrespective of the identified deficiencies in the existing surface water drainage systems, these systems are all that exists and still needed to operate in the best way possible until improvements or replacements can be constructed. Even on the most optimistic timescale capital works sub-projects are unlikely to commence for several years. Also it cannot be assumed that all the existing drains will need to be abandoned or replaced because some parts may be suitable for incorporation into the drainage improvements. The rapid works programme is designed to obtain the information needed to take these decisions.

135. There are two main components of the rapid works programme.

- topographic survey to locate and determine levels and size of existing drains, chambers, inlets and outfalls. Survey information compiled into drainage record plans; and
- use of locally available labour and equipment to open, clean and inspect drains.

136. The survey record plans are attached as Appendix 2 of Volume 2 Drainage Report. The inspection and cleaning of drains is ongoing.

3. Long-list

137. The Master Plan Drainage Strategy has identified drainage solutions for all catchments. Recognising that constraints on funding and resources mean that the Strategy will not be implemented wholesale at one time, the PPTA terms of reference require that during Phase I a long-list of high priority subprojects is compiled for detailed study during Phase II.

138. The long-list is determined subjectively based upon the reported and observed occurrence and severity of flooding, and the nature of the economic and financial costs of the flooding. Table 3 is the long-list of high priority sub-projects with summary details including indicative costs. Detailed description of the subprojects including plans as appropriate are at Appendix 1 of Volume 2 Drainage Report, including justification for inclusion the on long-list and indicative costs. Cost estimates are no better than ±20%. They exclude contract preliminary and general items and associated road works.

139. The first subproject listed is a Drainage Rehabilitation and Maintenance Program, this is establishing a programme of street and drain cleaning and maintenance and comprises procurement of equipment/services and for completion of drain cleaning and repair works that remain at the end of the Rapid Works Programme. The remaining subprojects are for built drainage infrastructure and presume that the operations from this first subproject will be implemented.

140. The subprojects for Tebakor and Municipal - Fres Wota have three options. The favoured Options A in both cases is a gravity outfall but this is also the most expensive option because it requires small bore 600 mm diameter rock tunnels. Options B would replace the tunnels by pumped outfalls. This saves on capital cost but will incur annual operating and maintenance costs. It is less fail safe than a gravity outfall. Option C requires large infiltration chambers. There are doubts that this will prove sustainable or provide adequate capacity but it is included for comparison and might be considered as an interim measure.

141. The remaining projects comprise gravity drainage. There is some flexibility in choice between which sub-catchments are drained and the phasing of works.

142. Table 4 provides a summary of the cost estimates in a single view.

Table 3: Long-list of high priority projects for detailed study during Phase II of PPTA

Subproject	Problem	Solution	Indicative cost †
Drainage Rehabilitation and Maintenance Program	• Sediment from un-swept roads enters and blocks drainage system which is poorly arranged for and receives little or no maintenance.	• Routinely sweep streets with vacuum sweeper. • Unblock and inspect existing drains. • Instigate routine inspection and maintenance of drains, routine emptying of silt traps, periodic purging of drain pipes.	Road sweeper: US$125,000 Jetting trailer: US$30,000 Initial cleaning: US$100,000 Total: US$255,000
CBD	• Street flooding and sediment deposition during any significant rainfall.	• Rehabilitate existing buried drains. • Install effective gully network. • Additional carrier drains in some side streets. • Silt traps and oil separators*.	US$477,000
Lini Highway (north)	• Ineffective drainage between CDB and Manples junction. • Ponding and sediment on road.	• Upgrade existing buried drainage. • Install additional carrier drains as required. • Install effective gully network. • Silt traps and oil separators at vehicle workshops*	US$328,000

Subproject	Problem	Solution	Indicative cost †
Tebakor	• Flooding of main road to airport and roadside businesses.	• Pipe and channel drains out-falling by gravity via 355 m small bore tunnel to Fatumaru Bay. • Development embargo on 6 ha sinkhole area of former town dump, ring area with interceptor drains and provide soakaway for sinkhole floor. • Silt traps and oil separators at vehicle workshops and filling station*	Option A, gravity outfall: US$3,018,000 Option B, pumped outfall: • Capital cost: US$1,540,000 • Annual operating cost: US$79,000 Option C, soakaway outfall: US$1,619,000
Seven Star (Ohlen)	• Flooding of road, small businesses and residential property (road is an alternative route when Tebakor is flooded).	• Pipe and channel drains. • Outfall to Tagabe River.	US$1,114,000
Seven Star (Anabrou)	• Flooding of road, small businesses and residential property (road is an alternative route when Tebakor is flooded).	• Pipe and channel drains. • Outfalls to Fatumaru Bay	US$777,000

Subproject	Problem	Solution	Indicative cost †
Municipal - Fres Wota	• Spot flooding throughout catchment including cemetery, some houses and much of stadium area. • Erosion of road shoulder and fretting of carriageway. • Situation is progressively deteriorating.	• Pipe and channel drains out-falling by gravity via 250 m small bore tunnel to Fatumaru Bay. • Silt traps and oil separators at vehicle workshops*	Option A, gravity outfall: US$3,856,000 Option B, pumped outfall: • Capital cost: US$3,034,000 • Annual operating cost: US$175,000 Option C, soakaway outfall: US$$3,270,000
Independence	• Inefficient drainage serving only carriageway • Erosion of road shoulder and fretting of pavement. • Open steel chute from Australian Embassy to outfall at Grand Hotel is perforated by abrasion and corrosion; this is also a health and safety hazard.	• Improve kerbs, channels and gullies both sides of road adopting existing carrier drain. • Repair or provide alternative to chute between Australian Embassy and Grand Hotel. • Oil separator for Tropical roundabout filling station and car wash*.	US$233,000

Subproject	Problem	Solution	Indicative cost †
Nambatu	• Limited system of channel drains becomes blocked because of changes in gradient. • Erosion of shoulder and carriageway.	• Replace and extend drainage system with pipe and channel drains. • Retain existing outfall. • Oil separators at Nambatu supermarket delivery area, and car park/filling station. • Oil separator at second filling station*.	US$404,000
Bauerfield	Culvert out-falling to Tagabe River prone to blockage	• Upgrade culvert. • Consider failsafe two stage inlet bar screen.	US$88,000
Seaside	Runoff on roads following contours drains into properties on the downhill side, at driveways, etc.	• Kerbs and gullies on downhill side. • Carrier channel or pipe to existing outfall to Lagoon. • Swale on uphill side where possible. Note: New or remade road pavement should cross-fall to uphill side and not be cambered; in that case kerbs and gullies would not then be required, but only provision for outfall of swales.	US$324,000

* Cost estimates do not include for silt traps and oil separators on existing private premises.
† Exchange rate assume vt95 = US$1.

Table 4: Summary of estimates for all subprojects

Estimate Summary	Option A Gravity outfalls	Option B Pumped outfalls				Option C Soakaway outfalls
Drainage Rehabilitation and Maintenance Program	$255,000					
All CBD (totals for 6 sub-catchments)	$477,000					
All LHN (totals for 7 sub-catchments)	$328,000					
Tebakor	$3,018,000	$1,540,000	plus	$79,000	per year O&M	$1,619,000
Seven Stars (Ohlen)	$1,114,000					
Seven Stars Anabrou	$777,000					
Municipal - Fres Wota	$3,856,000	$3,034,000	plus	$175,000	per year O&M	$3,270,000
Independence	$233,000					
Nambatu	$404,000					
Bauerfield culvert	$88,000					
Seaside	$324,000					
	$10,874,000	**$8,574,000**	plus	**$254,000**	per year O&M	**$8,889,000**

V. SANITATION

A. Introduction

1. Summary of Phase I Activities

143. A rapid review and analysis was completed of the current situation for sanitation during the Inception stage. The focus was on identifying the key issues and constraints to be addressed by the Master Plan and Investment Project. During the remainder of Phase I, more detailed studies were undertaken to determine feasible and affordable options for the delivery of safer sanitation services to all the residents of greater Port Vila. These studies and the detail of investigations carried out are presented in the Volume 3 Sanitation Report. The remainder of this section presents a synopsis of Volume 3, presenting the results of the studies and setting out the options as perceived by the PPTA Team.

2. Solutions

144. After a wide ranging consideration of technically viable solution for sanitation the PPTA Team distilled this down to two principal options.

- **Option 1**: A basic, least cost option preserving the current practice of on-site wastewater collection but with substantial improvements to common facilities, sludge disposal and management.

- **Option 2**: An enhanced option comprising construction of a gravity and pumped wastewater collection system and a wastewater treatment plant which will be able to serve most developed parts of Port Vila but preserving on-site wastewater collection for peri-urban and some other areas where measures similar to Option 1 will still be required.

3. Option 1: Basic, Least Cost Option

145. This option would provide a direct and rapid improvement of on-site sanitation for residents and visitors to Port Vila. It consists of the following:

- Improving, increasing and streamlining sludge collection activities by private tankers.

- Replacing the existing highly unsatisfactory sludge disposal method by installing a well designed and properly managed sludge treatment facility on the existing site at the solid waste sanitation landfill facility in the Bouffa Area, or at a new site to be purchased, close to port Vila Golf and Country Club.

- Improving the Department of Geology, Mines and Water Resources Laboratory in the Ministry of Lands and Natural Resources in order to improve the monitoring and control of treated effluent quality from existing individual, private wastewater treatment plants and receiving water bodies as well as the water quality in other sensitive areas. This would be complimentary to the enactment and enforcement of more stringent controls on effluent standards.

- Provision of multi-user sanitation facilities in rural and peri urban communities.

- Provision and/or rehabilitation of public toilets in the Central Area of Port Vila.

4. Option 2: Enhanced Option

146. This option included an extensive wastewater collection system and a full wastewater treatment plant and includes the following basic elements:

- Construction of a wastewater and sludge treatment facility at a site off Mele Road close to Port Vila Golf and Country Club.
- Installation of system of sewage collector pipes, interceptors and pumping stations, to serve (initially) the CBD, main residential areas and other critical zones.
- Improvement of sludge management (as in Option 1 but at the wastewater treatment plant not Bouffa landfill).
- Provision of multi-user sanitation facilities in rural and peri urban communities.
- Provision and/or rehabilitation of public toilets in the Central Area of Port Vila.

5. Commonality between options

147. The two options are not mutually exclusive and there are many common or overlapping features, in some cases only varying in the extent or proportion of the population serve by a feature.

148. For this reason the discussion which follows focuses first on the detailed requirements Option 1. Parts of this discussion then carry forward for Option 2, and how these relate is explained in the text. Other common requirements are discussed in the closing sections.

B. Option 1: Basic, Least Cost Solution

1. Sludge Collection and transportation to Treatment Site

149. The PPTA Team recommends that his activity will remain in the hands of the private sector as at present but that the existing fleet of tankers which consists of only 3 units, each operated by a family run business, needs to be renovated, restructured and reinforced in order to meet the growing demand for such services within the project horizon.

150. There is also a need to consider small size tankers (5 m^3 capacity), rather than the larger ones, to improve operational flexibility and reduce traffic disruption. Small size tankers are able to get into narrow residential streets and lanes giving greater penetration and a more comprehensive service.

151. Considering sludge production volumes and the number of trips required to dispose of the extracted sludge at the proposed sludge treatment facility, the number of vehicles of 5 m^3 capacity each to be made available to match population growth over the Master Plan period will be as shown in Table 5.

152. Therefore, the minimum number of tankers to be made available will be one additional tanker for added by 2015 and a further tanker by 2020. For the ultimate horizon 2030 two more tankers will be required. One tanker should be retained as a standby unit. The relationships between the separate business enterprises should be consolidated and the stand by units could be made available to all of them.

153. Tankers will be also be used to clean septic tanks, silt traps and grease and oil traps. They can also be used to haul wet sludge from private wastewater treatment plants if necessary.

Table 5 - Sludge Collection and Haul within the Project Area

Year	Sludge Production (m^3/year)	Total N° of trips per week to the disposal site	Minimum N° of tankers required (including standby tankers)
2015	2,960	12	5
2020	3,625	15	6
2025	4,430	17	6
2030	5,300	20	8

154. The tanker fleet should serve the whole of Efate Island as is the present practice, if this will be the case the total volume of sludge to be collected and the number of trips per week to site disposal will be increasing as in Table 6.

Table 6 - Sludge Collection and Haul for Efate Island

Year	Sludge Production (m^3/year)	Total N° of trips per week to the disposal site
2015	3,335	13
2020	4,055	16
2025	4,930	19
2030	5,850	23

155. The minimum number of tankers to be provided will however remain the same as that estimated for serving the Project Area alone.

156. It is proposed that suitable tanker vehicles would be purchased under a future Sanitation and Drainage Project. Tankers would then be the property of the Public Works Department, but a leasing agreement would be entered into, between the PWD and the private operator. Who would operate and maintain the vehicles.

2. Sludge Treatment & Reuse

157. Under this basic, least cost option the collected sludge from septic tanks, grease and oil traps and other sources will continue to be directed to the existing sanitary landfill in Bouffa area east of Port Vila where appropriate treatment facilities will be provided. A provisional layout for this plant is shown at Figure 3.

158. An additional alternative, which is attractive from a forward planning viewpoint would be to establish the sludge treatment facility at a new site off the Mele Road, close to the Port Vila Golf and Country Club. This is explained in more detail in the discussion of Option 2, (section V.C.). This would have the advantage of ensuring that the site for a future

Wastewater Treatment works would be secured, even though the construction of the Treatment Works itself would not be undertaken if this Option is selected.

159. At the sludge treatment facility one of the following treatment methods will be employed:

Sludge Pasteurization: The collected sludge is treated first by heating to 80°C in order to ensure bacteria and parasite eggs destruction. After this operation sludge becomes harmless and consequently suitable for application as fertilizer and soil conditioner.

