Technical Feasibility for Pursat Solid Waste Management[1]

[1] Prepared by the projection preparation technical assistance (TA 7986-CAM) consultant team.

Contents

A. Introduction

1. The approach to developing a suitable and pragmatic solid waste management (SWM) plan for the Pursat was based on the following principles:

- Site inspections to see the issues “on the ground” and understand local aims, expectation and priorities
- Review of other local schemes to assess successes and less successful approaches
- Review of other SWM schemes in
- Review of developed country approaches to provide a compass for the long term aims and avoid repeating the mistakes in these countries’ developing knowledge of SWM overall
- Provide an overview of these elements listed above, mainly in the report Appendices as background
- Select appropriate approaches for waste collection and haulage, including reviewing transfer station options
- Recommend remediation approaches for existing unsustainable waste disposal sites
- Review waste disposal and reuse models and propose an integrated approach to SWM incorporating training, institutional support and engineering interventions and equipment fleet upgrades.
- Consider the possible role of the private sector in all aspects of SWM
- Provide operations and environmental management plans
- Develop CAPEX AND OPEX for the various facilities

2. In summary, develop a pragmatic and cost-effective scheme to address current SWM issues but also provide direction for improved SWM intervention in the medium to long term.

3. **Appendix A - Glossary of Terms** contains a list of abbreviations and descriptions associated with SWM.

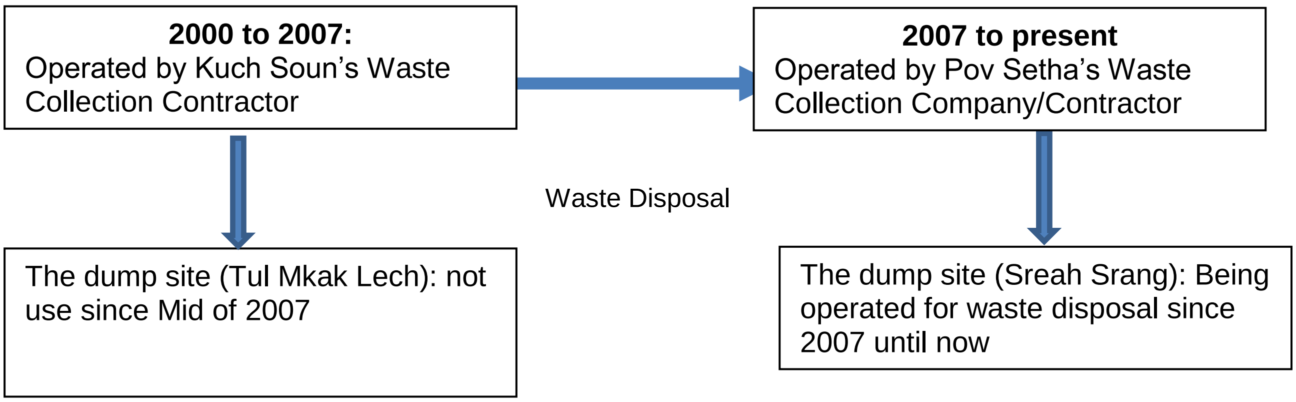
B. Existing Situation

1. History of SWM Collection

4. Pursat Municipality in Pursat province is located along National Road Number 5 north-east of Phnom Penh city. This Municipality did not have a solid waste collection service between until 1999. Therefore there were serious environmental problems. From 2000 until 2007, a waste collection contractor, namely Kuch Soun, provided a solid waste collection service but only for market waste. Residents and institutions had to manage their own wastes which they did in different ways such as burying, burning and illegal disposal into local water bodies and vacant land areas.

5. After 2007, a new company named Pov Setha’s Waste Collection Company has continued to run the waste collection.. This company has extended its service, not only servicing the market but also residents, institutions, commercial and business areas such as hotels, restaurants and hospitals; however the service still remains very limited. The company has contracted its service directly with Pursat municipality with involvement by the provincial department of environment.

Figure 1: History of Waste Collection Service in Pursat Municipality



Source: TA 7989-CAM Consultants.

2. Collection and Transportation

6. Solid waste management in Cambodia is mostly contracted to the private sector to provide an integrated collection system such as truck collection from along main roads, push cart collection for narrow roads, and collection from public waste bins and containers for markets.

7. Awareness of the people on the solid waste management issues is generally limited throughout the country. As a result, little attention is paid to proper waste management. Not all towns in Cambodia even have an official waste collection system. Solid waste collection, transportation and disposal are properly undertaken only in Phnom Penh city, Preah Sihanouk, Siem Reap and Battambang municipalities, which are the major population centers. In some towns waste is only collected from markets.

8. In Pursat municipality, the waste collection coverage area is very limited. The solid waste collection, transportation and disposal have been privatized by Pov Setha's Waste Collection Company which operates at a family scale. Thus the service is provided to only 1,500 households, approximately 15 percent of total municipal population. Thirty two (32) service users have also directly contracted for collection services including hotels, guest houses and restaurants. During the visit in May 2013, illegal waste piles and litter were found along many public roads, in the drainage system, on free land plots, Pursat waterways and the yards of many houses. The issue became more serious in the outskirts where no collection service exists at all.

9. In the collection service area, residents stored their waste for collection in various types of waste bins such as plastic waste bin, plastic bags (most common), jars and wood boxes places in front of their houses.

10. Working hours for waste collection trucks are from 06.00 am until 17:00 pm every day. Based on interviews with the company's owner Mrs. Pov Setha, waste collection services are provided every day for residents/houses along main roads and commercial areas such as hotels and restaurants, and every 2 days for the houses along small roads. The non-hazardous hospital waste is collected every day.

11. However some residents and institutions have complained that the waste collection service are very poor. The main complaint was that the waste collection service was very unreliable. Some residents advised that the collection truck came only once a month sometimes, thus the waste becomes very odorous.

12. Only three (3) trucks are used for waste collection in the whole municipality. Each truck has three (3) waste collectors and one driver. The company consists of 14 staff in total including 3 drivers, 6 waste collectors, 2 waste sweepers and 3 management staff.

3. Waste Types

13. The waste collection fleet only services households, hotels, restaurants, markets, institutions and hospitals. Only organic and kitchen wastes are collected from the hospital while other hazardous wastes are burnt in the hospital incinerator by hospital itself. Waste segregation and storage at the hospital is considered appropriate for a relatively small hospital. The hospital has two main waste bins for waste storage for non-hazardous and hazardous/medical wastes. Sharps are managed separately for later incineration on site.

14. The Pursat Referral Hospital has a total 202 beds for both general patients and TB patients. Only fifty percent (50%) of the beds are in use typically. The total amount of waste generated is about 200 kg/day of which kitchen and general waste is approximately 150 kg/day. The hazardous/medical transmitted wastes are around 50 kg per day. These medical wastes are burnt in a hospital incinerator which provided by JICA in 2008.

4. Collection Fees

15. The monthly waste collection fee per household is 4,000 Riel to 5,000 Riel for a typical residential house, 50,000 riel to 80,000 riel for restaurants while the fee for a hotel is 50,000 riel to 60,000 riel. The fee above is from negotiation between the waste service provider (the company) and service users, independent of the Municipality.

5. Street Sweeping

16. The waste company has responsibility for street sweeping but this is not undertaken comprehensively. There are only two street sweepers working for the waste collection company.

17. Based on meetings with the Provincial Department of Public Works and Transport, the PDPWT actually provides the service for sweeping main roads and removing garbage from drainage canals every three (3) months. The amount of solid waste collected from drains was approximately 30 to 40 tonnes per quarter.

6. Waste Treatment and Disposal

18. There are two existing dump sites in Pursat Municipality. The first dump site covers only 1 ha, approximately 5 km far to the municipal centre, located in Tul Mkak Lech village, Sangkat Roleap in Pursat municipality. This dump site was closed in 2007 because of complaints made by villagers living close to the dump site.

19. As a result of this closure, a second dump site has been opened which covers a total of 3 ha, supplied jointly by the municipality (1 ha) and by waste collection company (2 ha). It is located

in Sreah Srang village, Prey Gni commune (Sangkat) in Pursat municipality. The operating dump site is approximately 10 km distance from Pursat municipal centre.

20. The dump sites are in very poor condition as they were not designed but just evolved. The waste company truck dumps waste randomly without a proper staging plan and any environmental management such as placing cover material. As a result, serious environmental issues were observed such as leachate expressions, bad odours, burning at the current site and flies. These dump sites can become flooded during the wet season.

21. The municipality has proposed a new site for a controlled landfill located in Tul Mkak Keut village, Roleap commune (Sangkat) in Pursat municipality). This new site covers approximately 28 ha, and is approximately 10 km from the municipal centre. The site is owned by the province.

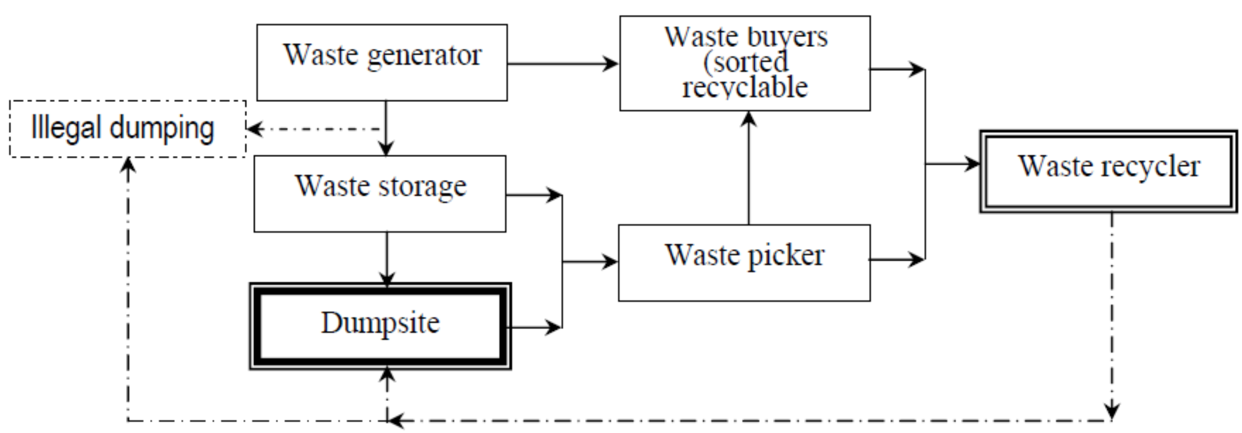
22. The new landfill site is regularly flooded to a depth of more than 0.4 m, while the access road into the site is inundated by over 1 meter in some years.

7. Waste recovery and recycling

23. There is no specific mandate addressing the application of 3R for waste management in Cambodia as a whole. However 3R is active in Pursat municipality through the informal sector such as door to door collection of recyclables by junk shop staff and independent individual recyclers.

24. There are also both small and larger junk shops operating and it is estimated that approximately 30% of the waste stream is presently being recycled, based on the throughput from a representative junk shop.

Figure 2: Cambodia's National 3R Strategy: Process



Source: MoE, 2008 (National 3R Strategy in Cambodia)

C. Legislative Environment

25. Several packages of legislation have been developed that are directly and indirectly related to solid waste management, and are summarized below:

- MoE, 1996: Law on Environmental Protection and Natural Resources Management
- MoE, 1999: Sub-decree on Environmental Impact Assessment Process. Royal Government, Council of Ministers, No. 72 ANRK.BK
- MoE, 1999: Sub-decree on Water Pollution Control. April 06 1999.
- MOE, 1999: Sub-decree on Solid Waste Management; Royal Government Council of Minister*;* No 36 ANRK.BK. April 27 1999.

1. Law on Environmental Protection and Natural Resource Management

26. The 1996 Law on Environmental Protection and Natural Resources Management states that this law has the objectives:

- to protect and upgrade environment quality and public health by means of prevention, reduction and control of pollution,
- to assess the environmental impacts of all proposed projects prior to the issuance of decision by the Royal Government,
- to ensure the rational and sustainable preservation, development, management and the use of the natural resources of the Kingdom of Cambodia,
- to encourage and provide opportunity for the public to participate in the protection of environment and the management of the natural resources, and
- to suppress any acts which may deleteriously affect the environment.

27. Article 12 states that the MoE shall collaborate with the concerned ministries to establish an inventory list which will indicate:

- the sources, types, and quantities of pollutants and wastes which are imported, generated, transported, recycled, treated, stored, disposed, or released into the airspace, water, land or on land surface;
- the sources, types, and quantities of all toxic and hazardous substances which are imported, produced, transported, stored, used, generated, treated, recycled, disposed, or released into airspace, water, land or on land surface; and
- the sources, types and extent of disturbances by noise and vibrations .

28. Article 13 states that the prevention, reduction and control of airspace, water and land pollution, noise and vibration disturbances and as well as wastes, hazardous and toxic substances, shall be determined by Sub-decree following a proposal of the Ministry of Environment.

2. Sub-decree on Solid Wastes

29. The 1999 sub-decree on Solid Waste Management established the legal basis for solid waste management including both municipal and hazardous wastes. The main purpose of the sub-decree is to regulate solid waste management in order to protect human health and the conservation of bio-diversity. This sub-decree applies to all activities related to disposal, storage, collection, transportation, recycling, dumping of garbage and hazardous waste.

30. The sub-decree also presents the rules and responsibilities in Article 4 which state that the Ministry of Environment shall establish guidelines on disposal, collection, transport, storage, recycling, minimizing, and dumping of household waste in provincial and city areas in order to ensure that the management of household waste in a safe manner. Authorities in the provinces and

cities shall then establish a waste management plan in their province and city for short, medium and long-term implementation. The collection, transport, storage, recycling, minimizing and dumping of waste in the provinces and cities is the responsibility of the authorities in provinces and city (Article 5).

31. Article 6 states that the Ministry shall also be responsible for monitoring the management of household waste, including disposal, collection, transport, storage, recycling while Article 7 states that waste disposal in public areas or any unauthorized site is prohibited. However, these Articles are not yet fully enforced.

32. In addition, in order to support this sub-decree, the Ministry of Interior and the Ministry of Environment established a joint declaration on solid waste management. This aims to support the local authorities and related agencies for effective implementation of solid waste management in their provinces or cities. This inter-declaration also presents penalties of between USD2.5 and USD25 for illegal disposal.

3. Sub-decree on Water Pollution Control

33. The 1999 Sub-decree on Water Pollution Control states that the main purpose is to regulate water pollution control in order to prevent and reduce the water pollution of the public water areas, so that the protection of human health and the conservation of bio-diversity should be ensured. Article 2 states that the sub-decree applies to all sources of pollution and all activities that cause pollution of the public water areas.

34. Article 8 states that the disposal of solid waste or any garbage or hazardous substances into public water areas or into a public drainage system shall be strictly prohibited. The storage or disposal of solid waste or any garbage and hazardous substances that leads to pollution water of the public water areas shall also be strictly prohibited.

4. Sub-decree on Environmental Impact Assessment (EIA)

35. The Sub-decree on EIA was established in 1999 by the Ministry of Environment. The Sub-decree describes that the main objectives are:

- To require an Environmental Impact Assessment (EIA) upon every private and public project or activity, and the EIA must be reviewed by the Ministry of Environment (MoE), prior to the submission for a decision from the Royal Government.
- To determine the type and size of the proposed project(s) and activities, including existing and ongoing activities in both the private and public sectors prior to undertaking the EIA process.
- To encourage public participation in the implementation of the EIA process and take into account their input and suggestions for re-consideration prior to the implementation of any project.

36. The Article 2 states that the sub-decree applies to every proposed and ongoing project(s) and activities, either by private, joint-venture or state government, and ministry institutions which are described in the annex of this sub-decree, except in special cases, where a project will be approved by the Royal Government.

37. The main responsibilities of the MoE include:

- Review and evaluate the Environmental Impact Assessment report in collaboration with other concerned ministries; and

- Follow up, monitor and take appropriate measures to ensure a Project Owner will follow the Environmental Management Plan (EMP) while project construction is taking place and accede to their EIA report's conditions. In Article 6, the Project Owner must conduct an Initial Environmental Impact Assessment (IEIA) in order to comply with the EIA requirement as stated in the annex of this sub-decree.

38. The Annex of the Sub-decree also describes the project sizes which need to prepare IEIA or EIA. It clarifies that a waste disposal site needs a full EIA if the beneficiary/users number exceed 200,000 people.

5. National 3R Strategy in Cambodia

39. The main objectives of this National 3R Strategy is to establish an efficient solid waste management system to build on the 3Rs giving jobs, incomes to people, reducing waste amount at dumpsites, and the like without causing severe risks and hazards to the environment, biological diversity and public health.

40. The Cambodian National 3R Strategy states that there are two target years, 2015 and 2020, related to this 3R achievement.

41. With the first target year in 2015, it aims to achieve an appropriate solid waste management system and practices through solid waste and garbage collection for appropriate disposal and treatment based on the capability, capacity and geographical feature. Solid waste separation for recycling purposes is targeted at 10-20 % of household wastes, 30-40% of business wastes and 50 % of industrial wastes, while the 20 % household and commercial organic wastes will be composted and used as fertilizer. In year 2015, the strategy also states that thirty (30%) of selected urban areas will have appropriate dump sites constructed and operational.

42. With the second target year in 2020, the 3R strategy also states that solid waste separation for recycling purpose will reach 50 % of household wastes, 70 % of business wastes and 80 % of industrial wastes while composting of household wastes and business/commercial wastes will go up 40 % to 50 %. The vision for the 2020 targets is that the 3R initiatives for solid waste management are carried out throughout the country to meet the environmental, economic and social values, with full participation+ by stakeholders at terms of both national and local levels

D. Waste Characterisation

1. Estimated Waste Components

43. Based on the other waste audits completed in Cambodia, as well as from other developing countries, the waste inspections indicate the following:

- The makeup is typical of waste from developing cities;
- International surveys indicate that often 50% of the organic matter will be green waste, derived from garden clippings, lawns and tree loppings, which is readily recyclable if a chipper is purchased in the future;

- There already is excellent recycling efficiency for the high value components such as metal, glass and paper. Therefore incorporation of high technology materials recovery facilities cannot be justified for these waste-stream components; and
- Recovery of plastics in comingled waste streams remains difficult. Until waste segregation is achieved throughout the city, it is appropriate to allow waste scavengers to recover the plastics manually as at present.