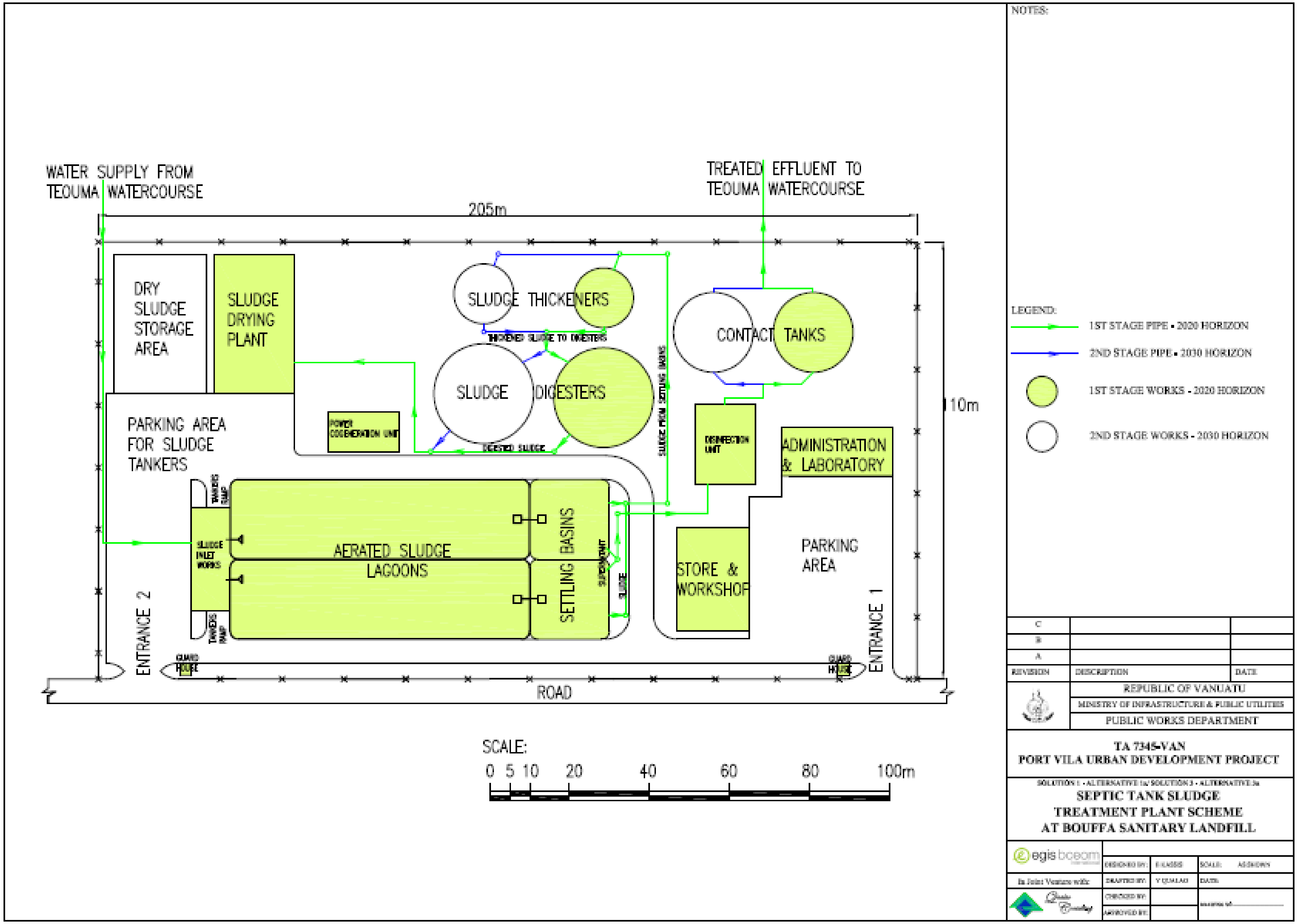
Sludge Anaerobic Digestion: This process has the advantage of a net positive energy output through the production of methane gas. The digested sludge can also be used as fertilizer or soil conditioner. To prevent water loss, sludge can be used in liquid form. Otherwise sludge drying units can be added.

Sludge Treatment in Facultative Ponds: This method employs facultative waste stabilization ponds. At the treatment works the collected sludge will first be screened and then diluted with make-up water. The effluent can then be macerated before it is released into the lagoon. Water lost by evaporation should be regularly replaced. If facultative ponds are constructed Bouffa landfill make-up water can be provided either from a well or directly from the nearby perennial Teouma River. In both cases water would have to be pumped to the ponds. In the case of Teouma River a pumping head of not less than 120 m can be expected.

160. Due to constraints of the fragile environment the discharge of a treated effluent from facultative ponds into a receiving waterbody is not recommended. Both the first two alternatives; would have far less negative impact on the environment. Moreover, anaerobic digestion has the advantage of an energy output because a by-product is methane gas.

161. The sludge digester capacity will be established on the basis of an average requirement of 0.045 m^3/capita. Because of the gas by-product sludge anaerobic digestion seems the most attractive option for Port Vila. Animal wastes (especially cow and pig dung) are also very amenable to anaerobic digestion since they yield large quantities of gas. Gas production can be combined with gas produced from the sanitary landfill, and would provide a significant energy source for electric power production. Also the digested sludge can be used as a fertilizer or soil improver in dry or in liquid form. The presence of unpleasant odours from the digester and the sludge dryer should not be a constraint provided that the plant is appropriately positioned away from habitation and taking account of the prevailing wind direction.

Figure 3 – Septic tank sludge treatment plant scheme at Bouffa Sanitary Landfill



3. Sludge Treatment by Anaerobic Digestion

162. Anaerobic sludge digestion involves the decomposition of organic matter in inorganic matter (sulphate and others) in the absence of molecular oxygen. Because of the need to secure the optimum usage of wastewater bio-solids and the developing trend towards energy conservation through recovery of the gas by-product, anaerobic digestion is becoming the dominant sludge stabilization process used in many countries.

163. The PPTA Team recommend selection of single stage high rate digestion, which is applied for modern type digesters. The sludge which reaches the digester is mixed by gas recirculation and also heated to achieve optimum digestion rates. Because there is no supernatant separation in a high rate single stage digester and the total solids in sludge are reduced by 50% approximately, to be converted into gas, the digested sludge leaving the digester is about half as concentrated as the raw sludge at the inlet of the digester. The digester cover will be of the fixed roof type.

164. The digester volume should not be less than 4,000 m^3 to achieve a solids retention time of 10 days at 35°C and an efficiency of solids conversion equivalent to 70%, for the year 2020 loading. A second digester of similar capacity can be added later, in order to meet the year 2030 loading.

165. For total gas production of methane and carbon dioxide, the combined and methane volumes produced for different years will be as shown in the Table 7.

Table 7 – Total gas production

Year	Total Gas (m^3/day)	Methane Gas (m^3/day)
2015	500	330
2020	615	400
2025	750	490
2030	890	580

Note: Figures in table have been established assuming that 65% of the digester gas is methane

166. The digested sludge can be kept in a liquid form and spread over agricultural land as a fertilizer or soil conditioner. Sludge drying using a direct drying option (rotary or fluidized type dryers) paves the way for other options as far as sludge reuse. However, the consideration of such options are not recommended for Option 1 (i.e., no wastewater collection system and treatment works), as they require high investment and operation and maintenance costs conflicting with the aims of the solution under discussion, which is to reduce investment and operational costs to the minimum.

4. Laboratory Requirements

167. As an alternative to the on site laboratory shown in Figure 3 the current Laboratory of the Department of Geology, Mines and Water Resources in the Ministry of Lands and Natural Resources might be used but first it would have to be appropriately staffed, refurbished and expanded. It could then assume responsibility for the monitoring:

- of the treated effluent quality from individual wastewater treatment plants before their discharge into the receiving water body; and

- of water quality in sensitive areas including at least, the harbour and the two lagoons.

168. This Laboratory can also be responsible for the monitoring of collected sludge characteristics before and after digestion.

(a) Laboratory premises extension

169. For Option 1 the existing laboratory premises in the Department of Mines, Geology & Water Resources can be used (A new laboratory at the wastewater treatment plant would be built under Option 2). But the existing laboratories are too small for even the Option 1 requirements and need to be expanded with a larger floor area and more rooms. It is estimated that not less than 90 m^2 will be required divided into four rooms for monitoring sludge treatment together with dealing with existing responsibilities such as rural water quality in other areas of the Country. The laboratory would consist of the following:

	Area
• Laboratory	30 m^2
• Storage Room for spare parts, reagents & site equipment	25 m^2
• Office 1	15 m^2
• Office 2	20 m^2

170. The two offices should be furnished and equipped for the use by the laboratory manager and his assistants

(b) Laboratory Minimum Staff

171. The staff of the Laboratory should consist of at least a Laboratory Manager and two technical assistants. A fourth staff member with the support of one technical assistant will be responsible for site visits and sampling works. All staff should be appropriately qualified and should be provided clear job descriptions.

5. Improving Sanitation Conditions in Informal Housing Areas - Communal Toilets, Showers & Lavatories

172. According to various social surveys and more particularly the survey carried out by the PPTA Team as part of this Study (see Volume 6), and as previously stated in the 1998 Sanitary Master Plan, informal settlements and peri-urban settlements remain the only place within the Project Area where shared sanitation facilities are in use, other than the public toilets in the Port Vila CBD.

173. However, well constructed and hygienic toilets and ablution facilities are lacking in these areas, where communal toilets and bathing facilities are serving as many as 30 to 40 people. Existing units are usually built with flimsy materials that can hardly resist the lightest storm. The units themselves are not well maintained and even the minimum levels of hygiene are not attained. Existing facilities are not suitable for use by the disabled or elderly.

174. Two principal facts related to sanitation and communal life are noted for the population living in these areas:

- Most households have access to the treated water supply provided by the private concessionaire. Water connections are in many cases shared between neighbours who make collective arrangements for paying their bills. All connections to the water distribution network are metered and no fraudulent use has been recorded.

- For power supply, one connection is providing, in some cases, power to between 15 and 20 households. Similar arrangements as for water are made for payment.

175. This can be considered as a good indication for potential sharing of services between beneficiaries. A similar system can be applied for sanitary and ablution facilities where they are properly constructed and well operated and maintained. The PPTA Team recommend that effort should be made to develop better communal sanitation conditions in these areas by embarking on a construction program of toilets and showers with a financial contribution from the users themselves supplemented by funds from an international loan or grant.

176. Based on this approach and taking into consideration the unplanned form of these areas; it would be quite reasonable to envision the provision, with the active assistance of the parties concerned: the land owners and the inhabitants, a sanitation structure particularly for that neighbourhood. These units can be built along access ways in order to make their construction, accessibility and their management and maintenance simpler.

177. In order to improve existing conditions and provide residents in these areas with the minimum requirements for good sanitation and hygiene the PPTA Team would suggest the provision of multi-purpose, multi-user facilities on the basis of one flush type toilet unit for not more than 20 persons. Genders will be served separately. Disabled persons from each gender will also have access to specially equipped toilets.

178. To achieve efficiency of scale, to provide a better service and streamline operation and maintenance, these units can be grouped up to five per gender on a single site. These can also be used as a model for developing public toilets in other areas of the Port Vila.

179. Toilet buildings should preferably be of lightweight construction and of moderate cost but well adapted to the population's needs and strong enough to resist adverse weather conditions. In general, the provision of flush type toilets together with showers, wash hand basins and a sheltered waiting area should be considered as a minimum requirement. Laundry and food preparation facilities can also be added if required.

180. Sanitation facilities will be connected to mains water and power supply and they may also have their own storage tank for the collection of rain water for drinking.

181. In order to gain maximum acceptance and use of such facilities in residential areas the following should also be considered:

- The maximum distance for users between their residence and the toilet compound should not exceed 250 m.

- For more safety, especially for the night usage, toilet compounds will be built along roads and access ways. They should also be provided with indoor and outdoor lighting.

- At least one toilet unit and one hand wash basin for each gender should be intended for disabled persons use.

- The toilet compound should be easily accessible for a maintenance team. This will be specifically the case for compounds provided with a septic tank, which need to be emptied and cleaned periodically.

- The compound can be connected to the wastewater collection system when it is located at a reasonable distance providing that the topography is favours connection.

182. Three sizes of communal toilet compound are recommended as shown at Figure 4: the large type, the medium type and the smaller type. The appropriateness of each compound type will depend upon, the area to be served, the housing density, the land topography, available infrastructure facilities in the area (access roads, water distribution network, power supply, etc.).

183. A summary description of what each of the toilet groups or toilet compound may include is shown in Table 8.

Table 8 – Suggested description for different size communal facilities

Toilet Group	Small	Medium	Large
Approximate total Area of the group or compound (m^2)	90	100	110
Number of facilities per gender			
WCs	3	4	5
Including WCs for disabled	1	1	1
Showers	1	2	3
Hand wash basins	2	3	4
Hand wash basins for disabled	1	1	1

184. The maximum distance between the nearest access point for maintenance vehicles (cleaning tanker) and the on-site wastewater disposal facility (septic tank or others) should not exceed 25 m. In special cases, trucks can be equipped for longer distances service but such distance should not exceed 50 m.

185. In general, the maximum distance for the connection of the toilets compound with a wastewater collection system will depend on the size of the compound, the land gradient and the cost of the connection.

186. Since informal housing areas are to be considered as unstructured neighbourhoods where the access to dwellings is often difficult, the location of the toilet compound should be the subject of a thorough consideration of potential locations and an analysis of costs which will include:

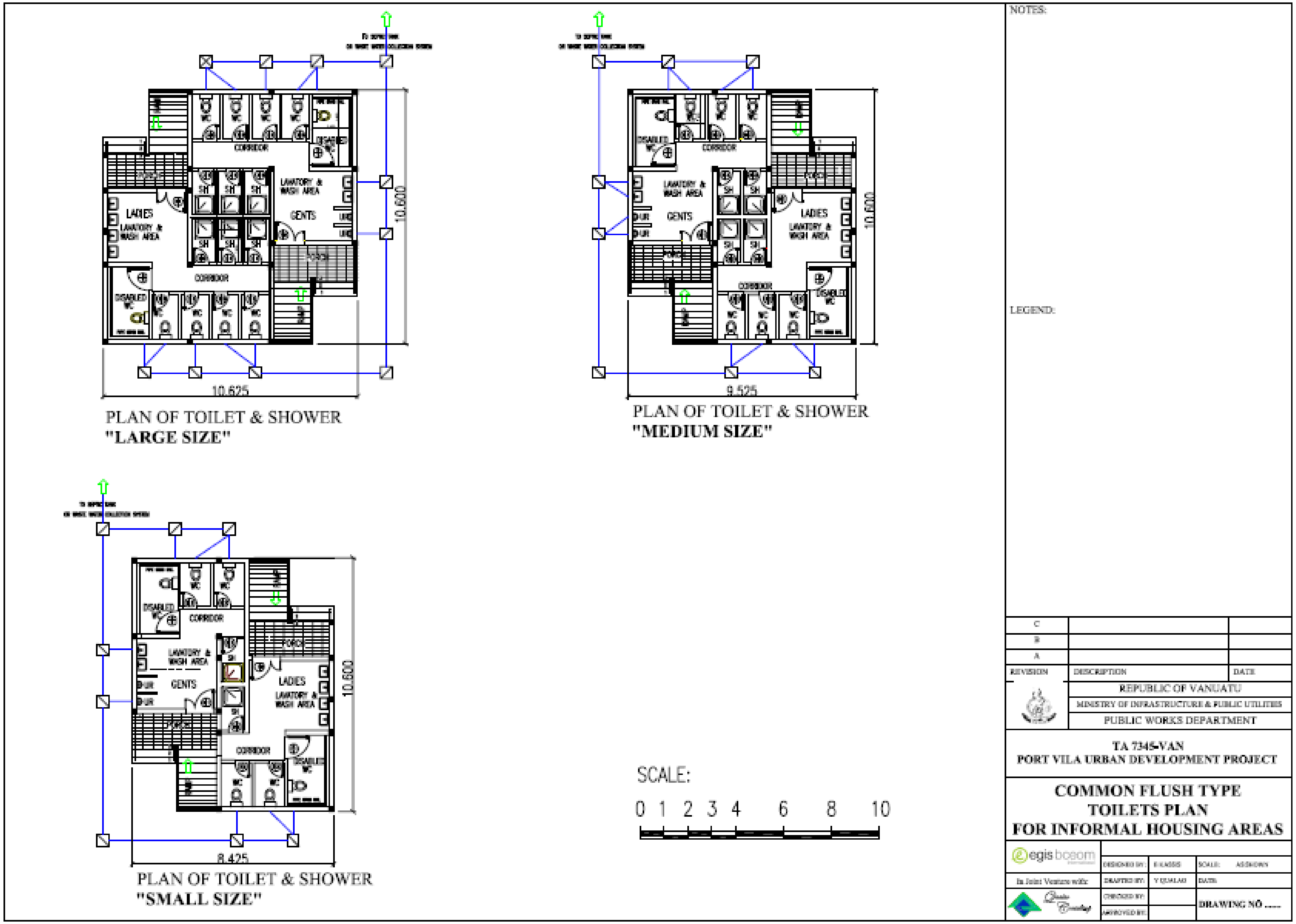
- cost of the access way;

- cost of connection to various utilities (water and power and wastewater);

- cost of compensation for population displacement; and

- the final decision to made with the beneficiaries.

Figure 4 – Common flush type toilet plan for informal housing areas



187. The compound should be operated and managed by the beneficiaries themselves who will provide the necessary follow-up and daily cleaning. They will also arrange for the payment for water and power bills as well as the cost of emptying and cleaning the septic tank where there is no sewer connect. A contribution, to cover charges, can be shared by all users in the form of a fee to be collected on regular basis.

188. Special measures are recommended to avoid damage and water wastage in toilet compounds. It is highly recommended to ensure the appointment of a caretaker at each toilet compound to avoid damage and water wastage. A room of 3 m x 3 m size should be provided for the caretaker at each of the large compounds (six units and more).

189. A tariff for using the toilet compound can be fixed according to the following criteria:

- tariff will be based on a lump sum paid by every household using the facility and/or;
- establishment of a 'per visit' fee by casual users; and
- tariff will be fixed based on operation and maintenance costs including the caretaker fee, water consumption, power consumption (lighting) and the cleaning of the septic tank or the sanitation fee where the compound is connected to a sewerage system.

190. In informal housing areas, the PPTA social survey indicates that communal contribution for the operation of public services can be successful. This is the case in the Blacksands area for instance where one power supply metered connection is used by not less than 15 to 20 households. The same applies to water supply where one connection can serve several households.

6. Public Toilets Improvement

191. Public toilets which are mainly found in the Central Business District (CBD) and within sport complexes are generally in poor condition with the exception of those located next to the handicraft art open market along Port Vila waterfront.

192. Public toilets need to be rehabilitated, upgraded and even rebuilt in some cases in order to meet hygiene standards and the growing requirements in some strategic areas such as the CBD where the number of visitors from the country side and abroad is on the increase. This is particularly the case at the Fruit and Vegetable Market where the existing toilets need both rehabilitation and expansion to meet the high demand not just for market traders and customers but also the passing public and people waiting for ferries, especially during peak hours.

193. In other places existing public toilets need to be rebuilt or completely refurbished after being vandalized and/or abandoned. This is the case of Korman stadium toilets and the toilets near the Anchor Inn Bar which are built on private property and are in the process of being dismantled.

194. Public toilets location and distribution in the Central Business District (CBD) are to be reviewed taking account of each area's development. New toilets provided should be of the modern type supplied with water flushing units and a sufficient number of wash hand basins together with appropriate waiting areas all for men and women separately. Disabled persons should have their own specially adapted facilities in all locations.

195. In this least cost option where no sewerage system is provided, sludge collection and disposal from individual on-site septic tanks should be provided. This should remain the responsibility of Port Vila Municipality.

196. For the existing toilets at the Fruit and Vegetable Market wash hand basins should be added. Two further toilet units should be added for each gender to meet the peak requirements. One of these toilets, in both the male and female areas, should be designated for disabled persons.

197. The municipal stadium toilet units need to be rehabilitated and expanded with the provision of more toilets, urinals and showers. One toilet unit at least is to be added for each gender in order to serve disabled persons. As a preliminary recommendation, two additional urinals and showers are to be added for men and three showers units for women. One of the shower units for each gender should be accessible to disabled persons.

198. The PPTA Team would suggest new public toilets in the following locations:

- Central Post Office
- Central Hospital Parking
- Independence Park
- Teouma Road Stadium (complete rebuild to replace existing facilities)

199. At each of these locations a number of toilets and wash hand basins should be provided for both genders. Moreover, the Independence Park and the Municipal Stadium at Teouma Road toilets should also have a number of shower units to cater for the requirements during sport events. A number of these units are to be adapted for disabled persons. The recommended toilets distribution and other facilities in these areas is indicated in Table 9.

Table 9 – Requirements for public toilets

Designation	Central Post Office	Central Hospital	Independence Park	Teouma Road Stadium
Flush Toilets (women)	4	4	4	3
Flush Toilets (men)	2	2	4	3
Urinals (men)	3	2	4	3
Additional Toilets for Disabled (women)	1	1	1	1
Additional Toilets for Disabled (women)	1	1	1	1
Shower (women)			4	3
Shower (men)			4	3
Additional Showers for Disabled (women)			1	1
Additional Showers for Disabled (women)			1	1

200. An entrance fee can be applied for public toilets in order cover their operation and maintenance costs. Moreover, toilets located at sporting venues may only be used when the stadium itself is open for users and visitors.

C. Option 2: Enhanced Solution

1. Description

201. Option 2 would provide a major improvement in the wastewater management of Port Vila and its peri-urban area. A wastewater collection system and a wastewater treatment plant will be provided to serve a part of the population living within the Project Area boundaries as defined previously in the report.

202. The remaining part of the population will continue to use on-site disposal facilities but with a net improvement of sludge management issues as far as its final disposal, treatment and reuse.

203. This Alternative is characterized by the provision of a wastewater collection system with sewage interceptors serving the Central Business District, residential areas and critical zones around sensitive water bodies. The main sewage interceptor will follow Lini Highway to the airport roundabout and then the Mele village road until Port Vila Golf and Country Club (PVGCC) where it will divert to a wastewater treatment site located on a large grazing area along the access road to Vanuatu Abattoirs Limited (VAL).

204. The site acquisition process will be simplified compared to other alternative areas. The site is located on the alluvial plain inland from Mele Bay. The site is a gently sloping about 1% with ground levels between 12 and 14 m MSL which makes it quite suitable for the wastewater treatment works. The ground elevation means the site is well above projected sea level rise, storms and surges all but an extreme tsunami. However, the alluvial soils may have low bearing capacities and heavy structures such as tanks, clarifiers, filters and pumping stations may require piled foundations. The ground conditions can be further investigated during the preparation of the outline design for the investment program.

2. Areas to be connected to the Wastewater Collection System

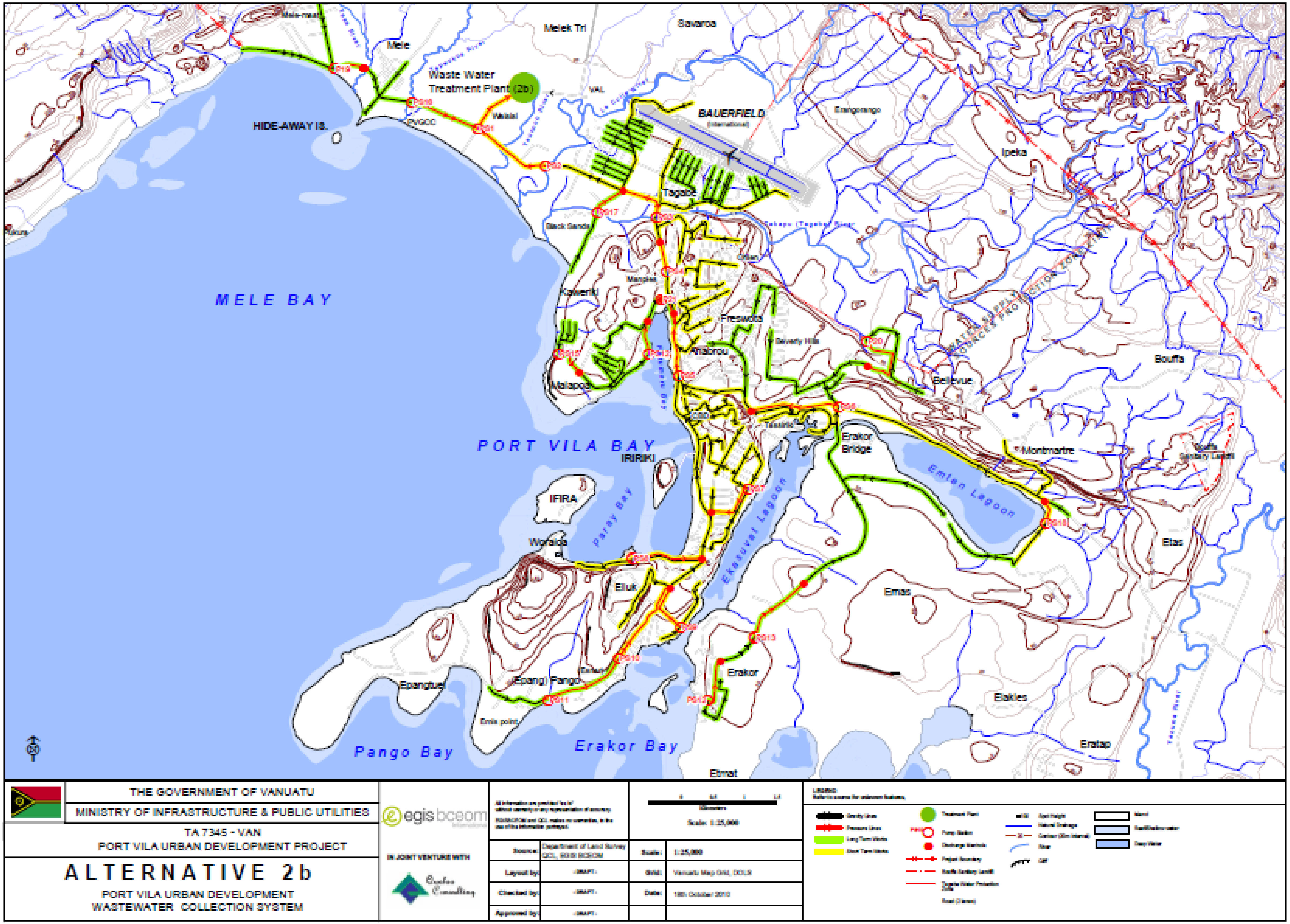
205. It is envisaged that most of the Census EAs of Port Vila Urban Area will be connected to the proposed wastewater collection and treatment system by 2030. The extent of the system is shown in Figure 5.

206. The following EAs of will have a lower connection rate:

- Tagabe Central, North and South, Agathis East & West, Namburu Central, North and South, Nambatri West, Blacksands, Ohlen, Teouma Road and Pango Road will all have a connection rate of 96%
- Bauerfield and Freshwota with have a connection rate of 84%
- Malapoa Point and Estate will have a connection rate limited to 56%
- In the Peri-Urban Areas (EAs from 710 to 722 inclusive) the connection rates is expected to vary between 28 and 60% by 2030.

207. The Islands of Iririki (EA 818) and Ifira (EAs 723, 724 and 725) will not be connected to the proposed system.

Figure 5 – Wastewater collection system



208. Within EA715 also designated as Chris Soles south-east of Port Vila there is a large residential development known as Teoumaville. Currently only a small number of houses have been built but by 2030 there will be at least 5,000 residents requiring sanitation. Most of Teoumaville is on the left bank of the Teouma watercourse which makes connection to the wastewater collection system more difficult requiring long pipe runs and additional pumping stations along the Efate Ring Road. Also the current flows are small and even by 2030 the predicted flow is not expected to exceed 300 m^3/day. This could be served by small local treatment facility rather than connect to the main facilities but before 2030 it is more practical and economical to rely on on-site sanitation solutions.

209. The construction of a wastewater collection system, treatment facilities and treated effluent disposal works is expected to be implemented in two stages:

- Short and Medium Terms (2020) - Stage I
- Long Term (2030) – Stage II

210. For the Stage I connection rates to the wastewater system within Port Vila Urban Area (EAs serial N° 801-847) are expected to be as shown in the Table 10. Note that in the peri-urban areas connection rates expected to be lower.

Table 10 – Predicted connection rates for short and medium term (2020)

EAs	Connections Rate
Urban Areas	
Melcofe, Georges Pompidou, Bougainville South and North, Industrial Park, Tongoa-Futuna, Seaside, Paama, Collardeau, Nambatu East, West and North, Jack Fong, Le Meridien-Palms, Public Works, Honda Farm and Hotel Le Lagon	70%
Tebakor Pressing, Stade, Court House, Vila East, Vila Central Hospital, Ex British Prison, Seven Stars & USP	63%
Tagabe Central, North & South, Aghatis East and West, Namburu North, South & Central, Namabatri West, Blacksands & Ohlen	56%
Bauerfield & Freshwota	49%
Ifira, Iririki, Pango Road & Malapoa College	0%
Peri-Urban Areas	
Melektree & Chris Soles	35%
Hideway Island, Worauba, Mele & Mele Bay	18%
Bellevue	12%
Erakor and Pango villages	0%

3. Wastewater collection system

211. The wastewater collection system will consist of some 99 km of gravity lines of between 200 and 500 mm diameter. The main gravity collectors of 400 and 500 mm diameter totalling some 4.7 km will be laid along the Lini Highway in the Central Business District and along the Airport and Mele roads until La Colle watercourse crossing.

212. A 400 mm diameter, 1,200 km long collector will be located along the road between the USP roundabout and the northern end of Lini Highway below the Public Works Department. It will join the Lini Highway – Airport Road collector North of Fatumaru Park.

213. For Stage I main collectors of 400 & 500 mm diameter will be installed. For the remaining pipes 200, 250 and 300 mm diameter a total of 60.5 km of lines will be provided. For Stage II the remaining 38.2 km of gravity lines 200, 250 and 300 mm diameter will be added.

214. Due to the topography, sections of the wastewater draining by gravity will require to be linked by 20 pumping stations. Pumping stations power requirements and pressurised rising main requirements over the two project stages will be as shown in Table 11.

215. As it can be noted, pumping stations N^{os} 1 to 9 will be implemented in Stage I up to 2020. Additional pumps will be need at these by 2030 for which space will be reserved inside the wet well. It is also to be noted that five of Stage I stations are the largest ones along the wastewater collection system as they will be installed along main interceptors and their total power for the first stage alone will exceed 100 Kw.

216. With regard to the pressurized rising mains, pumping stations N^{os} 1 to 7 will have twin rising mains. One of the pipes will be installed for Stage I while the second will be installed for the Stage II. Pumping Stations N^{os} 8 and 9 will have a single pressure pipe to be installed for Stage I.

217. Large water users are expected to connect to the wastewater collection system by their own means. Connection can be either by gravity or through a pumping station with pressure pipe which will connect pumps to a discharge manhole along the gravity wastewater system.