44. No quantitative waste audits have been completed in Pursat to date. The other Cambodian waste audit results presented below show a large range in waste composition, and some surprising results. For example, the JICA surveys of Kampong Chhnang and Battambang indicates that there was no greenwaste at all which is extremely unlikely. Usually it is up to 50% of the organic matter. There is no clear description in the report on whether the surveys were based on aggregated or disaggregated data, but some of the results for individual cities are unusual. Waste audits are often poorly performed and any non-organic material (such as cloth or paper) contacted by organic matter is collectively classed as organic, as the analysts are unwilling to fully segregate the waste components to the small scale required.

45. Given that only selected parts of the overall waste stream are being collected in Pursat, there is no point in doing a traditional waste audit on the commingled waste arriving at the dump site. The private contractor is obviously maximising returns by collecting mostly waste from commercial and institutional generators; hence there will be a bias in the comingled waste components.

46. An alternative approach is to undertake a series of waste audits on the various component waste streams such as domestic waste, hotels, restaurants, industry, institutions and market waste. However such a disaggregated approach fails when the various waste audits have to be combined. It is almost impossible to get reliable data are on the relative mass generation rates of such a wide variety of waste generators, hence combining the individual waste audit results and percentages into an overall total is often highly unreliable.

47. Also there are 11 industries in Pursat, the largest by far being MV Knitting. Security concerns by the owners prevented inspection of the site but discussions with their environmental officer confirmed that the main operating is just knitting cotton, together with a very small amount of fabric colouring. The company uses organic dyes and not lead based. The wastewater form the factory is pretreated before entering the municipal system. About three cubic metres a day of general waste is hauled away to the dump by the private contractor. It is mostly kitchen and contaminated packaging waste, with most packaging and containers being recycled. There is no hazardous waste as such to be disposed of. Therefore the small industrial base in the city would not have a significant impact on the overall waste stream.

48. In any case the general approach to Solid Waste Management is not critically influenced by the waste stream components unless there are some particularly unusual components, such as large amounts of hazardous waste or liquid waste. The inspections undertaken of the component waste streams and the overall waste being deposited at the old and current dumpsite indicated that the waste stream is typical of waste from a midsize city in a developing country with only a small industrial base. Therefore site specific audits are considered unnecessary at this time. This decision could be reviewed at the time of detail design if there is a major shift in the waste generation spread within the city or greater focus on more costly disposal alternatives such as incineration or centralised composting is mooted.

49. The amount of green waste observed at Pursat was typical of similar cities globally. The waste audits listed in the table below are for similar socio-economic situations and yard sizes. The Philippine's results are not for the capital city Manila but for regional cities such as Angeles and Mabalacat. The Philippines results are very accurate and are based on multiple replicated assessments of waste streams and weighing all separated waste components over a period of days at four different cities.

50. Coconut husks are not usually included in greenwaste or organics as the fibres are very slow to degrade, to due various mineral content.

Table 1– International Waste Composition Comparisons

Waste Type	% by Mass at Pursat (based on inspection of local waste)	% by Mass (range from Cambodian surveys)	% by Mass (from Vietnam waste audits)	% by Mass (from Philippines and Pakistan audits)
Organic Matter / percentage greenwaste of total organics	50 – 65/35%	63 – 80/8 %	53 – 77/ 20 to 50%	58 – 64/ 45 to 65%
Paper and Cardboard	2 -4	2 – 6	3 – 8	4 – 8
Plastic	10 – 15	3.30 – 15.50	9 – 16	15 – 18
Textiles	2 – 4	1.3 – 4.3	0.1 – 0.9	1 – 4
Glass	4 – 6	1.2 - 7.80	0.4 – 5.0	1 – 3
Metal	2 – 6	0.6 – 7.7	0.3 – 1.5	1 – 5
Wood	1 – 2	-	0.5 – 3	0.5 - 2
Other e.g. coconut husks, disposable nappies	10 – 15	2 -8	2 – 20	2 - 20

Source: TA 7986-CAM Consultants.

Table 2 –Local Waste Composition Comparisons

Composition (%)	Phnom Penh	Siem Reap*	Battambang*	Kampong Chhnang*
Kitchen Waste	63.30	65.18	71.88	80.46
Textile	2.50	4.34	2.88	1.26
Grass and wood	6.80	0	0	0
Metal	0.60	5.33	1.06	7.70
Ceramic and stone	1.50	0	0	0
Paper	6.40	0.88	2.72	2.10
Plastic	15.50	8.85	8.61	3.30
Rubber and leather	0.10	0	0	0
Bottle and glass	1.20	7.80	5.40	0.70
Others	2.10	-	-	-

References:
JICA, 2004: The study on solid waste management in the Municipality of Phnom Penh. Kokosai Kogyo Co., LTD.
* DoEPC, 2008: Report on solid waste management status, December 2008; Department of Pollution Control, Ministry of Environment, Cambodia.

51. Both glass and metal proportions at Pursat dumps were observed to be higher than typical of a developing country provincial city. The junk shops do not purchase tin cans so higher levels than normal of tin cans may be expected. But for some reason, whole bottles as well as cullet were present in significant amounts at the dumps. The presence of unbroken bottles is unusual at dumps where scavengers are active and junk shops do purchase bottles.

52. Also the above estimate for Pursat has been corrected to account for the higher proportion of market and commercial waste currently being collected, compared with household domestic waste which will dominate once the collection service is extended to the rest of the Municipality.

2. Medical Waste

53. These wastes typically do not constitute a large fraction of the overall waste volume but are potentially very dangerous.

54. Some medical waste was observed at the uncontrolled dump site, in the forms of pharmaceutical bottles. However Sharps and infectious wastes such as body tissue were not observed.

55. The current management of medical waste and recommended future approach is addressed later in this report.

3. Household Hazardous Waste

56. The site inspections identified only a very small quantity of household hazardous waste such as used fluorescent tubes. Following the Information and Education Campaign and implementation of basic waste segregation, all household hazardous waste should be deposited in a small dedicated cell within the controlled landfill.

57. This dedicated portion of the cell would also be used to accept other appropriate hazardous waste provided it satisfies the requirements for waste acceptance described in the controlled landfill Operations Manual.

58. The cell would usually have an operational life of only six months and is then covered with clay soil, and a second clay trench is then constructed within the overall cell.

4. Other Waste

59. Construction and demolition waste is presently not collected. When it is collected and once the future shredder/crusher is possibly available, then it can be processed and used as aggregate around the site.

60. The Operations Manual provides management approaches for other special wastes such as mattresses and tyres which are presently just co-disposed with the general waste

E. Waste Segregation and Minimization

1. Background

61. There is no waste segregation at source in a structured sense, apart from the recovery of high value recyclables from householders and commercial facilities such as restaurants and hotels, and primary waste scavengers.

62. The City has indicated little interest in pursuing waste segregation based on initial discussions. They are aware of the lack of success elsewhere, both in Cambodia and in other developing countries.

63. If waste is to be segregated, there must be some downstream benefit realised and recognised by the community. Segregation usually involves having one container for wet biodegradables (essentially kitchen waste) and one for dry matter including all non-biodegradables. Usually waste is segregated differentiating biodegradable from non-biodegradable waste to allow mechanised sorting of the recyclables centrally. However the amount of recyclables entering the local waste stream is minimal and would not justify a highly mechanised MRF and therefore traditional segregation.

64. The proposed SWM approach is to ultimately have greenwaste and construction and demolition chipped/crushed and reused as landfill access road cover in wet weather, erosion protection on external mound batters and as compost feed if some future composting scheme is adopted, such as with animal manure or biological sludges from treatment plants. This will not be justified for some decades yet though based on the local quantities of these waste.

65. Developed countries have up to 5 separate containers but three is more common for recyclables, green waste and residuals (both organic and inorganic).

66. Depending upon any move towards composting, the more traditional waste segregation of organics and non-putrescibles may be more appropriate. Again this will not have to be decided or implemented for many years based on the current waste generation quantities.

2. Receptacles and Waste Segregation Approach

67. The appropriate approach would be to continue with plastic or other bags initially and then eventually hard bins (plastic or metal) to be collected say twice weekly.

68. One issue usually raised by communities is the cost of having separate containers if waste segregation is to be adopted in the future. The costs of bag identification can be minimised by not requiring specially coloured bags as in some schemes. The option adopted elsewhere is the use of identifying coloured ties, regardless of the colour or type of container.

3. Waste Minimization

69. Households and many commercial establishments currently recycle or reuse much of the higher value products in their waste stream. Inspection of the current and closed disposal sites indicate very low levels of primary recyclables such as non-ferrous metals and paper/cardboard, but relatively elevated levels of glass. Other raw waste stream audits in SE Asia show much more of the former components. This low level of non-ferrous metals and paper being disposed confirms that efficient informal recycling is already occurring at source.

70. While there is good reuse and recycling and waste avoidance success in the City, it can be improved. To this extent, there is a need for an IEC campaign on waste minimisation, avoidance and recycling. This should also be extended to industry.

71. A major influence on the success of waste minimisation and, indeed, recycling is the pricing regime for waste disposal. A local option is the introduction of compulsory charges for all plastic bags used at shops. Plastic makes up a significant fraction of the current waste stream, typically 10 to 18% mainly as bags.

72. This is used in other developing countries such as Fiji in the Pacific. The charge is in the order of 80 Riels per large plastic grocery bag. The aim is twofold. Firstly, it is to encourage people to only use the actual number of bags required. Secondly it encourages people to reuse the bags, either for later trips to the shops or to use the bags for storing garbage rather than buying special garbage bags and liners. It has also had the effect of people using reusable bags instead of plastic.

73. **Appendix B – Waste Segregation and Minimisation** provides more details on these options.

F. Recycling

1. Inorganics Recycling

74. Significant recycling is already happening within the household and commercial establishments and these successes must be considered in assessing the overall aims for percentages recycled/reused. This means that when calculating percentage recycling metrics, the total waste mass generated by household and industry sites needs to be quantified, prior to any in-house sorting, recycling and reuse.

75. The current practice is that private collectors visit individual households or commercial establishments to purchase recyclables and they, together with waste pickers at the landfill site, sell

recyclables to junk shops and traders. It is already very efficient and significant recycling gains can only be made through recycling new components, such as green waste and demolition waste, or organic waste, until full segregation is achieved at all waste generators. If this is ever achieved, then mechanised separation facilities could be considered.

76. The local recycling market is largely self-regulating, meaning that junk shops will only buy materials that can be profitably on-sold. Facilitating recycling of non-economic materials through City funding creates a purposeful market distortion. This is acceptable as long as all the parties recognize the distortion and accept that any withdrawal of government support will make recycling this product uneconomic for the private sector.

77. The local junk shops purchase the following materials by a mixture of having their own staff visit domestic and commercial installations as well as people delivering their own materials for sale.

Table 3 – Junk Shop Purchasing Rates and Quantities

Item	Price (Riels/kg)	Quantity (Kg/day)
Cardboard and paper	350	700 to 800
Plastic bottles	800	700 to 800
Glass Bottles	100 per bottle	100 bottles
Steel	3000	20
Tin cans	Does not purchase	
Copper	12000 to 20000	5
Aluminium cans	4200	1000 to 2000
Plastic bags	Does not purchase	
Aluminium (not cans)	3000	50
Zinc anneal roofing	400	50 to 60
TOTAL		**2600 to 3700 kg/d**

Source: TA 7986-CAM Consultants

78. There are three major junk shops in the city as well as 7 or so much smaller ones. The owner estimated that his junk shop has 25% of the total market share, so the total amount recycled on a daily basis varies between 10 to 15 tonnes. The amount of waste being generated within the city is in the order of 33 tonnes per day. Therefore, even at the lowest level of recycling, approximately 30% of the waste being generated is being recycled which is a sound position from which to start Solid Waste Management planning.

79. Plastic bags can be recycled from comingled waste if done by waste pickers. Bags which have not been cleaned are sold in some other countries like Vietnam for the equivalent for 300 Riels /kg, whereas cleaned plastic bags attract a price of 1000 Riels/kg. Raw polyethylene pellets cost over 5000 Riels/kg. However the local recycling companies indicated little interest in recycling bags because of the large space requirements for the low financial yield returned. This may change over time as the volume of bags increases and the viability of installing a bailer or shredder increases.

80. Not all materials have to be sold to be recycled. For example, builder's rubble can be used for drainage or gas collection blankets in controlled landfills rather than just dumped into the cell as waste. This type of recycling just requires some forward planning and eventually a crusher/chipper at the controlled landfill site to further enhance recycling options.

81. Similarly, green-waste can be chipped and then used as a protective layer for the exposed cover material prior to grassing to prevent erosion of controlled landfill batters, or used on internal roads during wet weather. Green-waste often exceeds 50% of the organics content so it is a very efficient way to achieve high levels of organics recycling.

2. Organics Recycling and Composting

82. Composting can also be used to reduce the organic waste going to a controlled landfill, but the compostable material must be completely separated from the rest of the waste. This is best done at source by the householder. However, this requires considerable co-ordination and encouragement from the community and the City. Separation of the waste needs to be extremely thorough as an occasional piece of metal or other solids in the waste stream causes faster wear or even partial destruction of the shredding equipment and lowers the overall quality of the compost. Glass shards are common in organic waste and some centralised compost materials have even contained mediwaste sharps.

83. This introduces a legal liability for the City even if the product is given away to local residents or farmers. There have been many legal cases in developed countries where individuals utilising centrally produced compost have sued the municipalities because of contaminants in the compost product.

84. A sustainable market also needs to be found for compost generated centrally. This often proves difficult as demand is typically low and there are many better and cheaper sources of compostable material, such as sewage sludges, manure and greenwaste. Many schemes have failed because of a lack of demand for the final product. For example, there is 8000 tonnes of compost stockpiled in Manila, Philippines that cannot be sold or even given away.

85. The composting scheme operating at Battambang was inspected to ascertain the local sustainability of centralised composting schemes. This composting scheme is part of a larger NGO facility which includes education for waste pickers and their families, sleeping accommodation and kitchens, as well as training for children to become circus performers. This scheme accepts up to two tonnes per day of organic waste which is collected solely from the market. The waste is pre-sorted at the market by NGO staff to remove any plastics and other inorganics.

86. When delivered to the composting facility located adjacent to the landfill, it is again manually sorted to remove any non compostables. An end loader then mixes the waste and turns it on a weekly basis. Six windrow piles are stored under a covered area with each pile representing one month of composting. The composting operation requires continual monitoring to ensure that there is sufficient moisture in the windrows and also to monitor the nutrient to carbon ratio. Once the compost reaches six months maturity, it is then lifted into a mechanised trommel with 10 mm apertures to remove any larger material. It is then again sorted by hand prior to bagging and sale.

87. The composting operation is particularly inefficient because the raw waste is not shredded. This results in large items such as coconut husks entering the compost windrows which do not degrade even within the six month period. There is a shredder onsite but is no longer used. Even with two lots of manual sorting prior to shredding, glass was still sometimes mixed within the raw waste and shattered when it entered the shredder. This caused not only injuries to staff but also introduced glass shards into the compost.

88. Without all the capital works and almost all of the ongoing operating cost being covered by the NGO, this plant would not be financially sustainable.

89. Overall it would be better to encourage additional home level composting by subsidising the cost of composting bins and by providing free advice on the associated benefits and methods. This would help to reduce the overall volume of waste. Alternatively the household waste food can be used for domestic animal feed, such as for pigs, chickens or goats. Commune level composting may be required where the individual households do not have the compound area available to utilise the compost produced.

90. In summary, composting on a centralised basis is considered inappropriate. Overall the combination of future greenwaste and demolition waste recycling together with household based composting/feeding and encouraging more plastic bag recycling will suffice. More emphasis on glass recycling would also be appropriate.

91. More details are provided in **Appendix C - Recycling**

G. Population Projections and Waste Generation

1. Background

92. Preliminary estimates have been made for both population projections and waste generation rates for 30 years.

93. The population projections are based on the Census figures and growth rates for urban areas. The growth rate for urban areas stated in the Census has been reduced as it is expected that most growth will occur in Phnom Penh rather than provincial cities. So a lower growth rate was adopted.

94. The 'extended area' populations have been assumed to become part of the serviced area by 2015, that is, the municipality will have extended its boundaries as they have indicated. The adopted population figures allow for significant extension of the collection area over time. If this does occur to the extent allowed, then the landfill life will simply be increased and later cells can be reduced in size if desired. The equipment required for the landfill is the most basic possible so lower population growth rates do not impact on the equipment selected. Similarly for waste collection equipment, a basic fleet of various equipment types is still required

95. After 2030 a reducing urban growth rate has been adopted for the enlarged service area to the 30 year time horizon.

2. Waste Generation Allowance

96. Accurate waste generation data in Cambodia is very limited. There are very few if any functioning public weighbridges, and no portable truck scales for hire, so accurate aggregated waste generation figures are non-existent. Added to that, most cities do not have a high level of collection service efficiency to allow the mass of waste being hauled to be accurately related to a service area population in any case. Most local waste generation rates are based solely on mass estimates or very small samples being weighed and then grossly extrapolated. In summary, little credence should be placed on local per-person waste generation rates.

97. Therefore, the adopted waste generation rates for this project are based on a mixture of local rates determined during the local inspections and interviews, by comparison with rates from

similar communities locally and internationally, and finally by qualitatively comparing the data with a range of Cambodian results.

98. Generally the poorest communities in Cambodia reportedly have a generation rate of only about 0.35kg/p.d. As the income of the population increases so does the mass of waste generated per person. Other studies in Cambodia have indicated that a generation rate of more than 0.9kg/p.d is appropriate in cities such as Phnom Penh. (Source: MoE, 2004 and Waste Management Office of Phnom Penh Municipal Hall)

99. Projects in other developing countries like Vietnam and the Philippines often use a rate of at least 0.5 kg/p.d going up to 0.65 kg per person.day for provincial cities with a similar level of affluence to the local study area cities. Developed countries can generate up to five times this amount.

100. Based on the CDIA (2010) Urban Environmental Infrastructure Improvement; Project in Battambang. Cities Development Initiative for Asia; Asian Development Bank TA 6293-REG. Final Report-Part B, the assumed waste generation was 0.35 kg/p.d, including the poorer peri-urban and squatter areas.. However, based on MoE, 2011: Report of Waste Generation in Cambodia; Department of Environmental Pollution Control, Ministry of Environment (MoE) and Sethy, S., 2013: Municipal Solid Waste Management in Cambodia, the waste generation of Battambang was 80t/d or approximately 0.5kg/p.d. The estimates for Pursat and Kampong Chhnang were 35 and 26t/d respectively, also giving waste generation rates in the order of 0.5 kg/p.d.

101. These amounts account for at source (in-house or in-institution) recycling and reuse. Higher value recyclables such as glass, metal and paper are already being recycled at source. This is typical of most developing countries where these high value recyclables traditionally account for 3 to 5 per cent of the total waste stream for each component.

102. The waste generation allowance was therefore set at 0.5kg/p.d initially increasing to 0.65kg/p.d over 30 years to account for increasing community wealth and therefore higher per capita waste generation.

3. Recycling Allowance

103. As the wealth of the community increases, the amount of waste generated will increase.

104. However this does not translate into a proportional increase in the quantum of waste to be collected and disposed of. The key components in the amount of waste generated per person with increasing wealth relates to packaging, for such as paper, cardboard, tins and bottles. So as the amount of waste generated per person increases the amount of recyclables also increases, resulting in much smaller growth rate for the waste to be collected compared with the total increase in waste generated.

4. Collection Allowance

105. The current percentage of waste collection is estimated to be 30% in the city core.

106. The ultimate aim is of course to approach 100% collection efficiency but this may only achieved in the very long term following cultural changes which accept that littering is not desirable, and supported as well by a campaign of fines associated with littering. However significant

changes in the community attitude towards littering will be generational and not expected to be significant in the life of the controlled landfill proposed.

107. Furthermore, the 350 houses located on the canal and river bank will not be able to receive door to door collection in the future. Even with the provision of community bins and an IEC campaign, significant littering into the local watercourses must be expected from many of households in this community even in the future. The Municipality plans to relocate these householders to other sites in the future through a voluntary relocation scheme, but this may not succeed.

108. With the recommended improvements in this report, it may be expected that the collection percentage will increase to over 85% in the long term.

5. Soil Cover Allowance

109. Three types of soil cover are required to operate the controlled landfill correctly. The first and possibly most critical is the application of daily cover to a thickness of 100 to 150 millimetres. This cover provides a multitude of engineering interventions including a reduction in water infiltration leading to less leachate generated, less vermin on site, reduced bird numbers on site, reduced litter and reduced odours.

110. If an area of the controlled landfill is to be left uncovered for a period of a few months, and intermediate cover to a thickness of 300 mm should be applied.

111. Final cover usually consists of two layers. For the first layer is a 600 millimetre thick clay or silty clay cap to prevent rainfall infiltration. The final 600 mm thick layer is a growing medium of compost or some other silt to facilitate plant growth.

112. The application of cover can contribute between 15 and to 25% of the total controlled landfill volume. However smaller percentages are possible at well run controlled landfills recovering the daily soil application prior to commencing another lift of waste.

113. For this study, it has been assumed that 15% of the total controlled landfill volume will be cover material. This is because it is expected that the daily cover may in fact the only applied on a weekly basis or at some other lesser frequency.

6. Compaction Allowance

114. There are two options for providing compaction at the controlled landfill. The most common is the use of a tracked bulldozer which at the usual size of a D7 equivalent will achieve a bulk density to a maximum of 650 kg per cubic metre.

115. However if a purpose built landfill compactor is used, then the smallest of the usual size (being a 25 tonne unit or a Caterpillar 816 equivalent) should achievable density of 750 kg per cubic metre. If the midsize compactor of about 35 tons or a Caterpillar 826 equivalent is used, then the density would generally approach 900 kg per cubic metres.

116. Because of the small size of the controlled landfill, it is proposed to purchase a slightly smaller bulldozer such as a D6 which will a suitable size to be able to push and shape the waste

quantities and provide some compaction. A dedicated landfill compactor cannot be justified for the short to medium term waste loads.

117. The adopted density is 600kg/m3. This will be readily achieved on average as a landfill compactor is recommended when operating the later cells.

7. Controlled landfill Airspace Consumption

118. Based on the above assumptions, the cumulative waste volume taken up at the controlled landfill has been calculated on an annual basis.

119. Based on this theoretical waste volume, the controlled landfill cells have been sized. Traditionally the first stage or cell at a controlled landfill should provide some 5 to 10 year's capacity. Typically the overall controlled landfill site selected should have capacity for at least 30 years operation.

120. The design approach in this report is to have four cells in the ultimate controlled landfill with the first cell to provide approximately five to ten years operation. By utilising over-topping techniques to eventually combine the four cells into one mound, the total life will be approximately 30 years as required.

121. In reality there are numerous factors that could eventuate and impact upon the assumptions and predictions to alter this predicted controlled landfill life in the coming decades. However these impacts can be counteracting, such as a lower growth rate than that predicted could be compounded against a higher per person waste generation rate and so on.

122. Therefore it is recommended that the following table of cumulative waste volume be adopted as the best available predictions at this time. Any variations to the many components intrinsic to this prediction will only alter the life of the controlled landfill and not the concept nor the basic design. If the cumulative waste volume at the controlled landfill is either significantly larger or smaller compared with the predictions below, then the later cell sizes can be amended to compensate for these variations.

123. These projections will obviously be refined at the time of detailed design.

Table 4– Population, Waste Mass and Controlled Landfill Volume Projections

YEAR	Province TOTAL	Provincial Annual Growth Rate	Urban Growth Rate	Projected Serviced Population	Rate of Waste Generation post HH Recycling	Daily Waste Generated	Percent Collected	Daily Waste Collected	Annual Waste Collected	Cumulative Waste Collected	Cumulative Airspace Consumed in Landfill	Landfill Capacity	YEAR
	2008 Census	2008 Census	Medium Growth Scenario		kg/person.day (0.50 increasing to 0.65 over 30 years)	Tonnes/day		Tonnes /day	Tonnes/ year	Tonnes	Cubic Metres (Waste density at 600kg/m3; 15% cover volume; 15% recycling at landfill	Cubic Metres (Stage 1 and Ultimate)	
2008	410,706												2008
2009	415,684	1.21											2009
2010	420,620	1.19											2010
2011	425,673	1.2	2.34	49,100									2011
2012	430,990	1.25	2.34	50,200									2012
2013	436,541	1.29	2.34	51,400	0.5								2013
2014	442,293	1.32	2.34	52,600	0.51								2014
2015	448,221	1.34	2.34	75,700	0.51								2015
2016	454,395	1.38	2.49	77,600	0.52								2016
2017	460,872	1.43	2.49	79,600	0.52								2017
2018	467,602	1.46	2.49	81,500	0.53								2018
2019	474,534	1.48	2.49	83,600	0.53	44	20	9	3,300	3,300	5,400		2019
2020	481,613	1.49	2.49	85,700	0.54	46	25	11	4,200	7,500	12,300		2020
2021	488,836	1.5	2.49	87,900	0.54	47	30	14	5,200	12,700	20,700		2021
2022	496,201	1.51	2.49	90,100	0.55	49	35	17	6,300	19,000	31,000		2022
2023	503,674	1.51	2.49	92,300	0.55	51	40	20	7,500	26,500	43,200		2023
2024	511,229	1.5	2.49	94,600	0.56	52	50	26	9,600	36,100	58,900		2024
2025	518,839	1.49	2.49	97,000	0.56	54	60	33	11,900	48,000	78,200		2025
2026	526,503	1.48	2.47	99,400	0.57	56	70	39	14,400	62,400	101,700		2026
2027	534,392	1.5	2.47	101,900	0.57	58	70	41	14,900	77,300	126,000	134,800	2027
2028	542,076	1.44	2.47	104,400	0.58	60	70	42	15,400	92,700	151,100		2028
2029	550,036	1.47	2.47	107,000	0.58	62	70	43	15,900	108,600	177,000		2029
2030	558,124	1.47	2.47	109,600	0.59	64	70	45	16,400	125,000	203,700		2030
2031		1.47	2.4	112,300	0.59	66	80	53	19,400	144,400	235,300		2031
2032		1.47	2.4	115,000	0.60	68	80	55	20,000	164,400	267,900		2032
2033		1.47	2.4	117,700	0.60	71	80	56	20,700	185,100	301,600		2033
2034		1.47	2.4	120,600	0.61	73	80	58	21,300	206,400	336,300		2034
2035		1.47	2.4	123,400	0.61	75	80	60	22,000	228,400	372,200		2035
2036		1.47	2.3	126,300	0.62	78	85	66	24,100	252,500	411,400		2036
2037		1.47	2.3	129,200	0.62	80	85	68	24,900	277,400	452,000		2037
2038		1.47	2.3	132,200	0.63	83	85	70	25,700	303,100	493,900		2038
2039		1.47	2.3	135,200	0.63	85	85	72	26,500	329,600	537,000		2039
2040		1.47	2.3	138,300	0.64	88	85	75	27,300	356,900	581,500		2040
2041		1.47	2.2	141,300	0.64	90	85	77	28,100	385,000	627,300		2041
2042		1.47	2.2	144,500	0.65	93	85	79	28,900	413,900	674,400		2042
2043		1.47	2.2	147,600	0.65	96	85	82	29,800	443,700	722,900		2043
2044		1.47	2.2	150,900	0.66	99	85	84	30,700	474,400	772,900		2044
2045		1.47	2.2	154,200	0.66	102	85	86	31,600	506,000	824,400		2045
2046		1.47	2.2	157,600	0.67	105	85	89	32,600	538,600	877,500	1,146,900	2046

The population projections are based on the Census figures and growth rates for urban areas. The growth rate for urban areas stated in the Census has been reduced as it is expected that most growth will occur in Phnom Penh rather than provincial cities. So a lower growth rate was adopted. The 'extended' populations have been assumed by 2015 - i.e. the municipalities will have extended their boundaries as they have indicated. Afyer 2030 a reducing urban growth rate has been adopted for the enlarged service area to the 30 year time horizon.

H. Collection System Upgrade

1. Background

124. The private SWM collection company is not following the appropriate guidelines by DoE and as agreed in the contract between SWM collection company and the Municipality in 2009. Specifically, waste collection is specified as being from 1500 houses and the market on a daily basis, but is only done one or twice a week. The waste collection equipment is not in accordance with the contract and significant quantities of waste are loss in transport. The Company is required to supply public dustbins and carry out some awareness raising, but has not done so to date. Existing roadside bins are provided by communes and DoE but are emptied by SWM company. Road sweeping along main road NH5 is to be done but is not carried out.

125. The existing fleet is completely inadequate to collect waste and dispose of it at the disposal locations. It consists of two old vehicles each with a capacity of 11.5 cubic metres. On avergae the trucks combined haul 3.5 loads per day. At a typical uncompacted raw waste density of 250 kg/m^3 to 330 kg/m^3, and assuming the loads are 90% full, this gives the total hauled per day of 9 to 11 t/d. A figure of 10t/d has been adopted. There is a third much smaller truck which does not haul waste every day.

126. In terms of haulage capacity, identifying goals, objectives, and constraints can help guide the planning process. Issues that should be considered include the following:

- Level of service: What level of services is required to meet the community's needs? What materials need to be collected and what are the requirements for separate collection of these materials? What needs and expectations exist with respect to the frequency of pickup and the convenience of set-out requirements for residents?
- Roles for the public and private sectors: Is there a policy preference regarding the roles of the public and private sectors in providing collection services for wastes and recyclables? If collection is to be performed by private haulers, should the municipality license, franchise, or contract with haulers?
- Waste reduction goals: What are the community's waste reduction goals and what strategies are necessary or helpful in achieving those goals? For example, source reduction and recycling can be facilitated by charging customers according to the volume of wastes discarded, by providing convenient collection of recyclables, and by providing only limited collection of other materials such as yard trimmings and tires.
- System funding: What preferences or constraints are attached to available funding mechanisms? Are there limits on the cost of service based on local precedence, tax limits, or the cost of service from alternative sources?
- Labour contracts: Are there any conditions in existing contracts that would affect the types of collection equipment or operations that can be considered for use? How significant are such constraints and how difficult would they be to modify?

127. Communities can select the level of services they wish to have provided by choosing how often to collect waste and even the location from which waste will be collected at each residence. The greater the level of service, the more costly the collection system will be to operate. Factors to consider when setting collection frequency include the storage container type, cost, customer expectations, storage limitations, and climate. Most municipalities offer collection once or twice a week, with collection once a week being prevalent in developed countries and some developing countries.

128. Crews collecting once per week can collect more tons of waste per hour, but are able to make fewer stops per hour than their twice-a-week counterparts. Once-a-week systems collect 25 per cent more waste per collection hour than twice weekly collections. Personnel and equipment requirements for daily collection are generally 50 per cent higher than for once-a-week collection. Some communities with hot, humid climates maintain twice-a-week service because of health and odour concerns, but more often cannot be justified in reality.

129. Therefore there are significant savings to be made if the household collection service frequency is reduced from daily. Inner city commercial establishments such as restaurants and markets will still require daily collection. Thus less frequent collection should therefore remain the aim for the mid to long term when rigid containers are adopted rather than plastic bags or just open dumping on vacant land.

130. Based on the deficiencies of the existing fleet and also discussions with the city, it was decided that the following approach would be adopted to selecting the collection fleet:

- Door to door collection for households would be the aim of developing the collection fleet requirements. In general, daily collection would be the aim initially as plastic bags become damaged by dogs if left out too long for collection.

- In the longer term when there is a move away from small plastic bags to rigid containers, either metal or plastic, then the collection frequency could be reduced and greater efficiencies in haulage achieved.
- The exception would be hard to access areas where hooklift bins would be placed for households to take their waste to the bin locations, or be serviced by Riksaaf or handcarts in some areas. This would include the river households, including both the true boat houses and the floatable houses on the river banks.
- Institutions, markets and commercial activities such as hotels and restaurants would be served with strategically placed hook-lift or other bins such as plastic Mobile Garbage Bins, of various sizes.
- The waste reduction goals and associated recycling imperatives will be covered as part of the information and education campaign.
- Staff mobility and labour contracts was not seen as a major issue.

131. There will also be a general aim to increase mechanisation in the collection system by way of using garbage compaction trucks (instead of tip trucks) and hooklift bins (instead of uncontrolled dumping on vacant areas or drains).

2. Waste Compactor Trucks

132. Two sizes of compactor trucks will be utilised. The larger 20 cubic metre trucks, while still small compared with some units used internationally, will be appropriate for the larger roads within the city. The method of operation will involve the driver proceeding slowly down the street with staff walking to each house to collect their rubbish and place it directly in the compaction trough at the rear of the vehicle. The compactor truck will continue collecting in this manner until the vehicle is full, or the collection service is completed, then it will proceed directly to the controlled landfill for emptying.

133. The compaction vehicles do not need secondary dumping locations as the waste is compacted and it is efficient to haul the waste directly to the controlled landfill. These larger trucks could make up to two return trips to the controlled landfill each day, but initially on only trip per truck is proposed for redundancy reasons.

134. Even at a conservative waste density in the compactor of 500kg/m3, the large compactor trucks will haul 10 tonnes of waste, or the daily waste from approximately 4,000 to 5,000 households. This means that the efficiency of collection is maximised as there is a reduced need to make multiple trip to the controlled landfill.

135. To navigate the narrower streets and alleyways within the city, a number of smaller five cubic metre compacting trucks will be utilised. These vehicles will navigate the local narrower streets and alleyways until full when they will directly haul the compacted waste to the controlled landfill. These trucks would be expected to make at least two return trips to the controlled landfill each day.

136. These smaller compactors can also be equipped with lifting arms to lift the waste from pushcarts directlyl into the compactor trough, avoiding the need for manual emptying of pushcarts used in narrow alleyways and non-trafficable streets.

3. Hooklift Trucks

137. A hooklift truck will also be required to haul the bins from the city precinct to the controlled landfill.

138. These trucks will operate by bringing an empty bin back from the controlled landfill and placing it beside the full bin, and then loading the full bin and taking it to the controlled landfill for emptying.

139. These trucks would usually expect to make more than six return trips a day.

4. Tip Trucks

140. A body tipping truck will also be required for the collection of general litter throughout the city.

141. Alternatively additional hooklift trucks and bins could be used for this purpose once the community is more aware of the need for better SWM and littering is substantially reduced.

5. Riksaaf Vehicles or equivalent

142. There are a number of small streets and alleyways that are too narrow and uneven to allow access by even small compactor trucks.

143. Therefore a number of the Riksaaf three wheel vehicles, or equivalent, capable of carrying some 200 kg of waste will be utilised.

144. These vehicles would collect waste door to door from households and then carry the full load to hooklift bins acting as intermediate dumping areas.

145. These will only be used where small compactor trucks cannot reach.

6. Pushcarts

146. For the very difficult to access areas, additional pushcarts will be purchased.

147. The modern pushcarts can have capacities up to 600 litres and are fitted with a tipping mechanism to facilitate easy emptying into the hooklift bins. Alternatively a lifting mechanism can be attached to the compactor trucks to empty the pushcarts directly into the compactor. In this case, the filled pushcarts are parked along a suitably wide road that the compactor trucks can reach at the end of the day.

148. There are also versions of pushcarts connected to a bicycle to facilitate quicker turnaround if the collection area is somewhat remote from the hooklift bin.

7. Hooklift Bins

149. The hooklift bins will be a variety of sizes ranging from small 2 cubic metre bins up to even 30 cubic metre bins. All bins would be equipped with rear entry doors to allow walk-in and drive in access to the bin. Unless these bins have easy access, experience confirms that people will merely dump the waste by the side rather than either reach over the low side to place waste within the bin or enter through the rear doorway. Often children are sent to dispose of the waste and the sides must be low enough for children to reach over the sides, so a maximum height of 900mm is often adopted for the bin wall height.

150. Also a pushcart or Riksaaf truck can drive into the rear of the bin to empty their load without having to shovel it out.

151. The actual size mix and location of the bins will be determined after a detailed public consultation campaign at the time of detailed design. The hooklift bins will be placed at strategic locations based on the following criteria;

- Bins will need to be near areas where pushcarts and Riksaafs are used, to minimise hauling distances for these small vehicles
- Bins will also be placed near institutions such as schools and commercial precincts, especially markets, where door to door collection is inappropriate
- Bins will also need to be placed near the river house precinct.
- Preference given to using exiting sites where possible as the local community is familiar with the location

152. The final location of the hooklift bins will be determined at the time of detail design when the final specification of other haulage equipment is determined and will be based on a series of community consultation meetings and council discussions. However the number of bins will be kept to a minimum as the waste in bins is not compacted and therefore represents a less efficient haulage model than garbage compactors.