4. The Pumping Stations

(a) Introduction

218. The topography requires the provision of pumping stations along the gravity wastewater collection system. Pumping facilities will be designed for simple operation and durability.

(b) Type of pumps to be used

219. Submersible pumps are preferred because these require a simple pumping station design with minimum land take. Maintenance requirements are also lowest with this type of pump.

220. Pumps are installed in a wet well and deliver to a pressurised rising main discharging to a manhole where at the head of the next section of gravity sewer.

Table 11 – Pumping station power and pressure pipe requirements

Pump Station N°	Pump Station Power (*) (Kw)		Rising main size (mm)		Rising main length (m)	
	Stage I	Stage II	Stage I	Stage II	Stage I	Stage II
PS 1	105	240	400	2x400	750	1500
PS 2	125	290	400	2x400	1000	2000
PS 3	105	240	400	2x400	1000	2000
PS 4	120	280	400	2x400	500	1000
PS 5	170	360	400	2x400	1000	2000
PS 6	25	75	200	2x200	1200	2400
PS 7	18	96	200	2x200	1000	2000
PS 8	4	16	150	150	900	900
PS 9	14	26	200	200	750	750
PS 10	-	7.5	-	150	-	900
PS 11	-	2	-	125	-	900
PS 12	-	2	-	125	-	500
PS 13	-	4	-	125	-	1100
PS 14	-	4	-	150	-	400
PS 15	-	1	-	100	-	400
PS 16	-	6	-	150	-	1000
PS 17	-	3	-	150	-	500
PS 18	-	2	-	125		500
PS 19		6		150		500
PS 20		5		150		800

* Rounded figures

221. The design of the pumping facilities will take into consideration the need for the standardization of equipment and configuration, in order to optimize he investment and to simplify maintenance and operation. This standardization will apply for both civil works and equipment. Several standard arrangements will be used according to pump capacity, delivery head and power requirements.

222. Although pumps will be selected to allow the passage of solid matter, they will be provided with a coarse type screen in the form of a basket for an ultimate flow not exceeding 80 l/s. Large screens with automatic operation will be installed at larger size pumping stations which will be required along the main trunk sewer interceptor, close to the downstream end of the system.

223. All parts of the pump in contact with wastewater will be manufactured from corrosion resistant material as the sewage will be mixed with infiltrated flow that may include sea or brackish water.

224. The continuity of operation of pumps will be secured by the provision of a standby power generator for each station which will operate automatically during periods of mains power failure. Moreover and in order improve safety during power failure; the pump well will be equipped with an overflow line connected to a suitable drain.

225. All pumps will be protected against inundation especially in flood prone areas. The top level of the pumping station wet well roof will remain higher than the expected level of the 100 year return period flood, while the minimum vertical distance between the finished ground around the wet well structure and the well top slab will not be less than 500 mm.

(c) Site selection for pumping stations

226. Small size pumping stations (maximum flow not exceeding 80 l/s) can be located within a road reserve. Alternatively, the site to be selected should be adjacent to the road where sewer lines will be installed. The identification of the site for the construction of the pumping station and ancillary works should meet with the following requirements:

- The site should be accessible from the public road.
- Access should be wide enough to allow the entry of maintenance vehicles and plant of various sizes during and after the completion of works.
- Easy connection with power supply.
- Enough space for the construction of pump well, screen and valves chambers, standby power generating unit, fuel storage tank, electric control panel and power transformer. For large size stations, an additional space should also be provided to cater for odour control facilities.
- A minimum distance from inhabitation where possible for noise and odours protection.

(d) Odour Control

227. The best method for the control of unpleasant odours which may emanate from pumping facilities is by the provision of a closed pumping station and securing appropriate aeration for the sewage flow by taking the following measures:

- minimize stagnation of the wastewater by designing for regular flow cycle;
- aeration of the pump well; and
- injection of compressed air and/or reagents if necessary.

228. For large pumping stations (more than 200 l/s), gas from the wet well can be directed to a treatment unit before it is release to air. Gas treatment methods to apply may include:

- carbon adsorption of the produced gas;
- sand layers adsorption;
- adsorption on wood shavings; and
- chemical oxidation by using chlorine or potassium permanganate

229. However, the use of wood shaving, disposed in a way that extracted air from the pumping station can pass through, is to be considered as the most appropriate alternative for the project.

5. The Wastewater Treatment Plant

230. A provisional arrangement for the wastewater treatment works is shown at Figure 6. Details follow below.

(a) Expected flow rates to the wastewater treatment plant

231. Flow rates have been estimated for the wastewater collection system and are used to estimate the wastewater flow reaching the wastewater treatment works.

232. It is to be noted that flow estimates consider that the whole project area will be served by one wastewater treatment plant. Flow rates have been established taking account of all the incoming flow to the system and its fluctuation on hourly and seasonal basis including infiltration. All data have been established on the basis of the estimated water demand for the different categories of users and various needs.

233. Figures already established are conservative mainly for the peak hourly flow rates which can be attenuated by the available storage capacity of wastewater interceptors and pumping stations with their wet well and pressure header. Flows reaching the wastewater treatment facility will be those established for pumping station PS1 which will pump the whole intercepted wastewater flow directly to the wastewater treatment plant inlet.

234. The population served and the wastewater flow generated increase over the project period are summarized in Table 12.

235. Table 12 shows that flow demand rates per capita whether for dry or wet weather conditions steadily decrease throughout the Projection Period. This is due to the fact that early connections will cover large water users including holiday resorts and central business area where the permanent population is relatively low but the number of daily or non resident visitors is important. This trend of flow rate per capita decrease tends to stabilize over time.

236. The figures of 250 and 300 l/capita/day are most likely the ones to be considered beyond the design horizon 2030 in order to express the average wastewater production per capita for dry and wet weather conditions.

Figure 6 – Provisional treatment plant arrangement

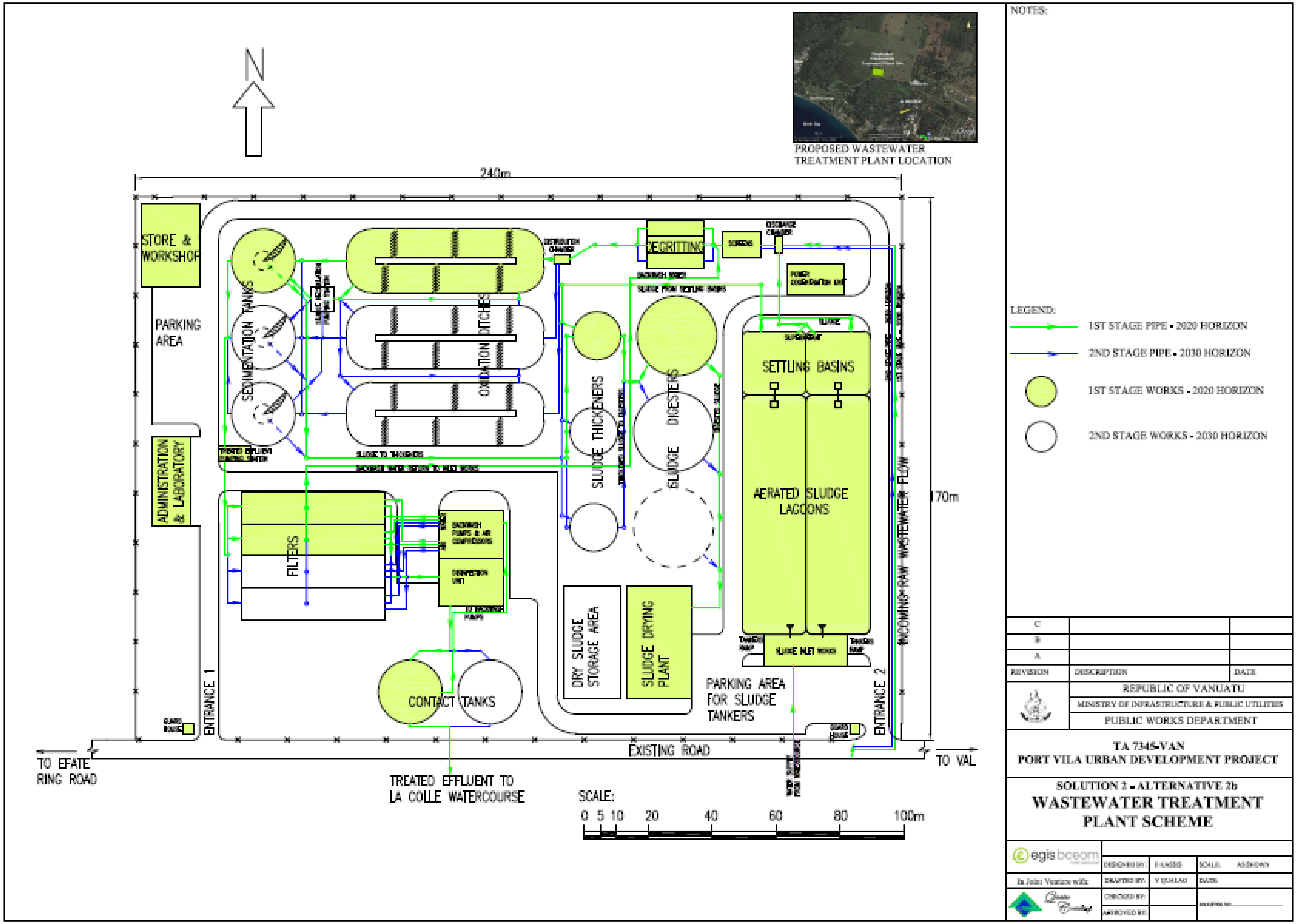


Table 12 – Population served and treatment works flows

Terms	Stage I		Sage II	
Horizon	2015	2020	2025	2030
Population to connect	12,000	22,500	41,000	66,600
Dry Weather Average Flow (m^3/day)	4,000	6,500	10,600	16,750
Dry Weather Flow in l/cap/day	333	289	258	252
Wet Weather Average Flow (m^3/day)	4,750	7,725	13,075	20,075
Wet Weather Flow in l/cap./day	396	343	319	301
Peak Hourly Flow (l/s)	200	292	448	634

(b) Mass Loading Data

237. The physical, chemical and biological characteristics of the wastewater and its composition are the other series of parameters to be established for the preparation of a wastewater treatment plant design.

238. Wastewater flow is generally constituted of 99.9% of water and only 0.1% of solid matter. Solids can be split into organic and inorganic. The organic matter consists of proteins 65%, carbohydrates 25% and fats 10%. Inorganic matter mainly constitutes grits, salts and metals.

239. Little information is available on wastewater characteristics in Port Vila and more particularly its biological parameters since tests are quite rare and they are mainly oriented towards the receiving water body quality and the treated effluent characteristics from individual wastewater treatment plants of main water users.

240. The only recent information available on wastewater characteristics within Port Vila is what has been established for Iririki Island Resort and the Le Lagon Resort wastewater. Analysis of wastewater flow influent samples to the wastewater treatment plant indicates that the 5 days Biochemical Oxygen Demand (BOD5) is averaging 135 mg/l and suspended solids concentration at 145 mg/l. For the Le Lagon Resort, BOD5 concentration from a test on the biological pollution of the wastewater effluent indicates a value fluctuating between 107 and 203 mg/l. This is an indication that the sewage strength is rather weak which is usual for large domestic water users in general.

241. Another factor indicating the strength of the domestic sewage flow is the BOD production per capita and per day. This varies from one country to another but the difference is largely due to the quantity and the quality of the wastewater (sullage) flow coming from kitchens, bathrooms and lavatories rather than of bodily wastes although variation in diet is to be considered as a significant factor. A suitable design value in tropical countries for the BOD5 per capita would be in the range of 40 g/capita/day.

242. However, due to the cosmopolitan character of the population living in Port Vila and more specifically those in residential and tourist zones, which will be connected at the early stage of the project, it would be more appropriate to consider, as daily per capita BOD, the

one which matches with the European Community Directives for establishing the size of wastewater treatment works: i.e. 60 g/equivalent/inhabitant/day. In the absence of important industrial activity within the project area, the use of a COD/BOD ratio equivalent to 2 will also be selected.

243. Using the wastewater generation per capita for both the dry and wet weather flow conditions, the average wastewater strength in terms of BOD5 and COD in Port Vila will be, all throughout the project period are shown in Table 13.

Table 13 – BOD5 and COD for project period

Year	2015	2020	2025	2030
Wastewater DW Flow (l/capita/day)	333	289	258	252
Wastewater WW Flow (l/capita/day)	396	343	319	301
BOD5 DW Flow (mg/l)	180	208	233	238
COD DW Flow (mg/l)	360	416	466	476
BOD5 WW Flow (mg/l)	152	175	188	199
COD WW Flow (mg/l)	304	350	376	398

DW: Dry Weather; WW: Wet Weather

(c) Wastewater Treatment Level

244. The selection of the wastewater treatment process is largely dependent on the final disposal and/or reuse of the treated effluent. Two levels of treatment are usually applied for the domestic wastewater flow in urban areas:

- Primary treatment and
- Secondary treatment

245. Primary treatment comprises screening and grit removal so that a portion of the suspended solids and organic matter is removed from wastewater.

246. Secondary treatment achieves the removal of biodegradable organic matter, in solution or suspension, and suspended solids. Nutrients removal is also added; nutrients to be considered are nitrogen and phosphorous.

247. Appropriate primary and secondary treatment will achieve the minimum requirements in accordance with the European Community Directives for treated effluent as follows:

- BOD5 25 mg/l
- COD 125 mg/l
- TSS 35 mg/l
- Total Phosphorous 1 mg/lp or 80%

- Total Nitrogen 10 mg/ln or 70-80%

248. However higher standards than these are required to protect areas of prime biological importance for complementary benefits to tourism and for environmental conservation (fauna and flora). In the case of the wastewater treatment plant site next to Port Vila Golf and Country Club the sensitive receptor would be La Colle River and more particularly the beaches where the river enters Mele Bay with importance to fisheries and bathing.

249. Higher standards can be achieved in two ways:

- a deep ocean outfall for the disposal of the treated effluent; or
- additional (tertiary) treatment to improve the quality of the effluent.

(d) The Wastewater Treatment Processes & Types

250. For Port Vila there are two suitable processes for the biological treatment taking into consideration the types of micro-organisms involved in what is predominantly domestic sewage and the environmental factors that affect process performances:

- Lagoon processes; and
- Aerobic processes.

251. Lagoon processes can all be considered in the suspended growth category. Aerobic processes include suspended growth and attached growth types.

(e) Lagoon Processes

252. Lagoon processes comprise large shallow basins known as stabilization ponds grouped as anaerobic and facultative (facultative refers to a mixture of aerobic and anaerobic conditions in the lagoon) ponds to achieve an appropriate level of secondary treatment. The process is quite simple and needs little aid from man since oxidation is rather slow. It has also the advantage of low maintenance cost. However, this leads to long retention times and for that reason large areas of land are required.

253. For a Stage I population estimated at 22,500 the minimum area required for waste stabilization ponds will not be less than 14 ha. For The estimated Stage II population of 66,600 the area increases to between 38 and 40 ha.

254. Although this type of biological treatment is one of the most suitable in hot climates, where the temperature is favourable to the process, the large land requirement would seem to rule it out for Port Vila.

(f) Aerobic Processes

255. The suspended growth process, commonly named the activated-sludge process is a conventional type of wastewater treatment used for BOD removal and nitrification and would be suitable for Port Vila. It has also the additional advantage in hot climates of reducing odour problems. Moreover, insect nuisance is also reduced with this type of treatment.

256. Primary and secondary sludge collected from sedimentation tanks can be treated in an anaerobic digester. The gas produced as a by product may be used for power generation.

257. Over recent years numerous activated sludge processes have been developed. Modifications have been evolved to meet specific objectives. The conventional plug flow type is a process where settled wastewater from a primary clarifier enters the front end of the aeration tank together with a re-circulated or returned activated sludge to be diverted from a secondary clarifier located, along the treatment train, to the downstream side of the aeration tank.

258. The conventional extended aeration process is a variation of the conventional plug flow process. The process uses a simplification by eliminating the need for primary treatment (no primary clarifier) and anaerobic digestion from the overall treatment system. The system operates in the endogenous respiration of the growth curve which requires a low organic loading and long retention time. Consequently larger aeration tanks with retention time in excess of 15 days are used. It is considered as very attractive for communities of the size of Port Vila providing that enough space is available. It has the advantage of requiring less complex operation and maintenance than other activated sludge processes. It can also promote de-nitrification in addition to nitrification.

259. The use of oxidation ditches instead of rectangular aeration tanks can also be considered a more advantageous process since it requires less energy for mixing than that needed for aeration. The tank configuration and shape (ring-shaped channel) promotes unidirectional flow so energy will be mainly used for aeration. Consequently, aeration equipment in the form of brush-type or surface type mechanical aerators require less energy for mixing than needed for aeration so that equipment design is based on meeting oxygen requirements instead of tank mixing. As a direct result, the system requires less energy in comparison to conventional extended aeration type of treatment process. This is considered as very attractive in a country where energy cost is high.

6. The recommended treatment process: Oxidation Ditches

260. Coming from the above discuss of suitable processes the oxidation ditch extended aeration process appears to be the most attractive for Port Vila.

261. Several treatment trains with interconnected and interchanged elements can be provided. For Stage I two treatment trains at least are to be provided for a matter of flexibility in operation and maintenance requirements.

262. Each treatment train will include in series, from inlet to outlet, the following facilities:

- Mechanical and hand operated coarse screens in parallel.
- Mechanical and hand operated fine screens in parallel.
- Grit removal tank comprising constant velocity grit channels.
- Oxidation ditch equipped with brush type aerators with a circulation velocity in the range of 0.25 to 0.30 m/s.
- Secondary clarifier.

263. Each treatment train will also be equipped with return activated sludge pumping station. Moreover and for the purpose of sludge treatment and disposal, a sludge thickener and an anaerobic single stage high rate type sludge digester with fixed roof cover will be provided. The facility will also be used for the digestion of the collected sludge by tankers

from on-site sanitation facilities. Gas production can be used for power co-generation while the digested sludge can be dried bagged and sold as land fill or soil conditioner.

264. The digested sludge can dry either on sludge drying beds or inside mechanical type driers. The first alternative seems to be economically more advantageous as no mechanical equipment is needed. However, adequately sized sludge drying beds require a large land area which may not be easily available. Moreover, due to the prevailing wet weather in Vanuatu, sludge drying beds will require protection by a shelter which must be strong enough to resist storm and cyclone damage. Consequently, it would be better to provide mechanical sludge drying plant which consists either of rotary or centrifugal dryers or of fluidized-bed dryers. There is a net advantage with the rotary type drier since the fluidized type dryer has much higher electric power demand.

265. As an alternative to reusing dry sludge, its incineration can also be considered. Sludge incineration several significant advantages such as:

- volume reduction and less space for disposal requirement;
- destruction of pathogens; and
- energy production potential.

266. But there are also disadvantages:

- high investment and operation cost for an incinerator which may not operate full time;
- requires highly qualified operation staff; and
- disposal of residuals which may be classified as hazardous waste.

267. Consequently, sludge incineration is not considered feasible for sludge disposal.

7. Sludge generated from on-site sanitation disposal facilities

268. It is important to note that with the wastewater collection and treatment alternatives a large number of the population living within the project area will still rely on on-site sanitation disposal facilities (septic tanks).

269. For a total population projection of 74,000 within the project area by the year 2015, not less than 84% of them will still rely on septic tanks. This rate is expected to fall to 50% of the total population within the project area by the year 2030 but by which time the population is estimated to reach or even exceed 132,000.

270. The sludge volume to be removed from on-site disposal facilities will slightly increase during the Stage I and reach 2,900m^3/year by 2020 while the 2009 production is estimated at 2,300m^3/year. After that, with the further expansion of the wastewater collection system and its extension to new areas, the quantity of sludge from on-site sanitation facilities will reduce to 2,650m^3/year by 2030. These figures, completed with what can be estimated as the number of trips for 5m^3 tankers to haul the sludge from where it is produced to the treatment site, are shown in Table 14.

Table 14 - Sludge Production from On-Site Sanitation Facilities with Wastewater Collection & Treatment serving a part of the Population Living within the Project Area

Year	Total Population	Rate of Population with on-site sanitation	Sludge Production (m^3/year)	N° of Trips per year for $5m^3$ Capacity Tankers
2015	74,000	84%	2,900	500
2020	90,600	75%	2,750	550
2025	110,800	63%	2,800	560
2030	132,750	50%	2,650	530

271. In the case where all Efate Island will be served by sludge tankers, sludge quantities to reach the plant will increase. The total sludge volume from on site sanitation will be as high as $3{,}200m^3$/year by 2030.

272. As has been mentioned for Option 1, the collected sludge can be treated in facultative waste stabilization ponds which will be provided on the same site as the wastewater treatment plant. Sludge will be screened and diluted with make-up water taken from the nearby La Colle River, macerated and finally treated in aerated type lagoons before joining the stabilized sludge of the wastewater treatment plant. Both sludge flows will then be diverted to the single-stage high-rate digestion facility at the wastewater treatment plant.

273. Another alternative for on-site sludge treatment in the plant would consist of its integration, after its dilution with make up water, to the treatment circuit of the plant. This would require an increase in works and equipment of some sections of the treatment trains.

8. The Use of Deep Ocean Outfall for the disposal of the treated effluent

(a) Water Quality Standards to Observe

274. The use of an ocean outfall for the disposal of the treated effluent requires a thorough examination of the marine environment where the outfall will be installed. This includes determining the dilution and residual concentrations of the discharged effluent at all points in the area affected by the discharge. A point or discharge zone will be considered as acceptable if the resulting pollutant concentrations are compatible with the water quality standards applicable in the affected areas. In case several discharge points are liable to meet the current water quality standards, then the investigations of further parameters related to hydrology, sedimentology and biology will help the identification of the best option.

275. The major limiting factors in the area will thus be bathing water quality and the protection of marine sports activities as well as the coral reefs flora and fauna. This will require in-depth investigations which are not part of the present study.

276. For the sea bathing micro-organism tests the European Directive of 8th December 1975 can be used as a guideline for compliance. The requirements of the directive are shown in Table 15.

Table 15 - European Community Directive – Guidelines for micro-organisms concentration in bathing areas

Per 100 ml	Total coli forms	Faecal coli forms	Faecal streptococci
Guideline value (G)	500	100	100
Absolute maximum (I)	10,000	2,000	

(b) Checking of the evolution of the effluent in the mass of the sea water

277. It is to be noted that an effluent discharged into the deep marine environment through a closed conduit goes through two dilution stages:

- an intense mixing as it rises from the bottom to the surface; and
- a dilution by horizontal transport and diffusion, when the plume having been spread over a certain thickness at a given depth, becomes a 'cloud' subject to normal currents.

278. Depending on the characteristics of the discharge outfall (flow rate, depth, jet diameter, angle) and the ambient conditions (currents, layering), the plume will rise to the surface or will be blocked at depth. It will spread out to a certain thickness and its dilution will vary. Close to the outfall, the plume still relatively concentrated, spreads out horizontally. It is subject to intense turbulent mixing, due to remaining kinetic energy and high concentration gradient between the effluent and the ambient environment. The more the gradient lowers, the more currents are uniform and dilution due to transport and mixing is weaker.

(c) Flow effluent rates and quality characteristics

279. The effluent flow rates to be used are those established for the ultimate year 2030. Therefore, the average flow rate to consider will be: 255 l/s (which include infiltration rate and seasonal peak factor).

280. The peak flow will be as high as 634 l/s in the case where it is considered that the flow entering the wastewater treatment plant is equivalent to the treated effluent discharged by the plant. In the case where the capacity effect of the treatment and the sea outfall will be considered, the peak flow can be reduced further.

281. When calculating dilution, the figure corresponding to the mean value between the average daily flow rate and the peak flow rates For Stage II 2030 will be considered. Concentrations adopted for the main pollutants are those proposed in the European Community Directive for the quality of the treated effluent from a wastewater treatment plant.

282. Concentration of micro-organisms commonly accepted for sewage treated effluent (primary and secondary treatment) will be considered for carrying out calculations on treated wastewater effluent disposal in a deep marine outfall. They can be summarized as follows:

- Total Coli forms 108/100 ml of water on average
- Faecal Coli forms 107/100 ml of water on average

- Faecal Streptococci 106/100 ml of water on average

283. The guidelines of the European Directive shown in Table 16 will be adopted as the standards for compliance.

284. The method for analyzing the influence of the discharge in the marine environment is fundamentally different from that of the discharge on the coast, for the following reasons:

- the environment is considered to be semi-infinite, thus with no rapid interference of dilution with the coastal morphology; and
- the currents which carry the effluent are considered to be uniform and always in the same direction.

285. Nonetheless, the phenomena responsible for the dilution of the treated effluent remain the same:

- the jet and the plume phenomena; and
- horizontal transport

Table 16 - Mean dilution ratios on the coast for micro-organisms

Test micro-organisms	Dilution ratios	
	Guideline	Maximum
Total coli forms	$2x10^5$	10^4
Faecal Coliforms	10^5	$5x10^3$
Faecal streptococci	10^4	-

(d) Opportunities for implementing a deep ocean outfall in part of Mele Bay

286. Several studies and site surveys have been carried out in Mele Bay and more specifically the section located between Mele Island and the mouth of the Tagabe River in Blacksands Enumeration Area for the ten year period of 1990 to 2000.

287. These investigations included: a near shore bathymetry and seabed morphology survey in June 1991, coastal fieldworks along the shore line in January 1992, and a Hydraulic Simulation in August 1998. All these have made recommendations that are not in favour of the construction of a deep ocean outfall in this area.

288. First, the three major rivers flowing into this part of the Bay, which are: Tagabe, La Colle and Tepwukoa have morphological unstable mouths. Such movement is very likely controlled by fluvial flood flow and the wave climate in combination with other factors. This instability can also be affected by sand mining. A 1983 report (Hepworth) is stated that the three rivers migrate over a 500 m section of shore.

289. The bay itself has been described as a large embayment made of extensive alluvial fans which have been formed from drainage into the Bay. The Bay has been considered as a sandy beach environment dominated by low-lying uplifted Holocene and older reefs.

290. The near shore bathymetry is dominated by a narrow shelf between the shore line and a break of larger depth at 10 m below the mean sea level. This is followed by a small 120 m intra slope basin sloping at 10% on average until 2.2 km from the narrow shelf.

291. Surveys also indicate that this part of the Bay has areas of sediment instability, slumping and sediments creep. Factors contributing to this instability are: a) the steeply sloping sea bed, b) the accumulation of thick sediments, c) large storm waves and seismic activity.

292. The seismic activity in the region is another source of energy which may trigger mudslides. Studies are also note that localized tsunamis could be generated by such sediments slumping and potentially affect the Mele plain. Seismic data show a variety of sea floor land forms which can be considered as an indication of significant instability of bottom sediments on shelf slopes.

293. Mele beach has no natural barriers that would contribute to the dissipation of storm wave. The bay is also exposed to waves from the southwest direction. Although such waves are not common, cyclones can come from this direction and the beach can be affected by cyclone waves and southerly swell which is mainly coming from the north west of New Zealand.

294. The 1985 SOPAC bathymetric study insisted on the need to keep Mele Island away from any wastewater discharge effects as it is quite important for recreational diving and its extensive reef together with its calm water surface make it attractive for tourist activities. The study discussed the location of a deep outfall off Blacksands beach. The study was also observed that the bottom slope of the bay may be unstable and unsatisfactory for outfall foundations. Secondary treatment may eliminate the SOPAC concerns about water quality and impacts on sensitive areas. But the concerns over outfall stability and the consequent works to ensure stability remains significant concerns.

295. A direct discharge of the treated effluent into the La Colle River would be the best alternative to consider. However, a higher level of treatment would be required but justified by the need protect the environmental quality of the Bay.

9. Use of Advanced Treatment of the Wastewater Influent as an Alternative to a Sea Outfall

296. Tertiary treatment is an option to look at for the following main reasons:

- Economic aspect: An advanced treatment of the secondary treated effluent of the wastewater treatment plant may well be less expensive than the construction of a deep ocean outfall with mitigation to meet environmental constraints.

- Technical aspect: Results of detailed investigations for the implementation of a deep ocean outfall are not satisfactory or not conclusive

297. Tertiary treatment is usually provided to achieve additional removal of suspended solids from the treated effluent which has received a primary (physical) and a secondary (biological) treatment. Removal of more suspended solids from the treated effluent is necessary before proceeding with more effective disinfection of the treated effluent flow.

298. Tertiary treatment has also to produce further reduction in Coliforms count. In this regard, it is to be noted that most of the BOD5 residual content (less than or equal to 25 mg/l) in a secondary treated effluent comes from the remaining bacterial pollution in the effluent. As quoted previously for the deep ocean outfall and according to the European Directives, more stringent conditions are to be secured for bathing areas as far as the bacterial pollution in water. In this regard, the absolute maximum for total and faecal Coliforms in water should not exceed 10,000 and 2,000 PMN/100ml respectively.

299. The need to remove more nutrients than with secondary treatment to limit eutrophication effects on sensitive water bodies. However, eutrophication is unlikely to happen in open parts of Mele Bay and more specifically where treatment works and the ocean outfall facilities will be located. Instead, this would be case of areas such as Fatumaru Bay (closed with a reef bank), Para Bay and the two lagoons of Emten and Erakor. However, the eutrophication risk issue should be considered for safety reasons.

300. In order to remove further nutrients above what can be obtained with secondary treatment the tertiary treatment facilities will include, , the following:

- Sand filtration by means of 1.0 to 1.50 m deep rapid sand filters made of granular sizing 1.0 to 2.5 mm and provided with backwashing and air scouring facilities.
- Disinfection with chlorine or any other appropriate means

301. Sand filtration is expected to secure a filtered flow of not less than 30 m^3/m^2/day through sand filters. This means that a minimum filtration area of 350 m^2 will be required in the for Stage I (2020) and 700 m^2 on foe Stage II (2030). Another 350 m^2 of filter area should be made available as standby.