153. There will not be any open secondary dumping areas where waste is merely placed on vacant land or into drainage easements for manual removal.

8. Vehicles and Collection Equipment Required

154. A range of factors were used in determining the number and mix of collection equipment required:

- Adopt 2027 as the target year when Stage 1 of the controlled landfill will be fully utilised. This will be some 8 years after the controlled landfill is commissioned in 2019 and also the new waste fleet is made operative. The design operating life for good quality haulage equipment would usually be 10 to 15 years. However, if cheaper units are purchased or the rigorous scheduled and preventative maintenance programs are not properly implemented, then the equipment will be far less reliable after 5 years.
- Assume that only 70 percent of the total waste generated is to be collected in 2027. Many cities in developing countries struggle to achieve 80 percent collection at present but aim to collect 90% in the future. The challenge with this particular city is the presence of the numerous river houses which will tend to just litter.

- In many cases hooklift bins, and to a lesser extent also the compactor trucks, will not be full when hauling to the controlled landfill. It has been assumed that on average the loads are only 80 percent of capacity. This will certainly be the case with the hooklift bins and tip truck
- With increased mechanisation of the fleet, an allowance must be made for both breakdowns and programmed maintenance. It has been assumed that only 80% of the mechanical fleet capacity would be available at any one time
- Also it is assumed that waste will only be collected 6 days a week so the quantity collected on working days increases to 7/6 times the average daily waste quantity generated.

155. Therefore it is assumed that approximately 41t/d will be collected out of 58t/d of waste generated in 2027 (70% collection efficiency). Collection is only over 6 days so the new fleet has to haul 47 tonnes per work day in a six day working week. Factoring in the allowances for only partially full loads (80%) and equipment being unserviceable due to maintenance or breakdowns (80%), the haulage capacity required by the new fleet is therefore 73t/d, say 70t/d capacity.

156. Based on this approach, the following new equipment is required to handle the projected waste load expected in 2022.

Table 5– List of Collection Equipment

Collection Equipment	**No. of Units**	**Trips/ Vehicle**	**Tonnes Hauled**	**Comment**
Waste compactor collection trucks (20m3 capacity - 10t)	2	1	20	Having two compactors hauling just one load per day provides some redundancy as well as allowing shorter working hours, thereby reducing traffic disruption in peak hours. Additional partial or full loads can be made if and when required
Waste compactor collection trucks (5m3 capacity – 2.5t)	5	2	25	Assume 2 loads per day per truck making 5t/d per truck.
Waste body-tipper collection trucks (7.5 tonnes)	1	2	10	10 t/d of litter clean up
Hook lift waste collection trucks (prime mover)	1			This is just the prime mover to haul the hook lift bins
Hook lift bins (from 2 to 12 m3)	30	6 equivalent loads in total per day	15	Assume a variety of hook lift bin sizes are hauled per day, on average 6 loads a day making say 15t/d.
Small motorised carts such as Riksaaf	2			Waste is dumped into hook lift bins
Pushcarts (various sizes to suit terrain)	40			Waste is dumped into hook lift bins or lifted directly into compactor trucks
TOTAL			**70t/d**	

Source: TA 7986-CAM Consultants

9. Interim Collection Fleet

157. The cost presented in later sections indicate that the operating cost for this collection system together with a correctly functioning controlled landfill will be at least three times higher than the current grossly ineffective system.

158. Therefore one alternative is to purchase less haulage equipment initially and continue to utilise the existing equipment by the private sector contractor. However this will then establish competing service standards within the one city as well as differential charging making the new system less attractive to consumers.

I. Review of Waste Processing and Disposal Options

159. Incineration of waste would considerably reduce the volume of waste for controlled landfilling. In the process of burning this waste it is possible to generate some energy. However, it is clear that the proceeds from energy sale would not offset the running costs, let alone redemption on the capital investment however. Incineration is not therefore considered a viable option especially since the waste is comingled and has significant organic material and elevated moisture content.

160. Baling domestic waste is a technique similar to compaction and uses pressure to bind the waste into a tight mass ready for disposal. This process significantly reduces the volume of waste and makes handling and transportation easier. However, baling plants are costly to purchase and operate. Baling of waste would not be an economically viable option in the study area given the small volumes of mixed waste involved.

161. An Integrated "Zero Waste" Approach was investigated as there is significant global interest in such schemes. The aim of such facilities is very clear, that is, to have a zero waste operation. Such schemes include trommels for waste segregation, metal removal magnetic drives, waste picker conveyors for recyclables recovery, composting schemes including screening and bagging, incineration and finally brick making with ash. There have been many pilot and short-term trials which have the theoretically achieved a zero waste position, but none in a sustainable real world application. They are not therefore recommended.

162. Most of the above methods, (together with composting and encouraging using household organics to feed domestic animals) can be used to reduce the volume of overall waste for disposal; however a disposal system is still required for the residual waste stream. Given the cost of the above methods, controlled landfilling is still considered the most appropriate method for disposal. It is proposed to eventually divert greenwaste for chipping to be used for mulching and re-use, crushing demolition waste for producing aggregate, and encourage recycling of other waste stream components, such as plastic bags, as well as variety of at-source organic waste reuse options related to the success of waste segregation. In summary, only residual wastes will be controlled landfilled.

163. The selection of the standard for the disposal facility has been based on the table below. The first option of open dumping is what is happening at present and cannot be supported in the future. The last option of a fully engineered sanitary landfill complete with artificial liner and leachate treatment is far too expensive for the relatively small city and far too complex to operate sustainably. Given that there is little difference in cost or operational difficulty between a controlled

dump and a controlled landfill, but the controlled landfill has significantly better environmental benefits, it is proposed that a controlled landfill is the most appropriate disposal system for the city.

Table 6 - Controlled Dump and Landfill Options

Type	Characteristics	Advantages	Disadvantages
Open Dump	• poorly sited • unknown capacity • no cell planning • little or no site preparation • no leachate management • no gas management • occasional or no cover • no waste compaction • no fence • waste burning • no record keeping • uncontrolled waste picking • no monitoring of groundwater	• easy access • low initial cost • low operating cost • aerobic decomposition • access to waste pickers • materials recovery	• high environmental impacts • unsightly • groundwater contamination • surface water contamination • high risk of explosion, greenhouse gases • vectors/disease transmission • reduced lifetime of dump site • inefficient use of landfill area • breeds vermin - rodents, flies • no record of landfill content • air pollution
Controlled Dump	• sited with regard to hydro-geology • planned cell development • grading, drainage in site preparation • partial leachate management • no waste covering • no compaction • fence • basic record keeping • uncontrolled waste picking • waste burning • no gas management • no monitoring of groundwater	• moderate environmental impacts • permits long term planning • improved stormwater control • less risk of leachate release • controlled access and use • access to waste pickers • materials recovery	• moderate environmental impacts • unsightly • groundwater contamination • surface water contamination • moderate risk of explosion due to gas • vectors/disease transmission • reduced lifetime of dump site • inefficient use of landfill area • breeds vermin - rats, flies • no record of landfill content • air pollution • high health risk to waste pickers
Controlled Landfill	• sited with regard to hydro-geology • planned cell development • grading, drainage in site preparation • improved leachate and surface water management • regular (not usually daily) cover • waste compaction • fence • basic record keeping • controlled waste picking • gas management • monitoring of groundwater	• low environmental impacts • permits long term planning • improved stormwater control • reduced risk of leachate release • controlled access and use • reduced risk to waste pickers • materials recovery • waste is covered by soil	• reduced environmental impacts • limited potential for groundwater contamination • limited potential for surface water contamination • low risk of explosion due to gas • reduced risk of vectors/disease transmission • extended lifetime of landfill site • efficient use of landfill area • reduced breeding of vermin - rodents, flies • no record of landfill content • air pollution
Sanitary Landfill	• site based on environmental risk	• minimized environmental risk	• high initial cost • high operating costs

Type	Characteristics	Advantages	Disadvantages
	assessment • planned cell development • extensive site preparation • full leachate and surface water management • full gas management • daily and final cover • daily waste compaction • fence and gate • record waste volume, type, source • no waste picking	• permits long term planning • improved stormwater control • minimized risk of leachate release • reduced risk from gas • vector control • improved aesthetics • extended lifetime • controlled access and use • eliminate risk to waste pickers	• longer development time • slower waste decomposition • minimized risk of vectors/disease transmission • minimized risk of vermin – rodents, flies • displacement of waste pickers • loss of recyclable resources • optimum use of landfill site

Source: Adapted from Municipal Solid Waste Management. United Nations Environmental Program, 2002.

164. More details on the waste processing and disposal options are provided in **Appendix D – Waste Processing and Disposal Options**

J. Controlled Landfill Details (Toul Makak Keut)

1. Description

165. The preferred site for the controlled landfill, called Toul Makak Keut, is a new site about 7 kms East of the town and more than 1 km South of National highway 5. The site is considered suitable as it is far from habitation, with the nearest house over 700 metres away, and is otherwise surrounded by fields. A resettlement area will be constructed in the locality as well, but sufficiently remote from the controlled landfill site.

166. Some land swap will be required for the last 500 metres of the access road, but both the DoE and Municipality confirmed that this swap has been agreed with the land owner. The existing access roads in the area are in very poor condition and without any true road structure. Any existing access road will have to be completely rebuilt to allow all weather access to the landfill. There is no formed access road from this road heading into the landfill site proper.

167. So essentially there is complete reconstruction of the 1,600 metre long access road coming off National Highway 5 leading into the landfill, followed by the internal landfill access road which is 160 metres long.

168. The land and surrounding areas reportedly suffer from regular flooding to a depth of about one metre. Therefore the access road will have to be elevated to provide all-weather access and the landfill protected by an encircling bund.

169. The site consists of mainly a sandy silt, with some areas exhibiting slight surficial cracking indicating some clay component. Clay will be required for constructing the liner underneath the cells. If there is insufficient clay of the required quality onsite, clay will have to be imported from a local clay pit. Costings for the site have assumed that the clay will have to be imported as a conservative approach. Local excavations indicated areas of gravel are present at depth.

170. The site does not have any major drainage issues and there are no water courses crossing the site. Most of the site is presently covered with brush and small shrubs, and surrounded by fields which are being prepared for rice paddies.

171. The controlled landfill will be developed in four main stages. The four stages will occupy an area of about 6 hectares excluding any allowance for some small buildings, roads, recycling put down area and any buffers around the waste mound.

172. There are no people to be relocated. The nearest community and sensitive activities such as local markets are suitably distant from the site.

173. Regarding the depth to water table, local landowners confirmed that wells need to be sunk to a depth of 30 metres to achieve a reasonable water yield. Wells to a depth of 10 metres remain completely dry. Therefore it may be assumed that any excavation required in the construction of the landfill will still remain many metres above the water table as required. This will be confirmed as part of the hydrogeological assessment at later detailed design.

174. Overall, the site is considered suitable for a long term controlled landfill and provides appropriate buffers to sensitive developments and also has a suitable hydrogeological profile with some clay content obvious. Cracking of surface oils was observed in a number of locations indicating significant plasticity which is required to achieve the low permeability necessary for the liner system.

175. The facilities to be provided under the future loan are part of Stage 1 as follows:

- A 120m by 120m initial cell (Cell 1) of the proposed four cell system required for the 30 year development, including associated bulk earthworks and compacted clay liner system
- The cell liner has been costed as a compacted clay liner, with the clay to either be sourced on-site and reworked or imported from local clay pits.
- Various buildings are required including a reception/gatekeepers hut, ablution blocks, meeting rooms, storage room, generator building, etc.
- Access roads both internal and external to the site necessary to reach Cell 1. The access roads are raised 1.5m high to prevent floodwater from overtopping the roads thereby providing all weather access to the site
- An encircling bund 1.5m high to prevent floodwater from entering the site
- Areas to allow processing and stockpiling of recyclables. This will increase in importance over time as the community becomes wealthier and as a result the amount of packaging and therefore recycling opportunities increase.
- Leachate pipe collection systems and pumping stations, together with re-injection and irrigation systems. A leachate treatment plant is not required reducing both CAPEX and OPEX as well as operational complexity
- Stormwater drainage systems
- Potable and non-potable water supply, and
- Ancillary works such as landscaping, weighbridge, lighting and fencing.

176. A large stockpiling area has also been provided near the buildings compound for the future storage of raw and chipped green waste, raw and crushed demolition waste, recyclables from the waste picking activities, and bulky items such as old tanks or car bodies, and finally any difficult to manage waste such as tyres which are not allowed to go into the controlled landfill mound.

2. Cell Staging

177. The first cell airspace is 134,800 cubic metres which is enough for about 8 years of operation. The second cell in isolation will provide a similar number of years of operation.

178. The next stage of landfilling will be over-topping both the first and second cells to develop a unified single cell which will provide a total of about 18 years capacity, going to a maximum height of approximately 30 metres above the base.

179. The excavation depths for the first cell were based on a number of factors;

- the desire to maximize the separation between the base of the controlled landfill and the water table thereby requiring the excavation depths to be minimised
- the need to provide a balanced cut to fill design such that there would not be excess soil at the completion of Cell 1 nor would there be a need for significant importation of cover material

180. In the end, the adopted excavation depth was approximately 1.4 metres on average. This will provide some 20,200 cubic metres of soil which can be used for cover material for the life of Cell 1.

181. After some 10 years of operation, the excavation levels can then be decided for Cells 3 and 4 to provide the right amount of soil cover based on operational experience to date, as well as protecting the ground water table. This decision does not have to be made until better information is available on actual waste generation rates and local hydrogeology.

182. The capacity of the completed controlled landfill incorporating over-topping of all four cells is some 1,146,900 cubic metres. This will be sufficient capacity for more than 30 years of operation. The total mass taken to the site is expected to increase to about 90 tons per day 30 years later.

183. This cell staging approach is appropriate as most controlled landfills develop the first cells to provide about 5 to 10 years years of operation and the ultimate site to provide at least 30 years capacity.

3. Staged Development Strategy

184. The recommended overall site preparation/excavation program is illustrated in the appended Site Excavation Plan

185. A possible staged excavation and filling program would be as follows;

- excavate and prepare Stage 1 for filling.
- fill Stage 1 to the levels shown, while excavating and preparing Stage 2 for filling.
- fill Stage 2 to the levels shown
- fill the infill area above Cells 1 and 2 while excavating and preparing Stage 3 for filling.
- fill Stage 3 to the levels shown.
- fill the infill area above Cells 1, 2 and 3 while excavating and preparing Stage 4 for filling.
- fill Stage 4 to the levels shown
- fill the final infill areas to levels shown on as the final landform

186. The design balances the need for cover material over the life of the landfill with approximately 15% of the airspace consumed as cover. The volume of cover available may be increased or decreased by several means:

- raising or lowering the base of the future landfill cell areas.
- varying the slope of the base between a minimum of 1 per cent and a maximum of 10 per cent.
- varying the thickness of daily cover between 100mm and 150mm depending upon the effectiveness/performance of the waste compaction operation.
- winning cover from previously placed temporary (internal) batters when placing new waste against them.

4. Surface Water Management

187. Managing both external and internal stormwater runoff is critical at controlled landfills. Often the uncontaminated stormwater runoff is mixed with the leachate to produce a large volume of very dilute leachate which is hard to manage.

188. A key element of site drainage will include management of stormwater impounded in the active cells following a significant rain event. While the waste will initially be deposited at the higher end of the cell fee and work down slope, there is still a possibility that protracted rain will introduce enough rain water into the cell to allow the impounded water to contact the active waste face.

189. Relocatable sump pumps will be provided temporarily in the lower area of the cell to remove any impounded uncontaminated stormwater.

190. To control any floodwaters entering the site in the wet season, a 1.5m high earthen bund will be provided encircling the entire controlled landfill site.

5. Leachate Management Strategy

191. Leachate is one of the biggest environmental issues at controlled landfill and is traditionally treated and then discharged. However it is proposed to adopt a different approach where leachate generation is minimised and the leachate is either reinjected or irrigated at the site, obviating the need for a leachate treatment plant. The basics of the management strategy are as follows:

- eliminate seepage of leachate from beneath the site by installing a compacted clay liner, based on the in situ clay being too permeable without reworking or importing clay from local pits to construct the liner
- eliminate lateral movement of leachate by grading the base of the site to the central area and intercepting this seepage in leachate interceptor/collector drains.
- reducing the volume of leachate generated by using filling, compaction, shaping and covering procedures which severely inhibit direct rainfall entry.
- reducing the volume of leachate generated by intercepting and by-passing all upstream surface water catchment areas around the fill area in surface drainage channels or bunds for floodwater.
- progressively pumping leachate from deleaching wells and recycling it through the waste by means of reinjection “dry wells” or irrigating previously worked areas or future landfill areas in dry weather.

- monitoring the groundwater quality hydrogeologically upslope and downslope of the site.

192. In this manner it is anticipated that there will be no excess leachate requiring treatment and then disposal to the local water environment.

193. With the available size of the site and the many years that will be associated with each stage of the development of the final landform, there is ample time available to modify the system if required, and monitoring programs will be sufficient to detect problems on site before they become a potential problem for downstream users.

194. More details on leachate management, including calculations on likely volumes generated, are presented in **Appendix E – Leachate Management**

6. Landfill Gas

195. Gases found in controlled landfills are composed mainly of carbon dioxide and methane but can include minor amounts of ammonia, carbon monoxide, hydrogen, hydrogen sulphide, nitrogen and oxygen as well as many other trace constituents.

196. The volume of methane and carbon dioxide that is produced in controlled landfills globally is a fraction of one per cent compared to that produced by volcanoes, deep sea geysers, fossil fuel burning, forest burning, industry, termites, cattle, rice paddies, warming of the northern hemisphere tundra and so on. Therefore the net effect of the production of methane gas and carbon dioxide gas in controlled landfills with respect to the environment is negligible. However, controlled landfill gas can represent a significant fraction of the anthropogenic associated greenhouse gas emissions, and as such appropriate systems should be installed.

197. The volume of gas that will be produced during Stage 1, or even after the final overtopping following Cell 4 completion, is too small to attract commercial reuse opportunities.