302. It would be preferable to inject a chlorine solution before filtration in order to protect filters from Algae growth.

303. Large doses of chlorine are generally required (not less than 10 mg/l) and contact time will be ranging between 1 and 2 hours. Consequently, retention storage is required downstream of the filters and prior to discharge to the receiving body. This should be not less than 1,000m^3 for Stage I and 2,000 m^3 for Stage II.

10. The plant layout and the number of treatment trains required for treatment works

304. The wastewater treatment plant will require an area approximately 3.80 ha. Two treatment systems will be provided:

- conventional three stage primary, secondary and tertiary wastewater treatment for physical and biological treatment for removal of suspended solids and reduction in faecal Coliforms; and
- sludge treatment from on-site sanitation facilities.

305. Sludge extracted from the sedimentation tanks of the conventional wastewater treatment system will join the treated sludge of the aerated lagoons in sludge digestion facilities. The digested sludge will be diverted to the drying plant before its reuse as dry material.

306. Three treatment trains will be provided for the conventional wastewater treatment. One of the trains will be implemented for Stage I. The two other treatment trains will be implemented later during Stage II the meet the anticipated requirement by 2030.

307. Two treatment trains as screens and aerated lagoons will all be provided for sludge treatment for Stage I.

308. For sludge digestion, one anaerobic digester will be built and commissioned for Stage I. A second will be added later, at the beginning of Stage II but with capacity to meet requirements up to 2030.

309. For sludge drying, two units will be provided for Stage I. One of these will be sized to cater for the whole sludge production. The second unit will remain as standby. For Stage II two other identical units will be added and one unit will remain on standby.

310. Some civil works will be implemented in their entirety at the start of Stage I. This will include the screening and the degritting plant, the backwash and disinfection building, the sludge drying plant, the store and the workshop as well as the administration building and laboratory. However initially these facilities will only be equipped for Stage I, additional equipment will be added during Stage II in response to actual requirements.

311. Access roads will be constructed within the site to provide access to all treatment units and other facilities. The site will have two entrances: The 'clean entrance' and the 'sludge entrance'.

312. The 'clean entrance' will serve the administrative and maintenance area as well as oxidation and sedimentation tanks, filters and the disinfection unit.

313. The 'sludge' entrance will be mainly used by tankers, hauling the collected sludge from on site treatment works. It can also be used to reach: inlet works, sludge digesters and the sludge drying plant.

11. The Receiving Water Body of the Tertiary Treated Effluent

314. Unless a deep ocean outfall is used the receiving water body of the treated effluent will most probably be the La Colle River which is located less than 500 m from the proposed treatment plant site.

315. There is little information on the hydrology of this perennial watercourse. Recent information comes from a 15 minute interval water level recorder install on the river between the 26th October 2009 and 3rd March 2010. This measured flows ranging 1.50 and 8.50 m^3/s.

316. Assuming that the maximum peak flow of the tertiary treated effluent discharged from the contact tank into the watercourse will be equivalent to 500 l/s by the year 2030 (average and peak inflow to the plant being equivalent to 232 and 634 l/s respectively) and a minimum dry weather flow in the river of 1.00 m^3/s, the minimum dilution rate of the treated effluent into the watercourse will be of the order 1 to 2.

12. Other possibilities for the use of the tertiary treated water effluent

317. The proximity of the golf course offers the alternative to discharge of at least a fraction of the tertiary treated effluent into La Colle River. The treated effluent would be suitable for irrigating the golf course, a practice now widespread around the world.

13. Accompanying measures for the discharge of the treated effluent flow into Mele Bay

318. As it was suggested in 1983 and 1984 reports, and considered again in the bathymetric study of 1986 during evaluation of the proposed Pango Ocean outfall, a Water Resources Control Board should be established in Vanuatu to regulate all matters dealing with the discharge of wastewater (either treated or untreated). The board would also have the responsibility for establishing conditions for the location and the construction of waste generating development both domestic and industrial. Monitoring requirements for the receiving waters should also be developed by the Board's Technical Advisors.

D. Energy production at the Wastewater Treatment Plant

319. In general, the anaerobic treatment of sludge, either from wastewater or sludge collected from on-site sanitation facilities, requires less energy than the aerobic treatment. It also produces renewable energy through methane emission.

320. Such energy production at wastewater and sludge treatment facilities would require a general assessment of the energy balance for two main reasons:

- the quantity of energy consumed; and
- the possible energy production.

321. The second issue is quite important as energy production costs in Vanuatu are high. Energy balance analysis in a wastewater treatment plant indicates that the potential energy in raw wastewater exceeds the energy requirements to operate the facility. With appropriate energy recovery technology, a wastewater treatment plant can be considered as a producer of energy. This can mainly be achieved from sludge digestion.

322. Energy captured in organisms entering the plant or in collected sludge can be related to the Chemical Oxygen Demand COD load of the effluent inflow or the transported sludge, which is the best parameter to express the concentration of organic matters in the waste. COD approximates the theoretical oxygen demand to oxidize the organic fraction of the waste completely to carbon dioxide and water.

323. In a closed system of anaerobic digestion, organic materials in sludge are converted by bacteria to a variety of end products and more specifically as principal gases: Methane CH_4 and carbon dioxide CO_2.

324. Based on calorific measurements, the per capita energy input can be considered as equivalent to 1,760 KJ (or 0.49 KWh) in terms of 120 g of COD per equivalent inhabitant. This specific organic load is subject to aerobic and anaerobic degradation processes, partly releasing the captured energy. Such carbohydrate degradation generates three different categories of energy which are:

- thermal energy;
- electrical energy; and
- synthesis energy.

325. Considering synthesis energy as negligible in comparison to the first two, we can consider that the biogas produced by an anaerobic sludge digester and which contain up to 65% of methane gas, has a potential energy which can distributed as follows:

- electrical energy 30 to 40%; and
- thermal energy 60 to 70%.

326. It can also be considered that one cubic meter of biogas may generate a total power of 6 KWh which means that the average figure for electrical energy generated from the produced biogas will be equivalent to 2 KWh. In fact this rate can be slightly lower where losses from the sludge digester generated gas are taken into account. Such losses are estimated to be in the range of 10 to 15% of the total energy production and may include the above mentioned thermal energy. However, at the present stage of the study, the rate of 2 KWh of electric energy produced from one cubic meter of biogas or 0.65 m^3 of methane gas will be considered. Conversely as far as the transported sludge from on-site disposal facilities and in the absence of records on pollution loads from this highly polluted product, rates applied elsewhere in tropical countries for collected sludge or ‘nightsoil’ can be considered. They would represent not less than 80 Kg of COD per cubic meter of sludge.

1. Electrical Energy Requirements at the Wastewater Treatment Plant

327. The operational requirements of a wastewater treatment plant in terms of electric power vary according to the process to be used and the wastewater influent pollution load. They also depend on the degree of treatment to be provided and the size of the facility also on several other parameters such as ambient conditions, ground topography (additional pumping energy), etc.

328. Energy demand will also vary hourly. The peak demand for instance, would occur for domestic water treatment plants between mid day and the early evening when persons return from work. However, what is needed in this section is the average daily energy demand of the plant in order to establish a balance between the energy required and the energy potentially produced in this facility.

329. In general, activated sludge treatment plants require between 400 and 900 KWh per 1,000m^3 of a typically loaded wastewater flow influent. Advanced treatment with filtration and disinfection would require a more electrical energy. However, at the present stage of the study, we will consider a second degree treatment.

330. It is also to be noted that not less than 50% of the energy requirements with or without a third degree treatment is concentrated in the activated sludge aeration. Pumping plant are also consumes a large amount of electric power.

331. Based on the fact that the oxidation ditch process is one of the activate sludge processes which consumes least energy, it can be considered that the average overall electric power demand of these plants is in the range of 400 KWh per 1,000m^3 of wastewater influent.

332. The above mentioned energy demand rate will be used for establishing the energy balance of Option 2 with a wastewater collection system and treatment works. However, pumping stations requirements all through the collection system will not be included.

333. For Option 1 with the use of a sludge digestion facility together with sludge screening, macerating with make up water and thickening, the total energy rate required will supposedly be much lower than above mentioned rate. As a first approach, it can be considered as

equivalent to 10% of the overall requirements in energy of the activated sludge process. However and as a matter of simplicity and in order to avoid cumulative approximations which may distort results, this energy requirement for sludge digestion will not be considered in the comparative balance of energy that we will establish below for Options 1 and 2.

2. Electric Energy Balance

334. The electric energy balance for the proposed alternatives Options 1 and 2 is shown in Table 17 where average energy requirements and production are expressed in KWh per day.

Table 17 - Electric energy balance for the proposed alternatives Options 1 and 2

Year	Option 1	Option 2		
	Energy Production (KWh/day)	Energy Production (KWh/day)	Energy Requirement of the WWTP (KWh/day)	Remaining Energy (KWh)
2015	900	2,550	1,600	950
2020	1,100	4,200	2,600	1,600
2025	1,350	6,900	4,400	2,550
2030	1,600	10,700	6,700	4,000

335. Table 17 shows that available cogeneration electric energy is more or less equivalent for both alternatives at the early stage of operation. The gap will become more important later on and more particularly in the long term when the available energy in Option 2 will be more than two times the energy produced by Option 1.

336. Nevertheless, this clear advantage for Option 2 in electric energy production should be considered cautiously as the other energy requirement for the system and more particularly for pumping facilities for the wastewater reticulation network may appreciably reduce and even eliminate quantities of energy available for the power distribution grid.

E. Operation and Maintenance Issues

1. Sludge Tankers

337. The only operation and maintenance equipment available in Port Vila for sanitation activities are the three sludge collection and transportation tankers which belong to three different private businesses. One of the tankers has 10,000 litres capacity while the two other are of smaller size, 5,000 and 4,000 litres capacity respectively. A fourth tanker of 4,000 litres capacity is expected to join the existing fleet this year.

2. Equipment Required

338. No other equipment and tools are available for cleaning and flushing operations or for the transportation of goods and personnel.

339. Assuming that either the Ministry of Infrastructure and Public Utilities or the Municipality of Port Vila will be in charge of the sanitation service, unless it will be attributed to a private concessionaire as it is the case for water and power supply, the following equipment and tools will be urgently needed to improve services within the project area:

(a) Cleaning & Flushing Equipment

340. Cleaning, flushing and other maintenance in such a system would necessitate the reliance on powerful and diversified means. This should be available whenever a wastewater collection system is built and starts operation.

341. Cleaning and flushing equipment of appropriate size and number would be installed on 16 T trucks for carrying out such works. Initially and for the short and medium term, it would be possible to rely on two such trucks. The second truck will very likely operate as a standby unit. Equipment to be provided on these trucks should allow the cleaning of not only sewage collectors but also house connections and pipes within the user's property. This type of truck can also be used for storm water drainage collectors, pipe and box culverts when they cannot be easily accessible for manual cleaning works.

342. Trucks should also have: a water tank, a mud storage tank, a vacuum pump and a cleaning equipment pack including hoses as well as cleaning and flushing head devices. Root control and removal tools from inside the sewer collection system should also be considered.

(b) Sludge Collection from Septic Tanks, and Oil/Grease Traps

343. The existing sludge collection fleet needs to be reinforced by new trucks for collection, cleaning and sludge transportation from on site sewage disposal facilities in non-sewered areas to final sludge treatment and disposal or elimination site. The existing sludge collection business should also be consolidated and more cooperation and coordination between truck owners should be established.

344. As developed before to address this issue and due to the urban structure, land topography and roads size of Port Vila, it is highly recommended to rely on small or medium size tankers rather than on larger vehicles. Tankers with a capacity not exceeding 5,000 litres are the most appropriate for this work. They can operate everywhere; even in less accessible areas. Each truck will be equipped with 50 m of hose and an appropriate sludge suction pump.

(c) Toilets Compound Cleaning & Maintenance Works

345. Cleaning and maintenance of individual toilet compounds can be considered as the responsibility of their users. Inherent costs should be covered by collected fees and maintenance work and cleaning will be the responsibility of an Attendant.

346. Day to day operation and maintenance works can be done by the beneficiaries themselves but periodic visits from the health control authority will be required.

(d) Safety Equipment

347. The provision of such equipment is considered as essential and mandatory to safeguard visual inspections of sewer lines and manholes. This also provides additional information concerning physical conditions of the system.

348. Among such equipment, basic elements for a wastewater collection system shall include a multifunction automatic and portable gas detector, a device used by the operation

and maintenance staff during inspection visits. The equipment detects hydrogen sulphide (H_2S) gas and gives an indication on the lack of oxygen inside the manhole and sewer line. It will also provide indication on gas explosion risks. The device to be selected should also be able to detect three types of gases simultaneously. Sound and light signals sent out will indicate that the threshold allowable limit of the gas concentration has been reached or exceeded.

349. The selected device should also allow for a continuous monitoring of the air in the sewage network without the need to proceed to regular and periodic tests.

350. For the early stage of the wastewater collection system operation, two gas detection devices will be needed.

F. Component cost

351. An attempt has been made to estimate the cost of the various alternative options, these are summarised in Table 18

Table 18 – Cost estimates for sanitation Options 1 and 2.

Description	Option 1		Option 2	
	Vatu	US $	Vatu	US $
Stage 1				
Sludge Treatment Facility	265,000,000	2,650,000		
Refurbishment and extension of The Ministry of Lands and Natural Resources Laboratory	18,000,000	180,000		
Construction of Common Toilets in Informal Housing Area	150,000,000	1,500,000	110,400,000	1,104,000
Rehabilitation of Existing Public Toilets and Construction of New Ones	37,850,000	378,500	37,850,000	378,500
Construction of a Wastewater Collection System with Pumping facilities			1,276,865,000	12,769,000
Construction of a Wastewater Treatment Plant (*)			794,520,000	7,945,000
TOTAL Stage 1	470,850,000	4,708,500	2,219,635,000	22,196,500
Technical & Financial Contingencies 15% Stage 1	70,628,000	706,000	332,945,000	3,329,500
GRAND TOTAL Stage 1	**541,478,000**	**5,414,500**	**2,552,580,000**	**25,526,000**

Description	Option 1		Option 2	
	Vatu	US $	Vatu	US $
Stage 2				
Extension of Sludge Treatment Works	108,200,000	1,082,000		
Additional Supplies for The Ministry of Lands and Natural Resources Laboratory	14,000,000	140,000		
Construction of Additional Common Toilets in Informal Housing Area – Rehabilitation works for Existing Ones	226,200,000	2,262,000	15,000,000	150,000
Rehabilitation of Existing Public Toilets	19,230,000	192,000	19,230,000	192,000
Extension of the Wastewater Collection System and Pumping facilities			819,344,000	8,193,000
Extension of the Wastewater Treatment Plant			724,900,000	7,249,000
TOTAL Stage 2	367,630,000	3,676,000	1,578,474,000	15,784,000
Technical & Financial Contingencies 15% Stage 2	55,145,000	551,000	236,771,000	2,368,000
GRAND TOTAL Stage 2	**422,775,000**	**4,227,000**	**1,815,245,000**	**18,152,000**

Note: Exclusive of land cost for the treatment Works.