198. Later stages may be attractive to reuse schemes that just burn the gas to heat brick kilns for example but not for generating electricity. In summary;

- The controlled landfill is too small to be economic for productive gas reuse such as power generation or scrubbing to make CNG
- The recommended option is progressively installing a gas blanket under the middle third of the final cover cap
- Collect gas and vent through 6m high passive vents
- If the methane is later required to be oxidised to reduce greenhouse impact, then a gas flaring system could be installed to convert the methane component to carbon dioxide. These units cost about $350,000 but are not required for at least a decade until the site has sufficient mass to generate enough gas to allow the flare to operate in a stable manner.
- Vertical gas wells can be retrofitted to maximise gas collection only if mandated in the future. The standard design for these vertical wells is to have them at a 50 metre grid pattern spaced over the site. The vents are slotted pipes 150 to 200 millimetres in diameter placed vertically in a 600 millimetre diameter gravel wick. These are usually only installed when there is sufficient waste on site to generate useful quantities of gas for commercial uses, and the earlier acid forming stages of the aerobic and anaerobic breakdown have finished and methane forming bacteria dominate.

199. Since any one or a combination of all of the above described treatments/controls can be implemented at a later date without detrimental effects, there is no need at this stage to make a final decision on this matter.

200. More details on landfill gas, including gas generation predictions, are presented in **Appendix F – Landfill Gas**

7. Maximising Landfill Capacity

201. As far as is practicable, the capacity of the site to accept waste should be maximised. The utiliosation of all the necessary environmental control measures and other infrastructure such as access roads can then be maximised economically.

202. The maximising of a site's capacity to accept waste usually involves the provision of relatively steep perimeter batters. Although compacted waste can be safely constructed on very steep batters (1H:1V) because of its inherent strength through a range of internal "reinforcing components" (plaster, timber, wire, metal, branches etc.) it has been found that final batter slopes are best designed at about 3H:1V so that a final soil and vegetative cover can be more easily established and maintained. An initial exterior slope of 2.5H:1V has been adopted which will settle over time to 3H:1V.

203. The upper level of the mounding is generally restricted to about the level of the surrounding topographic high points. This upper area of the landform should have a minimum final gradient of 5 per cent to encourage surface water runoff, allowing for some inevitable differential settlement of the waste mass over the long term.

K. Management of Specific Waste Types

204. Management of the waste entering the site is critical for both environmental and personnel safety.

1. Summary of Waste Categories

205. The waste entering the Site may be categorised as follows, with some examples given;

- Acceptable Wastes (General) – general household and commercial waste
- Acceptable Wastes (but Difficult) – tyres, mattresses
- Special Wastes (Sometimes Acceptable) – asbestos, liquid waste
- Prohibited Wastes – radioactive waste

206. The first two categories are always accepted, but the second category requires some special management.

207. The third category may be acceptable based on quantities involved, actual waste characteristics and so on, and is decided on a case by case basis.

208. Prohibited wastes are never allowed into the Site.

209. It is critical that all loads are inspected when they arrive at the Site gate or any future transfer station in the collection system.

210. See the standalone report **Landfill Operations Manual** for more details.

2. Acceptable Wastes (General)

211. The following general wastes will be accepted at the Site;

- domestic solid waste, as collected by city or private vehicles on a regular basis
- acceptable commercial and industrial waste regularly collected by contractors
- garden refuse (i.e. green waste or yard waste) that may or may not be collected separately to municipal waste
- inert waste, i.e. construction and demolition debris including concrete, timber, masonry, bricks, etc. These should be stored separately as they can be reused for gas collection blankets, etc.

3. Difficult Wastes (but always Acceptable)

212. Difficult wastes are those wastes that are allowed to be tipped at the Site but require special treatment to ensure that the best compaction/disposal is achieved. This class does not include hazardous or dangerous wastes.

- Tyres
- Mattresses
- Whitegoods (fridges, freezers or stoves)
- Car bodies
- Drums

4. Special Wastes (sometimes Acceptable)

213. These are other wastes that may be accepted on Site but will have to be decided on a case-by-case basis, and would include some hazardous and dangerous waste. Later sections provide more guidance on how to manage these materials, such as;

- asbestos
- medical waste, including "sharps"
- dead animals
- pathogenic wastes
- dry sludges, such as treatment plant sludges
- low level radioactive waste
- liquid waste, including paints and thinners
- toxic substances, such as acids and biocides (pesticides and herbicides)
- contaminated soil

214. See the Operations Manual for more details.

5. Prohibited Wastes

215. Items always unacceptable in the Site will include;

- hot loads, greater than 50oC in temperature
- pressure cylinders e.g. Condemned gas cylinders, fire extinguishers
- recyclables, except to the recycling area, such as greenwaste, bulk metals or reusable demolition waste
- large volumes of liquid waste
- radioactive waste
- large containers which cannot be crushed, and
- dangerous goods, such as reactive chemicals, explosives including unexploded bombs and so on. Dangerous goods are those wastes that can affect a person’s health or the environment. Some wastes appear to be safe when delivered to the Site but when tipped can react with the air, water or other wastes to form a dangerous material. Typical dangerous goods include;
  - Chemical wastes which can react to form dangerous gasses, liquids or solids. Chemical wastes can be either liquid or solid.
  - Radioactive wastes. These can come from hospitals, universities, research institutes and private companies
  - Liquid wastes can be dangerous. These include oils, pesticides, solvents, paints, etc.
  - Asbestos (can be safe if correctly packaged, but dangerous if dry and powdery)
  - Medical waste (may be safe if autoclaved or pre-treated in some other manner, but very dangerous if containing untreated used sharps and syringes)

216. There are many dangerous goods that can be delivered to a Site, and Site staff must exercise extreme caution when dealing with these wastes.

6. Pathogenic and Medical Waste

217. The provincial and referral hospitals both have incinerators and have a waste segregation policy in place. For example, the provincial hospital has 202 beds of which about 50% are usually occupied, and produces in the order of 200 kg of non-infectious wastes per day and less than 40 kg per day of infectious material. The infectious material includes general domestic waste which has come in contact with infectious material such as cleaning equipment as well as sharps. The simple but effective segregation procedure in place should ensure that the most dangerous components, namely the sharps and infectious waste, are sent to the incinerator on site rather than mixed with the domestic waste.

218. The incinerator was provided by the Japanese government and has a five KG maximum charging load and has a 25 minute minimum burn time. The incinerator is designed to reach 800° C which is adequate for the destruction of any infectious organisms but cannot guarantee an environmentally friendly burn for items such as plastics which usually require a 1200°C environment to be safe. An inspection of the ashtray indicated incomplete combustion but still the infectious matter would be inactivated. The ash is buried onsite in a plot close to the incinerator. Once this area is fully used, the ash could be sent to the proposed controlled landfill for safe disposal.

219. When the operator observes that the burn is incomplete, additional calorific fuel is added in the form of the timber in an attempt to improve the burn efficiency.

220. Various local small medical facilities, such as medical clinics, have inadequate facilities to correctly handle all their special waste. This has been confirmed by some medical wastes appearing in the waste dumps locally.

221. The main issue of concern is sharps (needles, scalpels). These should be managed by either:

- placing in a puncture proof container, disinfected and co-disposed with refuse in a dedicated cell at the Site, or
- destroying by burning in dedicated cardboard boxes fuelled by petrol or in special desk-top electric incinerators, for example. This is usually done at the Site of waste generation.

222. The key issue is that all medical facilities must segregate their waste at source prior to collection. That will ensure that only small quantities of the dangerous wastes are generated for special handling.

- green - biodegradable
- black - non-bio, non-infectious
- yellow - infectious
- orange - nuclear
- red - sharps

223. The ultimate solution is to require medical waste incinerators at the various institutions. Ash residual could be safely co-disposed with the refuse. The general requirements for an incinerator are that the temperature should be over 1 200^{o} Celsius and a residence time of 2 seconds. However the cost would be prohibitive for small facilities.

224. However because of local cost constraints, a dedicated disposal area at the Site for pre-treated medical and other special wastes will suffice at this stage. An alternative is autoclaving the hospital waste either at source or centrally at the SWM site.

225. In summary, infectious waste should be disinfected at the hospital or medical clinic and then deposited in a dedicated location within the landfill cell, along with household and other hazardous waste. The Landfill Operations Manual provides details on managing these wastes. The exceptions are the larger hospitals which have their own waste incinerators and adequate segregation procedures in place.

7. Household Hazardous Waste

226. The waste inspections identified only a very small quantity of household hazardous waste in the waste streams, such as used fluorescent tubes. Following the Information and Education Campaign and implementation of basic waste segregation, all household hazardous waste should be deposited in the dedicated cell within the landfill.

227. This dedicated portion of the cell would also be used to accept other appropriate hazardous waste provided it satisfies the requirements for waste acceptance described in the landfill Operations Manual.

228. The cell would usually have an operational life of only six months before it is then covered with clay soil, and an adjacent clay trench constructed within the overall cell.

L. Controlled Landfill Equipment

1. Landfill Compactor

229. A specialised landfill compactor can provide much higher waste densities than a large bulldozer. For the tonnage expected be received at the controlled landfill, even a small Compactor such as the CAT 816 model or equivalent weighing approximately 25 tonnes would be too large.

230. A landfill compactor would only be appropriate once the daily tonnage exceeds say 50t/d. For the ultimate costings meeting the 30 year time horizon, it has been assumed that a landfill compactor would be purchased, but this is not part of the initial equipment fleet.

2. Bulldozer

231. A bulldozer is essential at the controlled landfill for general pushing, shaping and preliminary compaction of the waste as well as soil cover placement and compaction.

232. A small bulldozer can achieve up to 600 kg per cubic metre density compared with a mid-size 826 compactor or equivalent which can achieve a density of up to 900 kg per cubic metre. The bulldozer is designed for the day to day pushing of waste whereas the compactor is only designed for trimming and will suffer driveline failures if used for extensive pushing activities.

233. Bulldozers are very flexible of pieces of equipment, and sometimes are taken from controlled landfill duties to be used for general roadworks or other activities that are more attractive to the city administration.

234. Given that a compactor will not be provided, it is essential that a suitable bulldozer is purchased and retained on site to ensure proper site operation. Given the initial quantity of waste expected at the site, a mid-size Caterpillar D5/6 dozer or equivalent would be appropriate.

3. Excavator

235. A 320 series excavator or equivalent is also required. The excavator would be used for loading cover soil on to the truck for deposition at the controlled landfill as well as removing waste which has to be relocated as required.

236. It also is used for general clean-up duties such as removing litter from stormwater drains.

4. Water tank

237. An 8,000l water tank mounted on a frame and equipped with a portable pump is required. This tank would be loaded on to the back of the tip truck and used to water down dusty stockpiles, access roads and cleared areas to limit dust, as well as initial response to fire control.

5. Tip truck

238. A six by four solid body tip truck is required for general haulage duties on site, as well as carting cover soil on a daily basis to the cell.

6. Leachate pump

239. A 5 l/s progressive cavity or multi-staged centrifugal, close coupled, submersible pump is required for the leachate pump station. This unit will pump leachate to either the leachate re-injection pit on top of the waste mound or the relocatable irrigation pipes. The pump unit will be fitted with the standard start and stop floats/electrodes.

7. Sump pump

240. A diesel powered sump pump handling 20 l/s will be required for placement in the lower end of the cell following extensive rainfall, when there is a risk that the impounded water will reach the active tipping face.

241. The pump has sufficient capacity to handle two consecutive days of rain and empty the cell prior to any further rain events.

242. Water would be pumped out over the encircling bund wall.

M. Controlled Landfill Staffing

243. Operators and general hands will be required for the SWM site operations, regardless of whether privatised or not. Staffing needs will be substantial given the need to operate the site correctly and need for specific skills for certain equipment like bulldozers. All workers on site will need to be provided with appropriate PPE and must wear it all times.

244. Waste pickers will still have a key role in final recovery of recyclables. They will be registered to ensure underage people do not access the site. They will also need to follow the site operators' instructions regarding where recovered materials can be stockpiled prior to sale, educated on the health and safety aspects of working near waste and heavy equipment, and provided with appropriate PPE.

245. An overview of the staff and skill sets required follow:

1. Head Office - General Manager

246. The general manager will be:

- Accountable for day to day management of the SWM program
- Reports on all financial and operational aspects of the SWM program on a monthly basis

- Accountable for all regulatory compliance issues
- Responsible for development of long term operational plans and strategic plans for the business
- Appointment of administrative and operational personnel if required in accordance with business plans and budgets approved by City
- Responsible for development of all principal contracts, calling and evaluation of tenders ; on-going administration and progress payments of all contracts
- Co-ordinates SWM program activity with the relevant executive officers in the various departments and council
- If suitably technically qualified, responsible for engineering development planning of the controlled landfill, and supervision of the operations contractor for the controlled landfill and transfer facilities. If not technically qualified, then some part time professional engineering support will be required.
- Clerical/secretarial staff may be required to support the GM. These could be supplied on rotation by the City or made new staff positions.

2. Site Staff

- Site Engineer (part time only)
- Site Supervisor
- Gatehouse personnel, if this function is not to be contracted out. This function is commonly contracted out to security companies, or at smaller facilities where cross-checking against a computerised weighbridge can be undertaken, it is included in the facility operations contractor's duties. The use of security companies as a contractor to the SWM program for gatehouse operation tends to provide a higher degree of security against the opportunity for petty or serious fraud associated with such operations (e.g. discounted rates paid directly in cash to the gatehouse operator)
- Equipment operators (including dozer and truck drivers)
- Grounds and environs maintenance personnel, particularly with regard to litter control and directing traffic on site where to landfill.

N. Climate Change Issues

1. Background

247. Landfills contribute to the emission of methane once the biochemical reactions are stabilised and the organic fraction is broken down. . However, reduction of methane emissions at urban landfills may not be cost-effective for Cambodia. This was shown in Phnom Penh where several foreign investment companies came to consider methane extraction however did not find it economically worthwhile. Phnom Penh landfill is far larger than the proposed controlled landfill in Kampong Chhnang, making the Kampong Chhnang site even less attractive for commercial gas harvesting..

248. However it should be noted that in Cambodia, rice paddies and wetlands are the major sources of methane, while methane production from urban solid waste accounts for only a small percentage of the total. Thus, national policy concentrates on the management of agricultural biomass, confirmed by the prevalence of investments in rural-based CDM projects. Furthermore, methane emissions can be reduced by investment in improved irrigation management, which also generates financial benefits

249. Cambodia's temperature has been rising steadily over the past 50 years. The average temperature has increased since 1960 by 0.8°C, and the frequency of unusually hot days and nights has increased. A further 0.3 to 0.6°C increase is expected by 2025, and some studies suggest temperatures may increase from 0.7°C to 2.7°C by the 2060s. All climate change models agree that average rainfall in Cambodia will increase, but the magnitude of change is uncertain. Estimates of the increase vary from as little as 3% to as much as 35% by the year 2100. Mean annual rainfall is predicted to increase, with the most significant increase in the wet season. In contrast, water flows in the dry season are predicted to decrease.

250. The following criteria have been used in conceptualizing the climate resilience measures for other infrastructure investments in Cambodia:

- An average precipitation increase of 5% up to 2050 (this is still a low estimate based on NAPA and MRC projections).
- An increase of annual peak flows in Mekong between Phnom Penh and Neak Loeung of at least 5% up to 2050 (no change during the wet season and 20-40 % increase during the dry season).
- Changes to the water level at individual locations have to be estimated based on local conditions

2. Response

251. Locally the main effect of climate change on Solid Waste Management will be hotter drier summers, more intense rainfall events in the wet season and possibly more frequent/more intense extreme weather events.

252. The hotter and drier summers means that grass and other vegetation planted on previously worked areas of the controlled landfill mound may die due to lack of water and heat stress. This will be overcome by a conscious plan to collect and pump leachate over the vegetation to act as an irrigant. This has been done successfully at many other controlled landfills and controlled dumps.

253. The more extreme wet weather events will be managed at the controlled landfill by ensuring that the external batters are protected against erosion resulting from the higher rainfall intensities.

254. The master drainage infrastructure will be sized to account for the higher rain fall intensities to prevent stormwater runoff entering the operating cells and associated recycling areas and stockpiles.

255. A further effect from the more intense storms will be a greater amount of debris damage to be managed at the Solid Waste Management facility. This will be managed by using the chipper to be purchased in the future to produce valuable products from any debris including any branches and trees which are damaged during the more violent weather activities. Alternatively a pit burner can be constructed at minimal cost to manage the additional tree and construction timber waste coming to the landfill after the storm events.

O. Remediation of Existing Dumping Sites

1. Closed Dump Site (Toul Makak Lech)

256. The closed dump is located on private land and was closed in response to many neighbourhood complaints. It consists of 2 cells both approximately 50m by 15m, and formed by pushing up a soil bund 1 to 2 metres high, and then filling with waste. There are also small piles of waste and windblown litter around the site but not in large quantities.

257. All exposed waste, apart from the windblown litter, has been burnt which will obviously greatly reduce the organic content and liberate most volatiles.

258. One cell is filled to bund level and covered with regrowth including bramble and grass. There were no signs of leachate leaching out of the encircling bund.

259. The other cell is filled to within a metre or so of the encircling bund top and has ponded water and hyacinth plus water tolerant grasses. There are signs of cattle access into this cell to either drink the water or eat the vegetation. The impounded water was relatively clear and not exhibiting organic contamination from waste leading to anaerobic conditions and gasification. There was no typical leachate odour present. One end of this cell is extended at the level of the bund top with a mixture of soil and waste, and covered with bramble and thorn regrowth

260. The local soil is a sandy silt but with some clay content. Some local dams were full of water which was impounded stormwater not groundwater. Some of the excavations showed clay slicks confirming the clay content.

2. Current Dump Site (Srah Srang)

261. The site is about 5 kms from town along a rutted laterite road. The land belongs to the SWM company but will be transferred to the Municipality in 2024. The area does not flood.

262. The site is about 1.5 ha in area with waste dumped on both sides of an old road alignment, and is severely environmentally degraded.

263. The waste is located predominantly in a U shape 100 metres long by 70 metres wide. The waste is approximately 20 metres wide and two metres high around the U shaped disposal area. In addition, a further disposal area continues along for another 70 metres and again is approximately 20 metres wide and up to two metres high.

264. There is also the evidence of illegal fly dumping along the access road at more than 10 locations.

265. The waste has being previously burnt and there was active combustion at the time of inspection.

266. The adjacent drain contained water at the time of inspection and there was leachate staining obvious within this water body, but not to the extent of making the water anaerobic and resulting in gasification. There was no obvious leachate odour from the drain.

267. The drain also exhibited signs of surficial cracking indicating substantial clay content. This was confirmed by the presence of slide marks from the excavator bucket along the drain slopes. Given the significant amount of clay in the local soils, it would not be expected that leachate would migrate vertically into the water table below.

3. Environmental Issues

268. In addition to the obvious environmental damage caused by waste fires, uncontrolled burning represents a serious health and safety risk. Incomplete combustion of the various plastic types at the dump can result in the formation of carcinogenic by-products such as dioxins. These airborne pollutants are being breathed in by the truck drivers and waste pickers at the site.

269. Small areas of surface combustion can be controlled with water and subsequent application of soil cover material. But the only way to completely extinguish subsurface fires at dumps is to excavate waste until the combustion source is reached. Therefore there is little choice in the remediation of this site but to adopt a cut and carry approach to remove all actively burning material and wet it prior to replacing and covering in accordance with a final design.

270. In summary, urgent action is required to prevent new fires starting in the dumping areas and to stop the fires in previously worked areas. Initially the surface fires should be extinguished and then deeper fires progressively excavated and extinguished as part of the initial activities leading to eventual full remediation.

271. While there was some obvious leachate contamination of the water course, the visual extent of the leachate contamination appeared only minor. The water courses were not black and anaerobic with gasification occurring, but rather just showed some colouration of the water column.

272. Some of the nearby water ponds appeared aerobic/oxic and were visually uncontaminated by leachate.

273. Whilst the leachate may be weak organically, it may still of course contain inorganics such as heavy metals and biocides.

4. Remediation Approch

274. For the closed dump site (Toul Makak Lech), the waste should be covered with 600 mm of low permeability soil and profiled to result in a minimum of all 5% slope to minimise rain water infiltration. The windblown waste around the site should be collected and placed within the partially full cell together with the waste from fly dumping on the rest of the site. For both the full and partially full cells, the existing perimeter bund should not be disturbed and additional clean soil brought in to form the clay cap and provide the final slope required. This is a very small remediation activity should be readily completed within 1 to 2 days. The waste is very old and has been burnt, so given the presence of some clay in the local soils, there is no justification in installing leachate management systems and gas recovery facilities.

275. For the current dumping site at Srah Srang, the waste deposited outside the U shape should be loaded and hauled for placement within the U shape.

276. The waste forming the U shape could then be pushed over the top of the waste hauled from the external areas, including all the fly dumping waste along the access roads and other isolated patches of waste, to form one consolidated waste mound. The consolidated mound should then be shaped to provide a minimum of five per cent fall on the plateau area, and 1 vertical to 2.5 horizontal slopes around the resulting perimeter bund.

277. The waste material should then be compacted as per normal controlled landfill operations and then covered. An impermeable layer of 600 mm of compacted clay would be provided on top of the final mound shape. On top of the impermeable clay layer, a similar depth of growing media would be installed, such as a loam or compost.

278. The biggest cost associated with remediation will be the excavation of burning/smouldering waste at depth, carting to a prepared area and spreading, extinguishing the fires, reloading the waste, returning it and finally compacting it. Minimising the quantity of waste that has to be extinguished will greatly reduce the overall remediation costs.

279. In summary at both to the closed and current dumping sites, the proposed approach is to prevent any further dumping happening at the old site and over a period of time to extinguish all fires within the waste mound at the current site. Once this has occurred, it is recommended that a simple cap be placed over the sites with a minimum slope of five percent to maximise rainfall runoff rather than infiltration. Given the very small size of the site together with the obvious presence of clay at depth, it is considered unnecessary to retrospectively install a leachate collection system and associated pumping schemes to irrigate or reinject the leachate.

280. Similarly because almost all of the organic material is either degraded or being combusted, there will be little landfill gas being produced therefore there is no requirement to install the gas management or collection system at this site.

281. Most of the remediation can be done prior to landfill construction by using the new landfill equipment which will be purchased early in the landfill construction process. The equipment can then be used to complete the remediation. The costs for the fuel consumed can just be drawn from the Municipal general operations budget.

282. The proposed remediation work will provide a training opportunity for the future landfill operators by using the same equipment that will be used at the site, such as the bulldozer, excavator and dump truck. This experience can then be transferred to operating the new landfill.

283. More details on other remediation options are presented in **Appendix G – Site Remediation**

P. Privatisation Opportunities

284. The options for privatisation are somewhat limited where the operation is just for a single local authority and the SWM collection system and recycling/disposal facility is relatively low technology. The collection system is unlikely to be fully mechanised in the foreseeable future to equipment such as side-lift trucks for mobile garbage bins (MGBs) of say 240-litre capacity. The controlled landfill will progressively have more recycling systems that will most likely only be basic, such as using mechanised chippers/crushers, thereby needing only lower cost and less trained staff to operate.

285. For these relatively simple operations, the private sector may not be attracted because of the low potential for innovative technical or management solutions that will make the private sector price cheaper than the City operating cost.

286. However if the City is interested in seeking greater private sector involvement, it can be sought on a non-commitment basis. This means that the City can seek tenders for one or more components of their waste management services and compare the offers. In any case, it is likely that the collection, recycling, and disposal aspects will be undertaken under different arrangements, contractual or otherwise.

287. Expanding private sector involvement in the collection aspects is the most promising opportunity. It is critical to consider the length of contracts for privatisation success. Short contracts of a year or two are insufficient to allow the investor enough time to recover his Capex exposure. Any privatisation contracts requiring extensive capital injection by the operator must be at least 5 years in duration, but preferably a minimum of 10 years, to allow amortisation of the

capital cost, such as providing a new waste compactor collection fleet. Alternatively the recommended collection fleet to be purchased under the loan could be leased by the city to the private sector operator.

288. Operation of the controlled landfill is probably not of great private sector interest given the relatively small size and low technology approach recommended for this Loan project, although again this could also be tested in the market place on a non-committal basis. Payment would usually be on per ton basis, with operational performance style specifications setting out recycling, environmental and operational criteria. In that case, the City would change to becoming a regulator rather than an operator.

289. Another option for private sector involvement will be if a pilot to small scale composting scheme is established. Whilst a full scale centralised composting scheme is not recommended for reasons listed elsewhere in this report, a pilot or small scale composting scheme could be established in partnership with local agricultural companies. Such a public private partnership would involve the private agricultural company agreeing to take and perhaps even pay for the compost generated. Even more critically than the take or pay agreement, there will be a need for the private company to agree to a stay on any form of litigation against the city if the compost contains foreign objects such as glass, plastic or metal residues or other contaminants.

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Q. Information and Education Campaign

290. The SWM Master Plan must address sustainability issues and not just engineering interventions. So an IEC is essential to upskill and educate the community, city and agency staff and civil society on many aspects of SWM, ranging from health and pollution impacts to waste minimisation and segregation benefits in the future.

291. At present there are some small community awareness Programmes on Solid Waste Management. These are jointly funded by the Department of Environment and some local NGOs.

292. It is critical to engage with the community and civil society to bring about a better understanding of the key waste management issues relating to the environmental and health impacts of poor waste management, waste avoidance, minimisation, reuse, recycling, household composting and the increasing need in the future for waste segregation especially green waste. In summary it will involve:

- Six month long program
- Household, community and school meetings involved - two group meetings / week with the number of participants between 15-20, together with a Media campaign. Meetings will be scheduled at times and locations convenient to all members of the community, especially considering constraints to the meaningful participation of vulnerable groups such as women, the poor, and ethnic minorities.
- Separate capacity building sessions for women to discuss feminine hygiene, sanitation and waste management issues (e.g., menstrual hygiene management)
- Gender- and culturally-sensitive literature and pamphlets to be developed based on existing sources
- Organize activities integrated with programs in schools, cultural and other venues.

- Organize thematic seminars noting the current state of the environment so that there are specific activities designed to meet the IEC objectives
- Training will eventually need to extend to the City residents generally and SWM staff

293. The above activities will be organized and prepared in a participatory manner, considering the recommendations for maximizing participation particularly among vulnerable groups as discussed in the social impact chapter of this Report

294. In detail, the IEC will need to address the following:

- community on waste minimisation, reuse and recycling
- community on using food scraps for animal feed or home/commune composting
- community on the impacts of illegal dumping and littering
- specific programs to address sanitation and waste management issues of women (e.g., menstrual hygiene management)
- specific programs will be required for the population living on the house boats or houses projecting over the water courses regarding the impacts of illegal dumping and littering
- City staff, waste pickers, site workers, equipment operators and so on for general controlled landfill recycling and disposal operations.
- community and city staff on segregating waste as it may be required in the future
- waste pickers educated on the risks and hazards of being exposed to waste and need for wearing suitable Personal Protective Equipment.
- Hospital and medical centre personnel on segregation of medical waste
- The cost implications of providing a higher service standard for both collection and disposal activities

295. There is plenty of ready-made literature, and training materials, that can be used and would be available through the multi-lateral donors and International nongovernment organizations (INGOs).

296. Some possible options are listed in the **Table 16.1 – IEC Components** below:

Table 7– IEC Components

Item	Issues	Approach
Environmental Management	Burning garbage causes air pollution and health risks	Explain the environmental damage caused by garbage fires
Environmental Management	Illegal disposal of garbage into creeks, rivers and vacant lots	Explain the environmental damage caused by illegal garbage dumping and littering, and the prosecution liability.
Waste segregation	Essential if mechanised recycling and composting schemes are to be efficient, but costly to have the necessary different receptacles and collection services.	Explain how to do this. Start at Household.level if segregation is desired.
Waste minimization	Purchasing products with least amount of packaging	Education on benefits of less cost of collection and wasted materials and landfill space consumed
Waste Toxicity	Reduce toxicity of products purchased and segregate hazardous waste for separate	Education on alternatives to certain chemicals, e.g. natural toilet cleaners

	collection and disposal	
Reuse	Reusing containers, such as bottles	Education on benefits as per packaging reduction and other sources
Recycling	Recycling containers, such as plastic bags for garbage containers	Education on benefits as per the above. Also need to market en masse for better prices (e.g. plastics and glass) and also obtain market access e.g. for sale of tin cans
Recycling	Drop off centers for selected items	Consider a centralized system for whitegoods, garden or green waste, hazardous waste, etc
Organic resue/ Composting	Do it at Household?	Training on methods and equipment required. Market development for local product. Also consider vermiculture? Encourage feeding of domestic animals
Greenwaste	How to manage yard and tree clippings	Chipper needed at the landfill in future. Chipping for mulch not composting is also an option
Menstrual hygiene management	Proper menstrual hygiene management, including disposal of menstrual materials	Incorporate into overall awareness actiivities, and work with groups such as WaterAID Cambodia on furthering awareness in schools.

297. The benefits will include:

- Compliance with Cambodian regulations
- Community educated about the socio-environmental impacts of poor waste management
- Community more willing to pay for better service
- Enhanced recyclable recovery rates. This will be incremental initially and then a major increase when greenwaste and construction and demolition waste are recycled in future years.
- Educated community on waste minimisation and the 3Rs (Reduce, reuse and recycle) including household composting where appropriate

298. The cost would be $50,000 for Pursat to manage and implement this campaign.

R. Institutional Support

1. Initial Support

299. The skills and experience in the City will need substantial upgrading to manage the controlled landfill operation, through Institutional/Capacity Development and a Training Needs Analysis for the key waste management staff.

300. Training would be best achieved by spending some time at a correctly functioning controlled landfill to observe all aspects of operation. Formal education is not a prerequisite as it is experiential knowledge that is required. These required skills are not text book based and observation is the best form of education together with some office based training on the theory.

301. Institutionally the waste management general manager will also need to attend controlled landfill operations training as well have an accounting capability to manage costs and budgets, as well as review monthly operational reports and prepare summaries for senior management.

302. The engineer will need training on controlled landfill design by visiting operational controlled landfills of a similar type. These skills are not only text book based and observation is the best form of education together with some office based training on the theory.

303. This initial support could be made part of the responsibilities of the Consultant who will undertake the detail design, construction supervision, commissioning and training for the project.

2. Ongoing Institutional Support

304. However the main requirement for institutional support revolves around the ongoing operation of the facility. Generally Solid Waste Management facilities do not fail because of design issues but lack of sustainable operational commitment. Many controlled landfills commence operation in accordance with the Operations Manual and Environmental Management Plan. However particularly if the controlled landfill is replacing an uncontrolled open dump, there are risks that bad habits learnt from operating an uncontrolled open dump re-emerge at the controlled landfill resulting in substandard operation.

305. In most cases with the contract for detailed design and construction supervision of a new Solid Waste Management facility, there is a training program prior to handing over the works as part of the deliverables. However this alone is unsustainable as the skills learned during the short term training program do not translate well to the on-going operational responsibilities. Most landfills soon therefater suffer from much the same failures, regardless of the amount of training given prior to handing over the works:

- Waste is not being placed according ot the staging plan and external batters and internal active tipping faces not profiled accordingly
- Waste is not being compacted correctly. The operators do not seem to recall the correct techniques for compacting waste to minimise fuel used and also maximise waste densities.
- Cover material is not being applied on a daily or even weekly basis resulting in excessive odour, vermin, birds, litter and leachate.
- Areas which will not be receiving waste for some months or even completed areas do not have the appropriate intermediate or final cover applied.
- Vegetation has not been planted on completed areas
- If the landfill is not self draining, then quite often impounded stormwater has not been pumped out as required in the operations Manual. This results in large quantities of very dilute leachate being generated and presenting a major management issue.
- The leachate irrigation and re-injection system is not being operated correctly resulting in emissions of leachate to the environment. This is usually manifested by a lack of maintenance on the pumping system and the irrigation pipe work at not being relocated on a regular basis.

306. Given the large capital commitment involved in developing a new Solid Waste Management facility, a two to three year monitoring/auditing system is required for the facility. This would involve an international specialist visiting the site every six months for a period of two weeks in order to review the operations at the controlled landfill facility, as well as collection and recycling facilities. The audit would assess the operation

by comparing it with the specifics of the Operations Manual and the Environmental Monitoring and Management Plan and standard practice.

307. The auditor must have considerable experience in the actual operations of engineered landfills rather than an academic background. It is not critical that the auditor has formal tertiary qualifications as the issues requiring assessment are not highly technical nor engineering based.

- It would be expected that the auditor would arrive at the site on Tuesday and review paperwork, particularly relating to the implementation of the operations manual and environmental management plan and associated water sampling results as well as visit the site. An experienced auditor should be able to do this within half a day and then convene a meeting of the operators in the afternoon. If as expected there are a number of substandard issues to be addressed, this allows the onsite operators to explain why some of these issues may have occurred, if being beyond their control. There may well be a lack of funding precluding the operation of the equipment onsite and therefore not operating in accordance with the Plans.
- Following this onsite meeting, the auditor would then spend one day assisting with improved operations on-site and prepare a quick summary presentation. The meeting would then be held on the third day to discuss these findings and understand why any substandard performance issues have not been addressed, especially management.
- Following this meeting, the auditor would then return to site and spend all day on site addressing any remaining onsite operational issues and provide additional hands-on and toolbox training as required. It is critical that these site days are a mix of hands on advice at the actual tipping face or recycling areas, supplemented by going over the original office based training plans as amended to provide the theory component as well.
- The auditor would then meet again with the management and senior operational staff in a workshop context on the following Monday. This would be the opportunity to agree a common way forward especially if there are management or funding issues impacting upon onsite operations.
- The auditor would then spend the next two days onsite closely monitoring all the revised operational activities and providing guidance and, as required, any formal classroom follow up.
- On Thursday the auditor would prepare a summary report of the initial findings, interventions undertaken, summary of meetings with the operators and management and any proposed operational or management changes for the coming six months. The auditor would call together all landfill operational staff and site management as well as office management to present this report and agree a common way forward based on the recommendations.

308. In summary almost all landfills fail from operational shortcomings rather than design issues. A structured training program, no matter how effective or comprehensive during the handover period, does not seem to translate into ongoing operational success. Therefore there should be 6 monthly audits undertaken by a landfill operational specialist (not a theoretician nor an academic) for a period of approximately three years post commissioning. The timing of the audits should not be overly regular and the arrival of the auditor should not be advised in advance otherwise special efforts may be made at the landfill to prepare for the audit that do not reflect the usual operational status.

309. The institutional support program post-commissioning will cost USD90,000 for the 3 year program.

S. Costs

1. Background

310. The costing for the site is for what may be considered the overall first stage which includes the full development of Cell 1, as well as the purchase of all required equipment. It also includes

the ancillary works described above such as access roads, buildings, lighting, leachate control systems and water supply and sanitation facilities.

311. CAPEX has also been determined for the 2046 case. Full details are provided in **Appendix H – Costings.**

2. 2016 Capital Costs

a. Controlled Landfill Construction Cost

312. The controlled landfill construction cost consists of four components namely:

- earthworks,
- buildings,
- roads, hard stand and trees screens and
- site infrastructure.

313. As mentioned above, the basic cell design has been developed in the absence of geotechnical information for the site. However inspection of the site indicates that most of the cell excavation will be into clayey soil rather than silt or rock. Inspection of the soil at the site indicated that at least some plastic clays are present, based on the cracking of the soil when it dries.

314. Therefore this clay soil maybe suitable insitu for construction of the liner under the controlled landfill, following wetting and compacting in three layers to make up the 600 millimetre thick clay liner. However to be conservative, it has been assumed that suitable clay material will be imported from local clay-pits, and the cost for purchase and hauling of this clay has been included. At the detailed design stage when geotechnical information is available, the design can be modified to respond to the actual soil conditions and possibly achieve significant savings in the clay liner cost allowed.

315. The unit rates for civil works and buildings were taken from recent contracts where rates were unavailable in the government approved costing schedules.

316. Some items have been included as PC unit rates for minor works such as those associated with water supply and sanitation.

b. Controlled Landfill Equipment

317. The controlled landfill equipment prices are based on indicative prices obtained from local suppliers. For the bulldozer and excavator, prices were obtained from Caterpillar which is one of the internationally recognized suppliers of such equipment. Similarly for the truck, prices were obtained from recognised suppliers such as Hino. There are many other suppliers of high quality equipment in these categories which are equally appropriate

318. The prices adopted represent mid-range quality equipment which should last for about 10 to 15 years if properly maintained. Much cheaper equipment is available from many other suppliers but the expected operating life would be substantially less, even with implementing the recommended programmed maintenance.

c. Land Purchase

319. Government land will be used and therefore there are no land purchase costs.

d. Collection Equipment

320. As with the controlled landfill mechanical equipment, prices were obtained from local suppliers for mid-range quality haulage equipment. The prime movers are either Hino or Isuzu brand (or equivalent) and the compaction equipment is imported from Europe. Again with the manufacturer's maintenance program being implemented, these vehicles should last about 10 years.