VI. PRELIMINARY PROJECT COST ESTIMATES

352. In order to give a financial dimension to the Master Plan a preliminary attempt has been made to estimate the order of cost of the physical components. At this stage however this estimate is presented in order to assist the decision making process on the selection of appropriate components for inclusion in an investment program for sanitation and drainage, which will be the focus for the coming stage of the PPTA Study.

353. Very little up to date information is available on the cost of the type of works proposed under the Master Plan, in Vanuatu, as no similar works have been undertaken previously. The costs presented Table 19 have been derived from similar projects carried out in other island nations in the Pacific region and can be taken as indicative only.

Table 19 - Summary of master plan proposals and preliminary cost estimates

Description	Component US$	Cumulative US$
DRAINAGE		
Priority 1. Drainage Rehabilitation and Maintenance Program	$255,000	$255,000
Priority 2. Tebakor	$3,018,000	$3,273,000
Priority 3. Municipal – Fres Wota	$3,856,000	$7,129,000
Priority 4. CBD	$477,000	$7,606,000
Priority 5. All Lini Highway North	$328,000	$7,934,000
Priority 6. Seven Stars (Ohlen)	$1,114,000	$9,048,000
Priority 7. Seven Stars (Anabrou)	$777,000	$9,825,000
Priority 8. Independence	$233,000	$10,058,000
Priority 9. Nambatu	$404,000	$10,462,000
Priority 10. Bauerfield Culvert	$88,000	$10,550,000
Priority 11. Seaside	$324,000	$10,874,000
SANITATION (Least Cost Option 1)		
Land Acquisition for Mele T/W site	$200,000	$200,000
Sludge Treatment Works	$2,650,000	$2,850,000
Refurbishment/building Laboratory	$180,000	$3,030,000
Construction of Communal Toilets	$1,500,000	$4,530,000
Rehabilitation of Public Toilets	$378,000	$4,908,000
SANITATION (Recommended Option 2)		
Land Acquisition for Mele T/W site	$200,000	$200,000
Construction of Communal Toilets	$1,104,000	$1,304,000
Rehabilitation of Public Toilets	$378,000	$1,682,000
Construction of Wastewater collection system	$12,769,000	$14,451,000
Construction of Wastewater Treatment Plant	$7,945,000	$22,396,000

VII. SUMMARY, CONCLUSIONS AND NEXT STEPS

354. This Volume sets out the main physical interventions required to provide for the sanitation and drainage needs of the Greater Port Vila region up to the year 2025-30.

However physical intervention by works alone will not be sufficient to secure a lasting and sustainable improvement in living conditions and the required environmental benefits.

355. The Socio-Economic Profile carried out as part of this PPTA (Volume 6) has indicated a widespread demand at grass roots level for improvements in particularly for storm drainage and flood control and to a slightly lesser extent, in increased accessibility to clean safe and hygienic public and private sanitary facilities. It has also clearly highlighted the need to raise awareness of sanitation issues and good hygiene practices among potential users. In particular the proper usage, management and maintenance of communal and public sanitary infrastructure.

356. An institutional review (Volume 4) has been carried out which has revealed a number of weaknesses in existing managerial and operational practices, these weaknesses will need to be remedied and current systems and practices replaced or strengthened to ensure the longevity and sustainability of infrastructure investments.

357. It is therefore very apparent that investment in physical infrastructure alone will not secure lasting benefits in the sectors under study. Physical investments will be required to go hand in hand with a range of carefully targeted financial, managerial and educational investments which may be termed 'soft' investments.

358. Such soft investments are equally or perhaps even more important than the 'hard' or physical investments. Considerable experience and technical expertise are required to prepare infrastructure projects. Engineers and technicians spend considerable time on the design, phasing, implementation methodology and all the other technicalities required to put infrastructure on or into the ground. Therefore a similar amount of care, professionalism and effort must be put into devising appropriate systems for the financing, operating and management of that infrastructure.

359. At this stage of the Master Planning process, Government and its development partners are presented with a number of options as to how the master plan targets may be achieved. These options differ in terms of timing, financial requirements, technical complexity, managerial requirements and their need for sensitisation of involved and affected stakeholders. As an example, in the case of the sanitation component the two major options 1) with only the reinforcement of the septic tank and sludge disposal system and 2) with a sewage treatment works and piped collection system, each will require substantially different management approaches. The selection of the preferred technical option will be required as a precursor to the design of the necessary and appropriate support systems.

360. Therefore early consideration of the available options and a decision on a preferred option is vital to maintain the momentum of the preparation of an appropriate investment programme.

VIII. PRELIMINARY ECONOMIC IMPACT ASSESSMENT

A. Introduction

361. This section discusses the economic impact assessment of the envisaged PVUDP. Although decision-makers and planners continue to explore a multi-sector approach to urban development in PV, the Consultant has so far provided technical assessment for the more urgent interventions in the drainage and sanitation services sectors which have long been delayed and neglected, and now seen to be an impediment to further development. The recently-concluded social survey was able to draw from community respondents the key issues affecting their communities and which, they emphasized, authorities should address

without further delay. The issues identified were consistent with the findings of the technical team and helped pinpoint the two main areas for immediate improvement: drainage and sanitation services. Other key concerns such as potable water availability and sufficiency, increasing incidence of specific diseases, flood protection, and waste disposal methods are all associated with sanitation and drainage services and facilities improvement.

B. Objective

362. The technical assessment identifies the potential disadvantages of ***not*** implementing planned development in these areas. The effect on the general public and the economy will include, among others, higher morbidity and mortality rates particularly in informal and peri-urban settlements, decreased tourism and employment in the sector, decreased national and personal income, and increased maintenance costs of dilapidated related infrastructure. The next step, preliminary economic impact assessment, attempts to put a value on these foreseen costs, and to demonstrate that voting not to undertake planned interventions results in unnecessary economic costs or burden to the economy. In economic terms, the assessment, combined with the findings of the technical assessments, dwells on the 'without-project' scenario. [Note, at this stage of the PPTA, the valuation exercise can be largely illustrative of monetary values, at best indicative. Some technical data is not readily available – e.g., traffic counts and delay and diversion studies, extent of crop and property damage, specific disease incidence by age category, etc. – thus, some assumptions based on international practice are used in lieu thereof].

1. Economic Costs

363. Economic costs will be incurred with or without undertaking measures to improve the current sanitation and drainage services. In the DCO Presentation on 4 November 2010, it was depicted how the delay in implementing a sewerage system project costing US$10 M in 1980 incurred a US$15 M increase, to total US$25 M if a similar facility were constructed in 2010 (25 years, hence). A decision delaying the same 15 more years to 2025 would result in further ballooning of the cost to US$50 M, mainly as a consequence of inflation. In the same DCO presentation, the "Do Nothing" (i.e., without-project) situation is deemed to incur costs including those that are social and economic in nature. It will ultimately lead to (i) a fall in tourism, (ii) lower national and personal income, (iii) more mortality and disease, (iv) rising unemployment of young people, (v) civil unrest, and (vi) increasing cost of maintenance of worn out infrastructure. The following section looks at the various costs attributing to the effects of the "Do Nothing" situation.

2. Health costs

364. The planned intervention in sanitation and drainage aims to control, if not stop, the spread of disease in order to ensure a healthy life and improved general welfare to all service beneficiaries. As healthier individuals, they will also be able to contribute more to the cash economy. Without the planned intervention, opportunities for improved general welfare and economy become limited or lost. Without-project, spread of disease can be out of control as historically documented for malaria and, recently, dengue fever even in the premier town of Port Vila. Effects can be debilitating. There are other illnesses considered less deadly but nonetheless could turn severe especially if left unchecked. Costs that may arise in a without-project situation include time lost due to illness, loss of potential income due to premature death, and cash spent for additional medical aid. Health is also affects the school-age population and has a corresponding cost when students miss school because of health problems.

3. Cost of time due to poor sanitation-related illness

365. Time spent away from productive activity as a result of illness has a corresponding cost to the economy. From HIES 2006, the morbidity rate based on poor sanitation-related diseases (e.g., malaria, dengue fever, etc.) is at 118 per 100,000 population. The economically-active population in Port Vila is at 74%. Daily wage rate is at Vt248. It is assumed that annual sick-calls average 10 days resulting from specific illnesses. The cost is derived as the product of the morbidity rate, economically-active population, the wage rate, days sick-call, and the area population. The present value estimated to year 2025 amounts to Vt0.807 M (US$0.01 M).

4. Income lost due to poor sanitation-related premature death

366. The mortality rate based on specific diseases is at 8 per 100,000 population. The income lost due to premature death is calculated as the product of mortality rate, the economically-active population, and the estimated average income. The present value of lost income due to premature death is placed at Vt8.238 M (US$0.092 M).

5. Cost of medical treatment

367. Medical treatment includes medication, consultation, visits to medical facilities and associated costs as transport fares, etc., and is estimated at Vt10,000 per sick individual. Medical expense is computed as the product of the morbidity rate, the affected population and estimated annual medical cost. The without-project cost of medical aid amounts to Vt4.37 M (US$ 0.05 M).

6. Cost to education

368. Education is key to progress and health is vital to learning. School-age children are found most vulnerable to disease caused by unhygienic practices made worse by poor sanitation facilities. The worsening effects of climate-change on drains and sewers aggravate vector spread. Port Vila's school-age group makes up 22% of total town population. Frequent absence from classrooms and lack of concentration therein due to poor health limit chances of success in school, and later, living more productive lives.

369. The average dropout rate associated with poor health before completing secondary school is assumed at 5% of school-age population. The lost future opportunity to earn higher income may be taken as the difference between the subsistence-level income a dropout would earn and the minimum-wage income that could potentially be earned if the dropout graduated secondary-school. The minimum wage rate in 2010 is assumed at Vt38,100 (HIES 2006 reports Vt26,000 plus 10% annual wage increase), with subsistence income estimated at half of this amount (HIES 2006). Based on this, the present value of the potential income lost without-project is at Vt1,900M (US$21 M).

7. Productive time lost to traffic diversion

370. The planned intervention in drainage seeks to mitigate flooding and its impact on road traffic. Port Vila has an average daily traffic of some 3,500 vehicles of various types. The identified flooding areas are spread out in the entirety of the network with varying degrees of impact. Without-project, about 50% of wage-earners are affected by climatic effects on the existing road network because traffic is diverted to avoid flood-prone sections. Traffic diversion adds distance, even creating congestion in otherwise busy streets, and more time spent away from productive endeavour. The present value of productive time lost without-project is estimated at Vt23,008 M (US$256 M).

8. Vehicle maintenance cost due to poor road conditions

371. Without-project transport O&M cost is estimated to be higher by possibly 30% more than the with-project as a result of poor road conditions made poorer by flooding. Transport O&M comprises routine maintenance and repair, tires, insurance, registration and fuel. Annual average transport O&M cost is estimated at Vt295,000. Without planned improvements on the drainage system, road conditions will continue to deteriorate and affect vehicle O&M. The cost in terms of money lost to economy will be as much as Vt2,112 M (US$23 M).

9. Tourism costs

372. Tourism is about selling the aesthetic value of a place, i.e., the scenery and ambience, and the hospitality of the local people. With poor infrastructure, the place loses aesthetic value, and with it, its attraction to tourists. Without physical improvement to check climate effects on infrastructure, the state of infrastructure will continue to decline. Result: tourist numbers drop.

373. Tourism is Vanuatu's top foreign exchange earner. Tourist arrivals in Vanuatu reached almost 250,000 in 2009. Port Vila arrivals alone accounted for almost 120,000. It is reported that about 70% do not return to Port Vila, and one reason could be dissatisfaction with the physical condition and appearance of the place. It is projected that tourists will continue to grow in number, but Port Vila could be losing them to other more attractive sites foreshore. Tourism-related sectors as hotel and restaurant operation, wholesale and retail trade, and transport and communication account for 66% of the country's GDP in 2009. Direct and indirect local domestic incomes gained from tourism activities totalled Vt10,200 M (US$96.2 M). Tourism contribution to GDP is about 20%. Under the without-project scenario, tourism numbers will continue to decline, employment levels will go down, and with it, incomes. Expected income from tourist spending will not be realized. This is a cost the economy will have to replace through other sectors to maintain current equilibrium.

10. Cost of decline in tourist spending

374. In 2009, tourist spending was about Vt15,000 M, while spending by travel agents for tourists was at Vt3,000M, totalling Vt18,000 M, 50% of which is spent in Port Vila. Average spending per Port Vila tourist would come to about Vt94,000. Assuming tourist arrivals increase 10% annually for the next 15 years till 2025, the present value of expected income from tourist spending will amount to Vt160,000 M (US$1,800 M). But as 70% are not returning, the equivalent amount is income foregone, which amounts to Vt110,000 M (US$1,200 M).

11. Loss of income due to decline in tourism jobs

375. In the without-project scenario, job requirements in the sector are expected to decrease. Presently, the sector employs some 5,000 employees, and a drop in their numbers will have a corresponding effect on the cash economy, as income foregone from decrease in tourism jobs. A simple means of estimating this cost is to value the difference between the number of jobs and corresponding income which have potential to increase with-project and the decreased jobs and corresponding income without-project. Again, assuming tourist arrivals increasing annually the next 15 years but with 70% not returning, at an average monthly salary in the sector at Vt90,000, the present value of potential job income with-project will amount to Vt120,000 M (US$1,300 M). Without-project, the present value of job income foregone will amount to Vt81,000 M (US$900 M).

12. Road maintenance cost

376. For Port Vila, PWD reports that the current road maintenance budget at Vt500 M annually is just about 25% of the required amount for routine maintenance, with practically nothing for drainage and sanitation. Working from this figure, the required annual amount would be Vt2,000 M (US$22 M). Assuming a conservative proportion for flood impact at 50% of the required amount, this would give Vt1,000 M annually in additional cost needed to include flood damage maintenance in the absence of a working drainage system. In the without-project situation, the present value of this additional cost in 15 years is estimated at Vt7,000 M (US$77 M).

13. Cost of delaying damage and risk prevention initiative

377. Studies show that mobilizing damage and risk prevention investments today, including those for flooding and sanitation-related disease, e.g., at 1% of GDP, would likely prevent greater damage later, e.g., at 5% of GDP (Stern report). Again, citing the 1980 cost estimates of a sewage treatment system at US$10 M, such intervention when undertaken in 2010 would have a current cost of US$25 M, a 150% increase attributing to inflationary effects alone. The greater cost would be to the economy, counting the potential damage and risks that could have been prevented had the proposed system been implemented as originally proposed. Presently, there is no readily available information on actual damage resulting from the 25-year delay or non-implementation of the system, but following from the estimate of damage and risk prevention above, the cost to the economy in 2010 would likely be US$50 M, double the cost of the proposed physical facility, and in 2025 (a 40-year delay), US$250 M.

C. Summary of Economic Costs ('Do-Nothing' or 'Without-Project')

378. The sum of perceived economic costs, excepting financial development costs, resulting from the "Do Nothing" or without-project situation is Vt247,900 M (US$2,800 M). In the with-project situation, this amount corresponds to cost savings in the economy and justifies the financial cost of undertaking the planned interventions in drainage and sanitation at (indicative) US$35 M. Table 20gives a summary.