321. Much cheaper equipment is available but as for the controlled landfill operating equipment, this much cheaper equipment could be expected to have a much shorter Service Life.

322. Local supplier prices have been used for the hooklift bins as well as the hand carts.

323. The CAPEX AND OPEX costs are summarised below with the full breakdown presented in the Appendices.

Table 8– 2016 Capital Costs

Item	**USD**	**Riel**
CONTROLLED LANDFILL	**$1,137,000**	**4,548,000,000**
Earthworks	$74,650	298,600,000
Buildings	30,900	123,600,000
Roads, Hardstand and Tree Screen	675,400	2,701,600,000
Site Infrastructure	356,037	1,424,148,000
CONTROLLED LANDFILL EQUIPMENT	**$482,000**	**$1,9288,000,000**
WASTE COLLECTION FLEET	**$609,000**	**2,436,000,000**
TOTAL	**$2,227,000**	**8,911,948,000**

3. Operating Costs

a. Controlled landfill

324. The operating costs have been determined based on using actual local rates for the controlled landfill staff. A suitable staffing mix has been proposed including some part time senior management through to a number of general hands on site to ensure litter collection and other essential activities are carried out onsite.

325. The equipment operating costs are based on real world data and not just fuel consumption costs. The operating costs listed include an allowance for regular and programmed maintenance as well as replacement parts as the age of the fleet increases. Obviously the operating cost increases over time as the motors become less efficient and more extensive repairs are required.

326. The equipment operating costs do not include a sinking fund contribution to allow for replacing the equipment at the end of its useful life.

b. Collection

327. The equipment operating costs are based on real world data and not just fuel consumption costs. The operating costs listed include an allowance for regular and programmed maintenance as well as replacement parts as the age of the fleet increases. Obviously the operating cost increases over time as the motors become less efficient and more extensive repairs are required.

328. The equipment operating costs do not include a sinking fund contribution to allow for replacing the equipment at the end of its useful life.

329. The staff operating costs have been determined based on using actual local rates for the sanitary worker staff. A suitable staffing mix has been proposed including some part time senior management through to a number of general hands to ensure street sweeping, litter collection and other essential activities are carried out.

Table 9– 2016 Operating Costs

Item	USD	Riel
CONTROLLED LANDFILL OPEX/year	$90,000	360,500,000
COLLECTION COSTS/Year	$399,600	1,598,000,000
TOTAL OPEX/Year	$489,600	1,958,000,000

Source: TA 7986-CAM consultants.

330. The actual cost per domestic Household will be lower as commercial facilities, such as restaurants and hotels, as well as institutions such as schools and offices, will pay a higher charge for waste removal. This additional cost for non-domestic waste removal will reduce the net cost to a domestic household.

331. Even with the redistribution of costs, operating costs are significantly more than the current budget of notionally $1 to $1.50/month per household. Implementing the upgraded scheme will require community support which will be initiated at least through the information and education campaign, a progressive increase in tariff over a number of years and municipal and/or provincial government support in the early years.

4. Funding Options

332. The present system of a private contractor being reimbursed directly by the households and commercial institutions is not an efficient system. The city should be responsible for entering into a contract with the private contractor and to pay them on a per household or per tonne basis, and the City is to collect the funds in such a manner as to be efficient and also pro-poor. The contractor would charge the commercial operators such as hotels and restaurants directly, at least initially.

333. There may also have to be payment from the City to the Contractor to empty rubbish bins in park areas and also hook lift bins near the river houses for example. This could be based on an agreed fee or just a straight tonnage payment for all waste hauled.

334. A land tax is now applied to properties with an improved value of greater than 25,000 U.S. dollars. However only a small percentage of all the houses within the city exceed this valuation and

as such the land tax would not be a suitable basis on which to apply a Solid Waste Management surcharge.

335. Similarly a significant percentage of the houses are not connected to reticulated water supply, so a surcharge cannot be fairly applied to water rates to fund SWM costs.

336. However almost all houses, including many of the river houses, are connected to electricity. It would be possible to apply a surcharge to the electricity bills to cover the Solid Waste Management costs. A differential rate could be applied to domestic dwellings verses commercial and industrial establishments with suitable consideration for cross subsidies, and to embed a pro-poor approach to the overall rating structure.

337. Such a scheme operates in Phnom Penh where approximately $1.00 is applied each month to the electricity bills of the household to cover SWM. This amount is only a fraction of the real cost but it is a start and will allow householders to see the significant improvement in the on-ground Solid Waste Management service, be exposed to the IEC campaign, and therefore over a period of time be willing to pay a higher premium to enjoy the higher service standards.

338. Servicing the smaller markets and other waste generators such as public bins in Parks will have to be a social good cost to the City. There is an opportunity to apply a surcharge to the rents charged to the stallholders, however the main market is not under the direct control of the city and a funding scheme will have to be developed to allow the surcharge money to be returned to city accounts. The Ministry of Economy & Finance leased the market to a private operator in 2005 for 20 years.

5. 2046 Capital Costs

339. The 2046 capital costs were developed for the controlled landfill and collection equipment.

340. For the controlled landfill, the main difference between the 2016 and the 2046 controlled landfill is the addition of three more cells and the associated bulk earthworks, liners and leachate management systems. There are also appurtenant works like additional gravel roads, landfill gas control systems, fencing and lighting systems.

341. In terms of new infrastructure, the only new element included is the controlled landfill gas collection system. This is a relatively inexpensive component and consists of vertical gas wells at 50 metres centres over the completed site with the wells extending to only 2/3 total controlled landfill depth. The gas collection pipes do not need to extend any deeper as the lower portion of the site is saturated with leachate and the gas generation rates and mobility is much lower. A landfill gas flare has been included in the costings as it is expected within the next decade or two that controlled landfills will be required to convert landfill gas to carbon dioxide or used productively.

342. The operating equipment has been essentially doubled to allow for replacement of all the original equipment within the 30 year time frame. A landfill compactor has been incorporated into the costings as this will be required as the future waste volumes to be managed will require a landfill compactor.

343. Regarding the waste collection equipment, it has also been assumed that equipment purchased in 2016 will have to be completely replaced by 2046. Also the equipment types have been kept in the same ratios as those proposed initially. It is assumed that the on-going road development will not be at a much higher standard with universally wider roadways and access

paths. If however there is substantial improvement in the quality of the secondary and tertiary local roads and alleyways, then the mix of equipment can be varied to include a larger proportion of the bigger fleet and less of the smaller equipment. This will have a minor impact on price but is of course 30 years in the future.

Table 10– 2046 Capital Costs

Item	USD	Riel
CONTROLLED LANDFILL	$2,461,000	9,845,000,000
Earthworks	$492,063	1,968,250,000
Buildings	$30,900	123,600,000
Roads, Hardstand and Tree Screen	$800,000	3,200,000,000
Site Infrastructure	$1,138,277	4,553,108,000
CONTROLLED LANDFILL EQUIPMENT	$1,572,000	6,228,000,000
WASTE COLLECTION FLEET	$1,745,000	6,980,000,000
TOTAL	$5,778,000	23,113,000,000

Source: TA 7986-CAM consultants

6. IEC Campaign

344. The information and education campaign described above will cost approximately USD50,000.

7. Implementation Support and Operations Audits

345. The on-going implementation support and operations audits on the controlled landfills will result in a total cost for the mooted three year programme of USD90,000.

T. Future Steps

346. The next step is to complete the detailed design of the works and prepare tender package for goods, services as well as works. It will then be necessary to ensure contracts are managed efficiently and that construction materials, workmanship and safety and other safeguards aspects (e.g. environmental requirements) are satisfactory. Consultants will be appointed to assist the City in Contract Management and Construction Supervision tasks.

347. The likely schedule of the next stage is presented in **Appendix – I - Schedule**

Appendix A Glossary of Terms

Aerobic process. Biological treatment process that occur in the presence of oxygen. Certain bacteria that can survive only in the presence of any dissolved oxygen are known as obligate anaerobes.

Anaerobic process. Biological treatment process that occur in the absence of oxygen. Bacteria that can survive only in the absence of any dissolved oxygen are known as obligate anaerobes.

Amenity. The current existence of healthy, pleasant and agreeable (community) surrounding.

Aquifer. A saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

Avoidance/reduction. Reducing the quantity of waste produced and the quantity of resources consumed during the manufacture and life-time of the product.

Batch. Samples taken from one site in one day.

Beneficial use. The environmentally benign and useful application or use of a resource which is of public benefit, including welfare, safety, health and aesthetic enjoyment.

Bioremediation. The remediation or decontamination of any contaminated matter by the use of processes involving biological organisms.

Biosolids. The particulate matter, mainly organic, removed during the treatment of sewage.

Building and demolition waste. Solid and inert waste materials, arising from the demolition, erection, construction, refurbishment and alteration of buildings and construction, repair and alteration of infrastructure including roads, bridges, dams, tunnels, railways and airports.

Buffer distance. The distance between the tipping area of a controlled landfill site and a segment of the environment to be protected.

Cell. A section of a controlled landfill.

Clean excavated natural material. Material consisting of clay, soil and crushed rock which is not contaminated or mixed with any other material.

Clinical waste - (also called Medical waste). Any cytotoxic or contaminated solid waste which includes:

- Sharps: Any object capable of inflicting a penetrating injury contaminated with blood and/or body fluids. This includes needles, needle or syringe combinations and any other sharp objects or instruments designed to perform invasive procedures.
- Bulk body fluids, blood and blood products: Including any vessel, bag or tubing containing body fluids, blood or blood products.
- Disposable and dressings linen: Heavily soiled with blood and/or body fluid.
- Microbiological and pathological waste: Including discarded laboratory specimens, cultures and materials that have contact with such, and biological reagents.

- Tissue**:** Human tissue, organs, body parts, placentas and products of autopsy and animal tissue.

Commercial and industrial waste. Solid and inert waste generated by businesses and industries (including shopping centres, restaurants and offices) and institutions (such as schools, hospitals and government offices), excluding building and demolition waste and municipal waste.

Composting. The process of the conversion of organic materials by micro-organisms into soil conditioners, compost or humus. By definition, it is a process which must be carried out under controlled conditions yielding cured products.

Construction waste - ***see Building and demolition waste***

Cover material. Approved material for use to cover dumped waste.

Decomposition. The breakdown of organic waste material by micro-organisms.

Degradation. An environmentally significant natural, physical, chemical or biological transformation to a lower state.

Demolition waste - ***see Building and Demolition waste.***

EIS. Environmental Impact Statement.

EMMP. Environmental Monitoring and Management Plan

GFI. Government Financial Institution

Greenhouse Gases. Gases, such as methane and carbon dioxide, which in turn contribute to global warming.

Groundwater. Water saturating the voids in soil and rock; water in the zone of saturation in the Earth's crust.

Hazardous Waste. Waste which, through toxicity, carcinogenicity, mutagenicity, flammability, explosivity, chemical reactivity, corrosivity, infectiousness or order biologically damaging properties, which may present danger to the life or health of living organisms when released into the environment, excluding:

- municipal waste (other than chemical waste specially collected); and
- legal discharge to sewer, subject to trade waste or customer contract.

HHW. Household Hazardous Waste

IEE. Initial Environmental Examination

Industrial waste - ***see Commercial waste***

Inert waste. Wastes which do not undergo environmentally significant physical, chemical or biological transformation and have no potentially hazardous content once controlled dumped. This waste from building and demolition includes bricks, concrete, glass, plastics, metal and timber. They must not be contaminated or mixed with any other material.

Inert waste controlled landfill. Any landfill that accepts only inert wastes (*see* definition above). Inert waste landfills are usually subdivided into two classes:

- Class 1 - all inert waste including stabilised asbestos cement and physically, chemically or biologically fixed, treated or processed waste.
- Class 2 - all inert waste except stabilised asbestos cement or physically, chemically or biologically fixed, treated or processed waste.

Controlled dump/landfill Environmental Management Plan (EMP). A detailed plan for the operations of a controlled landfill site from a greenfield state to a fully rehabilitated state including after-care.

Controlled dump/landfill gas. Gaseous emissions from the decomposition of waste. Also called biogas.

Controlled dump/landfill site. A waste facility used for the purposes of disposing of waste to land.

Leachate. Liquid released by, or water that has percolated through, waste and which contains dissolved and/or suspended liquids and/or solids and/or gases.

Litter. Solid waste that is outside the tipping area of the controlled landfill site and is not part of the formal waste collection system.

Material recovery. A form of resource recovery of wastes otherwise destined for disposal in which the emphasis is on separating and processing waste materials.

Medical waste - *see Clinical and related waste and Contaminated waste*

Methane (CH_4). An explosive, odourless and colourless gas produced in a controlled landfill by organic waste undergoing anaerobic decomposition.

MRF. Materials Recovery Facility

Mulching. The size-reduction of organic materials using one or more of the following processes: cutting, milling, shredding, grinding and other means.

Municipal waste. Solid and inert wastes arising from the three waste sub-streams:

- Domestic waste - household solid and inert wastes placed out for kerbside collection
- Other domestic waste - residential solid and inert wastes arising from domestic clean-up and garden waste
- Other waste – municipal generated solid and inert wastes arising from street sweepings, litter bins, parks and garden clean-ups, tree loggings and council engineering work.

Organic waste. One or more of the following types of waste: garden, untreated wood, fibrous, vegetables, fruits, cereals, biosolids, manures, fatty foods, meat, fish and fatty sludges.

Poorly stabilised material. A treated material which is prone to further degradation or decomposition.

Public authority. A public or local authority constituted by or under an Act and includes:

- a Waste Board, or
- a department of the public sector, or
- a member of staff or other person who exercises functions on behalf of a public authority , or
- a Nationally owned corporation or a subsidiary of such a corporation.

Putrescible waste. Waste being food or animal matter (including dead animals or animal parts), or unstable or untreated biosolids.

Recycling. The process by which waste otherwise destined for disposal is collected, reprocessed or re-manufactured and used to make a product.

Remediation. Work for the remediation, rehabilitation and monitoring of premises the subject of a licence and that is required by the conditions of a licence to be carried out:

- While the premises are being used for the purpose to which the licence relates, or
- after the premises cease being used for the purpose to which the licence relates, or both.

Reprocessing. Physical, chemical and biological processing used to transform waste, otherwise destined for disposal, into a raw material used to make a product.

Resource recovery. The extraction and utilisation of materials from mixed waste. Material recovered can be used in the manufacture of new products. Recovery of value includes energy by utilising components of waste as a fuel, production of compost using solid waste a medium, and reclamation of land.

Re-use. A process by which waste otherwise destined for disposal is cleaned or repaired for use, for the purposes of prolonging the original product lifetime prior to treatment or reprocessing.

Run-off. The portion of precipitation that drains from an area as surface flow.

Run-on. Where surface water runs off one site and flows onto the site in question (i.e. the controlled landfill site).

Sludge. Semi-liquid waste produced as a by-product of an industrial process.

Solid waste. Any non-hazardous, solid, degradable waste. This includes putrescible wastes; garden wastes; uncontaminated biosolids; and clinical and related waste. All solid waste shall have an angle of repose of greater than five degree (5^0) and have no free liquids.

Stabilised material. Material not prone to further degradation or decomposition.

Surface water. Surface water includes all natural and constructed waterways or channels whether flow is intermittent or not; all lakes and impoundments (except lined dams associated with controlled landfilling activities); and other marshes, lagoons and swamps.

SWM. Solid Waste Management

SWMP. Solid Waste Management Plan

Toxins. Substances which are harmful to humans, animals or plants.

Transfer station. A waste facility used to transfer waste from collection vehicles to a bulk haul vehicle, generally in order to achieve long distance transportation efficiency.

Treatment. Physical, chemical or biological processing of a waste for disposal.

Waste. Waste includes:

- any substance (whether solid, liquid or gaseous) that is discharged, emitted or deposited in the environment in such a volume, constituency or manner as to cause an alteration in the environment, or
- any discarded, rejected, unwanted, surplus or abandoned substance, or
- any otherwise discarded, rejected, unwanted surplus, or abandoned substance intended for sale or for recycling, reprocessing, recovery or purification by a separate operation from that which produced the substance, or
- any substance prescribed by the regulation to be waste for the purposes of this Act.
- A substance is not precluded from being waste merely because it can be reprocessed, re-used or recycled.

Waste facility. Any premises used for the storage, treatment, reprocessing, sorting or disposal of waste.

Water table. The surface of the groundwater.

Appendix B Waste Segregation and Minimisation

1. Households currently recycle or reuse much of the higher value products in the waste, such as glass bottles, plastic bottles, paper and cardboard and metals.. Other raw waste stream audits in SE Asia contained three or more times as much of these components typically. This low level confirms that efficient recycling is already occurring at source. This small recyclables quantity in the raw waste was further confirmed by examining the waste at the current disposal site and noting the small number of waste pickers working at the dump.

2. While primary recyclables are being removed at source, there is still a requirement for other improvements in waste minimisation and avoidance.

3. The USEPA has produced booklets such as "*The Consumers Handbook for Reducing Solid Waste*". This booklet is particularly comprehensive and addresses the integrated waste management approach, or the cradle to grave approach. This addresses all phases of waste management including advice on reducing the amount of unnecessary packaging. The handbook also covers the issue of adopting practices that reduce waste toxicity, and the associated issue of household hazardous waste collection that is often overlooked in these publications. The composting section is also very basic and provides the details for constructing and operating a household or commune level compost scheme.

4. Also the UNDP funded Project "*Public and Private Sectors Convergence for Solid Waste Co-governance in Urban Poor Communities*" would provide good educational material as input to developing a local plan and strategy. These booklets, and many others which relevant NGOs will have already prepared, should be used as a basis for developing local educational information.

5. While there is good reuse, recycling or waste avoidance success in the City, it can always be improved. There is a need for an IEC campaign on waste minimisation, avoidance, recycling, etc. This should also be extended to industry as well, where a waste register may be established to facilitate reuse between industries.

Source Reduction Options

6. Source reduction or waste minimisation is a necessary component of a waste management strategy. The benefits of waste minimisation include pollution prevention, reduced need for waste treatment and disposal facilities, and cost savings. The following sections review the major strategies employed to encourage waste minimisation, and are in compliance with the legal framework discussed in the previous chapter.