Table 20 - Summary of Economic Costs

Particulars	Vt mill	US$ mill
Cost of time due to illness	1	0
Income loss due to premature death	8	0
Cost of medical treatment	4	0
Cost to education	1,868	21
Productive time lost to traffic	23,008	256
Vehicle O&M cost of poor road condition	2,112	23
Cost of decline in tourist spending	110,194	1,224
Income loss due to decline in tourism jobs	81,381	904
Road maintenance cost	6,811	76
Damage and risk prevention delay	22,500	250
Total Cost 'Without-Project'	**247,886**	**2,754**

IX. ANNEXES

Annex 1: Summary of master plan drainage strategy by catchment

Annex 2: Demand forecasts for drainage

Annex 1: Summary of master plan drainage strategy by catchment

Catchment		**Know problems**	**Solution*†**
No	**Name**		
1	CBD	Poor street drainage, standing water following rain, sediment and dirty streets, drains prone to blockage, no pollution control.	Rehabilitate and extend existing pipe drains, add correctly located gullies (~300 No), install gully pots and catchpits, correct pavement falls, oil separators and associated measures at polluting locations.
2	Lini Highway (north)	Incomplete road drainage, standing water at low spots and flat areas, sediment accumulates on road.	Rehabilitate and extend existing pipe drains, add correctly located gullies, install gully pots and catchpits, correct pavement falls.
3	Tebakor	Primary access between town and airport floods where road runs through sinkhole depression. Second sinkhole site of former town dump cannot drain but is encroached by informal housing.	Pipe and channel drains out-falling via either: 1. 550 m long small bore rock tunnel to Fatumaru Bay; 2. Pumped outfall to Fatumaru Bay; and 3. Soakaway (unlikely to be sustainable). SUDS in catchment and isolate and stop development at former town dump.
4	Seven Star Ohlen	Road crosses two sinkhole depressions in valley bottom prone to flooding, roadside property at lower level also floods.	SUDS in catchment. Pipe and channel drains out-falling to Tagabe River.
5	Seven Star Anabrou	Road crossing sinkhole depression in valley bottom, side roads and roadside property at lower level prone to flooding.	SUDS in catchment. Pipe and channel drains out-falling to via Lini Highway to Fatumaru Bay.
6	Municipal - Fres Wota	Erosion and local flooding problems in residential areas, cemetery and Municipal Stadium. The Stadium complex is within an extensive sinkhole which is at the lowest point of the catchment and which floods during heavy rain.	Pipe and channel drains out-falling via either: 1. 575 m long small bore rock tunnel to Fatumaru Bay; 2. Pumped outfall to Fatumaru Bay; and 3. Soakaway (unlikely to be sustainable). SUDS in catchment.

Catchment		Know problems	Solution*[†]
No	Name		
7	Fres Wind	No specific problems reported.	SUDS in catchment. When roads are upgraded, any drains required can outfall to Tagabe River.
8	Malapoa	Properties on down-slope side of road can have problems with runoff spilling from road.	Re-grade roads on side-long ground to cross-fall to up-slope side; provide swale, ditch or channel drain on up-slope side to outfall to mitre drain or channel towards bay. Where cross-falls are not possible use kerbs on down-slope side, inside of bends, etc to control flow to outfall. Generally apply SUDS in catchment, use natural slopes to outfall to bay.
9	Kaweriki	No reported problems as little development, but more extensive development has potentially the same problems as Malapoa.	Re-grade roads on side-long ground to cross-fall to up-slope side; provide swale, ditch or channel drain on up-slope side to outfall to mitre drain, or channel towards bay. Where cross-falls are not possible use kerbs on down-slope side, inside of bends, etc to control flow to outfall. Generally apply SUDS in catchment, use natural slopes to outfall to bay.
10	Black Sands	Informal housing without engineered roads. No reported problems.	Apply SUDS principal to add drainage in conjunction with road improvement. Drains to outfall to Tagabe River.
11	Mele Road	Blocked cross drainage, no pavement drainage,	Can use SUDS roadside ditches, provide sufficient cross-drainage culverts and oil separators at small industrial sites as necessary. Outfalls to Tagabe River.
12	Switi	Flat area but no reported serious problems.	Rely on SUDS, if drainage outfall is needed in future this can discharge to Tagabe River.
13	Bauerfield approach road	Channel and culvert outfall to Tagabe River is not maintained and can cause drain to back up during floods.	Primary solution is to maintain drain and culvert, removing cut vegetation not throwing it into the drain. Further improvement would come from a larger culvert with two-stage non-clogging manually raked inlet screen.

Catchment		Know problems	Solution*†
No	Name		
14	Tagabe	Mixed industrial, housing sub-division in flat area, ground conditions are alluvial. Drainage problems may arise as plots fill.	Maximise use of SUDS, collecting roof drainage and forming roadside swales. Where runoff collects use ditches or lined channels to cross Mele Road to outfall at Tagabe River.
15	Bladineres	Housing sub-division in flat area, ground conditions alluvial. Drainage problems may arise as plots fill.	Maximise use of SUDS, collecting roof drainage and forming roadside swales. Where runoff collects use ditches or lined channels to cross Mele Road to outfall at Tagabe River.
16	Rainbow Garden	Housing sub-division in flat area, ground conditions alluvial. Drainage problems may arise as plots fill.	Maximise use of SUDS, collecting roof drainage and forming roadside swales. Where runoff collects use ditches or lined channels to outfall at La Colle River.
17	Beverley Hills (north)	Plateau area (note escarpment drains to Fres Wota). No reported problems. Drainage problems may arise as plots fill.	Maximise use of SUDS, collecting roof drainage and forming roadside swales. Where runoff collects use ditches or lined channels to outfall at Tagabe River.
18	Beverley Hills (south)	Plateau area (note escarpment drains to Fres Wota). No reported problems Drainage problems may arise as plots fill.	Maximise use of SUDS, collecting roof drainage and forming roadside swales. Where runoff collects use ditches or lined channels to outfall into Lagoon.
19	Bellview Park	On ridge, no reported problems.	Maximise use of SUDS, collecting roof drainage and forming roadside swales. Where runoff collects use ditches or lined channels to outfall at Tagabe River.
20	Monmatre	On ridge, no reported problems.	Maximise use of SUDS, collecting roof drainage and forming roadside swales. Where runoff collects use ditches or lined channels to outfall at Tagabe River.
21	Teouma Road	No reported problems.	Maximise use of SUDS, beside Emten Lagoon so provide direct outfalls as required. Oil separators required at sites of potential pollution within existing small industrial estate.
22	Teouma	New sub-division currently sparsely occupied. No reported problems. Drainage problems may arise as plots fill.	Maximise use of SUDS, the site has good slopes for drainage so excess runoff can be directed to outfall into the local watercourse as required.

Catchment		Know problems	Solution*†
No	**Name**		
23	Tassiriki	Drains blocked on highway.	Clean and upgrade drains on highway with suitable outfall. Maximise use of SUDS in residential areas. Catchment is beside Ekasuvat Lagoon so direct outfalls are possible.
24	Independence	Majority of road has kerbs and sidewalk but carrier drain and inlets only for one carriage even where road is cambered. Fretting and erosion at side roads, bus bays, etc and road pavement in poor condition. Low spot is prone to flooding and carrier drain prone to blockage.	Rehabilitate existing carrier drain, this includes a corrugated steel chute down a steep slope between the Australian Embassy and Lini Highway at the Grand Hotel. The drain also collects some drainage in CBD before discharging to harbour beside th Grand Hotel. For roads provide gullies and gully pots connecting to existing carrier drain, an oil separator is required at the filling station.
25	Seaside	Properties on down-slope side of road can have problems with runoff spilling from road.	Re-grade roads on side-long ground to cross-fall to up-slope side; provide swale, ditch or channel drain on up-slope side to collect to discharge at existing outfall to lagoon. Where cross-falls are not possible use kerbs on down-slope side, inside of bends, etc to control flow to outfall. Generally apply SUDS in catchment.
26	Lini Highway (south)	No serious problems but existing drainage arrangements are sub-standard.	Rehabilitate and extend existing pipe drains, add correctly located gullies, install gully pots and catchpits, correct pavement falls.
27	Nambatu	Existing channel drains and culverts in dip are not maintained and are blocked, higher up the catchment there are no sidewalks, carriageway edges are fretting and the road shoulder is eroding.	Use SUDS (swales) in side roads, sidewalk and kerbs on main road with gullies, gully pots and carrier drains to the existing outfall near the oil depot. A new branch drain is required to connect the existing drain at the loading area for supermarket; this drain also serves part of Lini Highway. At least two oil separators are required at the supermarket.
28	Wharf Road	Erosion from uncontrolled drainage.	Provide sections of kerb to control runoff on the inside of bends and places where there is runoff down the slope, side drain on up-upslope side, upgrade culverts with drop structures.
29	Nambatri (golf course)	Previous problem of road flooding in dip has apparently been resolved.	None required.

Catchment		Know problems	Solution*†
No	Name		
30	Nambatri	Properties on down-slope side of road can have problems with runoff spilling from road.	Re-grade roads on side-long ground to cross-fall to up-slope side; provide swale, ditch or channel drain with outfall to lagoon via ditches at the several side roads as required. Generally apply SUDS in catchment.
31	Eslasfir	No report problems.	Generally apply SUDS in catchment.
32	Eleo Pango	New sub-division on plateau.	Generally apply SUDS in catchment. Outfall to valley towards lagoon but SUDS and the travel distance to the lagoon will probably absorb excess runoff by infiltration before it reaches the lagoon.
33	Pango Point	No report problems.	Generally apply SUDS in catchment.
34	Ekasup	No report problems.	Generally apply SUDS in catchment.
35	Erakor	No report problems.	Generally apply SUDS in catchment.
36	Mele	No report problems.	Generally apply SUDS in catchment.
37	Mele Maat	No report problems.	Generally apply SUDS in catchment.
38	Korman	Drains blocked on highway.	Clean and upgrade drains on highway with suitable outfall. Maximise use of SUDS in residential areas. Catchment is beside Ekasuvat Lagoon so direct outfalls are possible.

Notes:

* All solutions require road sweeping and regular emptying of gully pots, catchpits and oil separators.

† SUDS includes collection of roof drainage, soakaway for drainage within plots, swales, ditches and ponds to encourage infiltration and reduce peak in flow and reduce pollution of runoff, silt traps at gullies and catchpit, oil separators; these measures to be applied when circumstances are suitable.

Annex 2: Demand forecasts for drainage

Catchment		Enumeration area		Growth by enumeration area	Requirement for drainage
No	Name	Name	EA No		
1	CBD	George Pompidou	813	Average growth	Immediate requirement
		Bouganville North	814	Average growth	
		Post Office	815	Average growth	
		Bouganville South	816	Average growth	
		Court House	817	Average growth	
		Independence Park	819	Average growth	
2	Lini Highway (north)	Namburu South	810	Low growth	Immediate requirement
		Melcofe	811	Average growth	
		Stade	812	Average growth	
		Jack Fong	839	Average growth	
3	Tebakor	Agathis West	807	Average growth	Immediate requirement
		Tebakor Pressing	808	Average growth	
		Black Sands	835	Average growth	
		Jack Fong	839	Average growth	
4	Seven Star Ohlen	Bauerfield	801	Low growth	Immediate requirement
		Agathis East	804	Average growth	
		Tagabe South	805	Average growth	
		Seven Star	836	Average growth	
		Ohlen	837	Average growth	
5	Seven Star Anabrou	Agathis East	804	Average growth	Immediate requirement
		Namburu North	809	Average growth	
		Seven Star	836	Average growth	
6	Municipal - Fres Wota	Stade	812	Average growth	Immediate requirement
		Fres Wota	840	Low growth	
7	Fres Wind	Tagabe South	805	Average growth	Immediate requirement
8	Malapoa	Malapoa College	806	Average growth	Immediate requirement

Catchment		Enumeration area		Growth by enumeration area	Requirement for drainage
No	Name	Name	EA No		
		Blacksands Malapoa Point Malapoa Estate	835 846 847	Average growth Low growth Average growth	
9	Kaweriki	Blacksands Malapoa Point	835 846	Average growth Low growth	Medium to long term
10	Black Sands	Black Sands	835	Average growth	Medium to long term
11	Mele Road	Tagabe North	803	Average growth	Immediate requirement
12	Switi	Tagabe Central	802	Average growth	Medium to long term
13	Bauerfield approach road	Tagabe Central	802	Average growth	Immediate requirement
14	Tagabe	Tagabe Central Tagabe North	802 803	Average growth Average growth	Short to medium term
15	Bladineres	Tagabe North	803	Average growth	Short to medium term
16	Rainbow Garden	Tagabe North	803	Average growth	Short to medium term
17	Beverley Hills (north)	Teouma Road	843	High growth	Short to medium term
18	Beverley Hills (south)	Teouma Road	843	High growth	Short to medium term
19	Bellevue Park	Bellevue	718	High growth	Short to medium term
20	Monmatre	Bellevue	718	High growth	Short to medium term
21	Teouma Road	Teouma Road	843	High growth	Immediate requirement
22	Teouma	Chris Soles	715	High growth	Short term
23	Tassiriki	Le Meridien	842	Average growth	Immediate requirement
24	Independence	Vila East Ex British Prison Colardeau	820 821 825	Low growth Average growth Average growth	Immediate requirement
25	Seaside	Vila East Ex British Prison Vila Central Hospital	820 821 822	Low growth Average growth Average growth	Immediate requirement

Catchment		Enumeration area		Growth by enumeration area	Requirement for drainage
No	**Name**	**Name**	**EA No**		
		Tongoa/Futuna	823	Average growth	
		Seaside Paama	824	Average growth	
26	Lini Highway (south)	Nambatu West	826	Low growth	Immediate requirement
27	Nambatu	Colardeau	825	Average growth	Immediate requirement
		Nambatu West	826	Low growth	
		Nambatu East	827	Average growth	
		Public Works	828	Average growth	
28	Wharf Road	Nambatri West	829	Average growth	Short to medium term
29	Nambatri (golf course)	Honda Farm	830	Average growth	Short to medium term
30	Nambatri	Nambatri	831	Average growth	Short to medium term
		Hotel Le Lagoon	832	Average growth	
31	Eslasfir	Pango Road 844	844	Average growth	Short to medium term
32	Eleo Pango	Pango	719	Low growth	Short to medium term
		Nambatri West	829	Average growth	
33	Pango Point	Pango	722	Average growth	Short to medium term
34	Ekasup	Erakor	717	Average growth	Short to medium term
35	Erakor	Erakor	717	Average growth	Short to medium term
36	Mele	Mele Bay	712	Average growth	Medium to long term
		Mele	713	Average growth	
37	Mele Maat	Hideaway Island	711	Average growth	Medium to long term
38	Kormam	Le Meridien	842	Average growth	Short to medium term
		Teouma Road	843	High growth	
39	Teouma Coastline	Chris Soles	715	High Growth	Short to medium term