Integrated Resource Recovery (IRR)

7. Integrated Resource Recovery (IRR) is the recommended approach to waste management for the City. This aims to *"instil an understanding and support within the community of waste management principles".*

8. Fundamentally, this can only be achieved by creating the opportunity for members of the public to play an integral and valued role in the decision making process, from initial planning through to system implementation and operation. This has to cover all aspects including resource recovery systems and technology.

9. It should be developed in three phases, as follows;

- *The Strategic Framework* – rationale, opportunities, vision, goals, implementation paths, and evaluation of public sector participation
- *The Strategy*; Why should communities participate in waste management decisions – detailed assessments of international practices in waste management aspects, including analysis of different communication methods
- *Principles of Public Participation* – Develop roles and responsibilities for o, the city (elected representatives and staff), National agencies such as DONRE, civil society, NGO's, industry, commune representatives and other interested parties

Pricing

10. A major influence on the success of waste minimisation and, indeed, recycling is the pricing regime for waste disposal.

11. In addition, charging the full cost of disposal will provide a commercial incentive for business and industry to become involved with waste minimisation and recycling.

12. In setting the appropriate waste disposal charges the following factors need to be considered;

- operational costs
- present and future costs of purchasing and developing disposal sites
- costs of new equipment in the future
- rehabilitation and long term site monitoring and after-care
- possible costs associated with environmental disadvantages, and
- charges set by external waste management or environmental authorities.

Legislation

13. Waste minimisation legislation has been utilised in many parts of the world in order to control the generation of waste. Examples of such legislation follow.

14. Many countries have Container Deposit Legislation CDL, such as South Australia, which is governed by the Beverage Container Act. This legislation requires a deposit on containers for products defined as beverages under the Act, with exemptions granted by Regulation. Refunds on containers with deposits are paid at point-of-sale or collection depots and are collected from there for reuse or reprocessing. The primary reason for the introduction of CDL was as a litter-control measure.

15. The Industry Commission considered CDL as part of its study and found that there was no convincing case for container deposit legislation. The Commission found that deposit schemes are expensive to operate and impose high costs on both producers and consumers and are inefficient compared with other available economic instruments.

16. CDL operates as a disincentive for the kerb-side collection of recyclables because it lowers the value of the remaining waste stream by lowering the quantities of high-value recyclables such as glass and aluminium.

17. Such a scheme would work in Vietnam but only if adopted on a regional basis. The degree of success will probably not be too high as there is already very efficient recovery of glass and bottles, first at source by users and then scavengers at the dumpsite.

Packaging and Plastic Bag Legislation

18. Although this type of legislation is usually enacted at National government level, it is appropriate that agencies lobby and support the introduction of such legislation.

19. A local option is the introduction of compulsory charges for all plastic bags used at supermarkets. This is used in other developing countries such as Fiji in the Pacific. The charge is in the order of 80 Riels per large plastic grocery bag. The aim is twofold. Firstly, it is to encourage people to only use the actual number of bags required. Secondly, it encourages people to reuse the bags, either for later trips to the shops or to use the bags for storing garbage rather than buying special garbage bags and liners. It has also had the effect of people now bringing hessian and other reusable bags to the shops and not using many if any plastic bags.

20. Plastic makes up an estmated 10% to 15% of the current waste stream.

21. Town Planning and Building Requirements

22. In Europe many countries require waste management issues to be addressed as part of the planning approval process. Typical elements range from estimation of the type and quantity of waste generated, the requirement for waste audits, and plans for disposal of waste, both on-going and as generated by the building activity.

23. For example, Australia has an industrial waste minimisation policy that incorporates;

- planning procedures to ensure waste minimisation is part of the planning approval process
- requirements for developers and others to indicate where construction wastes or other materials are to be disposed.

24. The city, as part of the planning approval process, could require commercial and industrial applicants to provide information on waste minimisation and recycling programs/activities to be incorporated into the proposed development. This would include both the construction and operational phases. In addition details of expected wastes for landfilling both quantity and composition should be requested from each applicant.

Education

25. A major key in any Government body achieving reduction of waste to disposal is the education of the community, both general society and business. Locally a National Government initiative is required to support education with respect to waste management. This effort could possibly be best directed through a combination of national campaigns, supplemented with funding for local level education through local NGO's.

26. Internationally, for example, both National and State governments have launched "limited" advertising campaigns, through the "Be Smart" and "Wilson Family" programs respectively. The Queensland Recycling Advisory Council (QRAC), a joint initiative of the container and beverage

industry and the State Government, has also produced school resource kits and launched a recycling competition amongst schools.

27. The USEPA has produced booklets such as “The Consumers Handbook for Reducing Solid Waste”. This booklet is particularly comprehensive and addresses the integrated waste management approach, or the cradle to grave approach. This addresses all phases of waste management including advice on reducing the amount of unnecessary packaging. The handbook also covers the issue of adopting practices that reduce waste toxicity, and the associated issue of household hazardous waste collection that is often overlooked in these publications. The composting section is also very basic and provides the details for constructing and operating a household or Barangay level compost scheme.

28. It is considered that education is the fundamental key to a successful waste reduction strategy.

Waste Segregation

29. There is no segregation at present at households apart from internal sorting prior to disposal to allow feeding of domestic animals and sale of high value recyclables..

30. If waste is to be segregated, there must be some downstream benefit realised and supported by the community. Neither the proposed high technology scheme nor the proposed simplified scheme benefits from traditional segregation. This involves having one colour for wet biodegradables (essentially kitchen waste) and one for dry matter including all non-biodegradables. Usually waste is segregated differentiating biodegradable from non-biodegradable waste to allow mechanised sorting of the recyclables centrally. However the amount of recyclables entering the local waste stream is minimal and would not justify a highly mechanised MRF and therefore traditional segregation. But this is still a sensible first stage to segregation to assist the waste pickers to maximise recovery.

31. The likely future SWM approach is the have greenwaste chipped and reused as road cover in wet weather, erosion protection on external mound batters and as compost feed if some future composting scheme is adopted, such as with animal manure or biological sludges from treatment plants.

32. Therefore the appropriate segregation option would be ultimately to adopt a three-bag approach to segregation of the greenwaste and all other waste, and include waste segregation training into the IEC. This allows greenwaste to be chipped and reused at the landfill site.

33. One issue usually raised by communities is the cost of having separate containers. The costs of bag identification can be minimised by not requiring specially coloured bags as in some schemes trialled. Rather the option adopted elsewhere is the use of identifying coloured ties, regardless of the colour or type of container.

34. Develop countries have up to 5 separate containers but three is more common for recyclables, green waste and residuals.

35. In summary, there is a need to segregate all greenwaste as much as possible at all levels, especially at City level with their parks and gardens activities and not just household level. The IEC will also need to involve the private company hauling waste for the peri-urban areas.

Household Hazardous Waste Management

36. The management of household hazardous waste (HHW) is one area of waste minimisation that can significantly reduce both water system and landfill pollution.

37. The proper management of HHW is an issue that emerged in the 1980's in the US along with the awareness of problems caused by toxic chemicals and hazardous waste. Collection of HHW at single-day events has been the standard approach adopted by local government.

38. In many places, collection days have become institutionalised as annual or semi-annual events. In other places, permanent drop-off sites have been established for the ongoing collection of HHW. Established recycling markets for a number of hazardous materials allow materials to be diverted from the waste stream through special collection programs. Used motor oil, one of the largest single categories of hazardous waste generated from homes, is currently collected throughout several cities and states. Scrap battery collections attracted interest in order to reduce heavy metals in landfill leachate and incinerator emissions. Household batteries are targeted for collection in many areas of the US.

Appendix C Recycling

Introduction

1. Recycling is a form of resource recovery that allows the use of recovered materials in a form similar to its original use, as in recycling paper for use again as paper or cardboard. The City eventually needs to develop a Solid Waste Management Plan which will advocate such practices as it diverts a considerable amount of useful materials present in the waste stream from being disposed of in landfills.

2. Recycling issues are also addressed in other sections in this Plan, such as Container Deposit Legislation in Source Reduction Options and generally the section on Legal Environment for Source Reduction, and are not repeated in this Section.

3. The Cambodian National 3R Strategy states that there are two target years, 2015 and 2020, related to this 3R achievement. With the first target year in 2015, it aims to achieve an appropriate solid waste management system and practices through solid waste and garbage collection for disposal and treatment based on the capability, capacity and geographical feature. Solid waste separation for recycling purpose is 10-20 % of household wastes, 30-40% of business wastes and 50 % of industrial wastes while the 20 % household organic wastes and commercial wastes will be composted and used as fertilizer. In year 2015, the strategy also states that the thirty (30%) appropriate dump sites will be constructed and operated at selected urban areas.

4. 0With the second target year in 2020, the 3R strategy also states that solid waste separation for recycling purpose will reach up to 50 % of household wastes, 70 % of business wastes and 80 % of industrial wastes while composting of household wastes and business/commercial wastes will go up 40 % and 50 %. The vision of the 3R Strategy to 2020 targets that the 3R initiatives for solid waste management are carried out throughout the country to meet the environmental, economic and social values, with full participation by stakeholders at terms of both national and local levels.

5. It must be noted that these percentages are based on the waste generated at sources not collected from households. Significant recycling is already happening within the household and commercial establishment and these successes must be included in the overall percentages recycled/reused.

Evaluation of Existing Programs

6. There are no existing recycling programs that have been implemented or supported by the Municipal government. The current practice is that waste pickers sell recyclables to junk shops and traders, and the junk shops have staff actively seeking to buy recyclables door to door from households and commercial institutions..

7. The local recycling market is largely self-regulating, meaning that junk shops will only buy materials that can be profitably on-sold. This means that dirty plastic bags are not recycled for example, as is the case in most cities.

8. The City is simply too small to support recycling schemes at all levels of the collection and generation hierarchy for all waste types. A large city may be able to convince a junk shop operator to buy dirty plastic bags for recycling if there is a local industry that can recycle the waste into

drainage pipes for example. Unless such a facility is nearby the cost of transport can make it uneconomical to transport such light material unless chipped and baled.

9. Facilitating recycling of non-economic materials by governemnt sponsoring creates a purposeful market distortion. This is acceptable as long as all the parties recognize the distortion and accept that any withdrawal of government support will make recycling this product uneconomic for the private sector. This is the reason that private sector involvement in non-economic but sponsored recycling schemes that require significant CAPEX is often not forthcoming.

10. The local junk shops/recyclers are relatively small scale operations apart from two mid sized facilities.

11. There is no significant local NGO involvement in solid waste management, unlike in many other countries where NGOs and cooperatives become involved.

Recycling Program

12. Recycling Programs are required to address the generation of both biodegradable and non-biodegradable wastes. Specifically for biodegradable wastes, the City should aggressively mobilise programs since these wastes can be converted into compost at the household level:

Areas to address	**Recycling Program**
Bio-degradable wastes	Facilitate education program on household composting and domestic anaimal feeding opportunities. Consider supplying composting bins for interested households
Non-biodegradable wastes: post-consumption	Manufacturers to set-up 'Buy-back/redemption centres' for these wastes
	Promote the use of post-consumer recyclable materials in production (material cycling)
	Educate the junk shop operators to better coordinate their suppliers to improve collection efficiencies at the household level and central level
	Focus recycling on products presently not recycled such as plastic bags, as well as expand the paper/cardboard, metals and glass recycling.
	Processing of materials into products that can be reintroduced into the market (ie. tin cans can be re-sized into smaller units for consumer use, polystyrene can be moulded to produce new products like mouldings and frames)
	For materials that the City does not have any technology for recycling, such as dirty plastic bags, the City will coordinate with agencies like DOE and academic institutions dealing with R&D on this area.

Types of Materials to be Recycled

13. The results of waste characterisation activities and waste composition analysis described earlier in this document and any further information obtained in the course of past collection of solid waste by the City can define the type of waste streams available for recycling. At this time however the waste audit results for the city corresponds with the waste audits conducted in Hanoi and other cities in Vietnam which indicate very high levels of recycling at source for the high value commodities such as metals, glass, paper and cardboard.

14. If a small scale composting schemes described later is implemented, the use of presently non-saleable recyclables as raw materials for making a range of pipes etc. from plastic bags should be investigated. Separating out plastic bags for a mixed waste stream will require that a centralised facility is installed using trommels and a bag breaker. If the small scale composting trial is successful with segregated market waste and is then trialled on mixed waste requiring mechanised segregation, then the oversize material exiting the separation trommel would be hand sorted and plastic bags would be recovered.

15. The option of recycling plastic bags, and in particular cleaning soiled bags, must be considered in the whole-of-life perspective from an environmental context. A somewhat similar scheme operates in Manila on laminated plastic and foil juice containers where these are recovered from the landfill and washed prior to being sewn into handbags and other carry bags. Superficially the scheme is highly successful and has attracted international recycling markets and achieves a very high sale premium. However the washing processing is causing significant local water pollution as obviously the soiled containers are highly contaminated with organics. So if a similar scheme to wash an ever higher percentage of the total mixed waste stream is proposed locally, then a recirculation system will have to be installed for the plastic bag wash-water with only the bleed off being directed into the leachate management system.

16. They also must be an understanding about the conflicts when recycling schemes are instituted. For example if landfill gas is to be maximised for productive reuse and power generation, heating or vehicle fuels, for them composting should not be allowed nor greenways diversion as this reduces the organics entering the landfill and therefore the gas production. If however organics are to be diverted either through green waste and/or small scale composting schemes (either at source at household level or as a small scale trial at the solid Waste Management site), then this will obviously increase the direct recyclables' percentages achieved. Therefore the aim of the recycling schemes needs to be agreed and understood.

Categories of Recyclable Wastes for Diversion

17. The results from the conduct of waste characterisation activities to validate waste generation estimates will be the main information input to determine other categories of recyclable waste present in the waste streams for diversion. The city should seek the assistance of various resource groups to implement proactive recycling measures such as buy-back and material reclamation programs.

Solid Waste Advisory Board

18. The City should consider establishing a multi-partite Solid Waste Advisory Board. This board would welcome proposals that will stimulate the demand for production of products containing post-consumer and recovered materials for as long it meets the acceptable quality

standards and consistent with the set guidelines. Members of the Board should come from the recycling, manufacturing/packaging sectors and NGO. The City should spearhead the development of such proposals.

Recycling of Specific Waste Types

19. Not all materials have to be sold to be recycled. For example, builder's rubble can be used for drainage blankets or gas collection layers in landfills rather than just dumped into the cell as waste, or using excess soil for cover material. This type of recycling just requires some forward planning. Similarly, greenwaste can be chipped and then as a protective layer for the exposed cover material prior to grass establishment to prevent erosion of landfill batters, or used on internal roads during wet weather.

Composting

20. Composting can be used to reduce the organic waste going to landfill. It is a very basic and natural biochemical process, which breaks down the putrescible fraction of a waste stream. It has considerable potential for reducing the quantities of domestic waste for disposal at a landfill, as a large proportion of compostable material is found in the domestic waste stream.

21. The compostable material must be completely separated from the rest of the waste. This is best done at the source - by the householder. However, this requires considerable co-ordination and encouragement from the commune and the city. If centralised, separation of the waste needs to be extremely thorough as an occasional piece of metal or other solids in the waste stream causes faster wear or even partial destruction of the shredding equipment and lowers the overall quality of the compost. Glass shards are also common and some centralised composts have contained mediwaste sharps. This introduces a legal liability for the City even of the product is given away local residents or farmers.

22. A sustainable market also needs to be found for compost generated centrally. This often proves difficult as demand is low and there are many other better and cheaper sources of compostable material. Many schemes have failed because of a lack of demand for product.

23. Overall it would be better to encourage home level composting by subsidising the cost of composting bins and by providing free advice on the associated benefits and methods. This would help to reduce the overall volume of waste. Commune level composting may be required where the community is impoverished and individual households do not have the compound area available to utilise the compost produced.

24. In summary, composting on a centralised basis is considered inappropriate for the entire waste stream. The trend is definitely towards household based composting where possible.

25. Basic low-cost designs and training are available in the literature, such as in the USEPA "The Consumers Handbook for Reducing Solid Waste". This manual also describes how to operate the compost system and what materials to use.

26. However the fact remains that a compost scheme, be it a household or commune approach, will not be able to manage all wastes generated, either in terms of volume or waste type. It is a worthy supplemental scheme however to a landfill.

Hybrid composting scheme

27. A centralised scheme designed to handle all organic wastes entering the landfill site and then be productively reused is still not supported. The reasons are outlined elsewhere but essentially it is the difficulty of segregating appropriate organics for composting, which means excluding any meat or oils and fats and other non-vegetable inorganics. This is essentially impossible in a mixed waste collection system. Developing a sustainable segregation scheme to the extent of partitioning household and commercial organics for composting is considered unviable. The further concern described elsewhere is the essential sustainability of the market demand, especially when the market expects the compost to be entirely free of contaminants sites as such as viable plant seeds, glass splinters, metals and especially medical waste such as sharps. Such pure compost has not been obtained on a sustainable basis elsewhere.

28. If a centralised scheme treating all incoming organics is considered inappropriate, a smaller scheme may be appropriate to trial. One option would be to establish dedicated hook-lift container bins at the larger wet markets just for vegetable waste and paper. These are the two components are the best for composting. The dedicated container could be transported to the Solid Waste Management site and placed in a windrow for open air passive composting. If the scheme proves successful, then it could be expanded to all the market's to collect suitable compostable material. This the approach used in Battambang.

29. If this proves successful, then a mechanised plant could be installed to treat a fraction of the total incoming waste stream to separate out the combined organic stream. This could then also be composted in open passive windrows. Once the compost is ready, it would then need to be screened in say a 3mm vibrating inclined screen to remove most of the contaminants, especially plastic as well as hopefully all glass and metal material.

30. If this later stage which requires expensive mechanical equipment and elevated energy costs is to be undertaken, then a PPP should be established with a local landholder who will commit to taking all compost generated and not suing the city in case of any contamination.

31. The advantage of the staged approach to selected composting of income inorganics is that the initial outlay will be minimal and will determine if the compost is a viable product for the local private sector plantation owners. If the land holders indicate on-going interest, then the scheme can be expanded as described above.

Recommended Approach

32. The city supports the concept of recycling and is committed to the success of enhanced recycling. Based on this, the City will;

- Commit to the principles of encouraging and supporting recycling efforts. The improvement will come through activities such as;
    - Implementing waste segregation schemes, later for green waste, especially in the municipal services as opposed to households initially
    - The city investigations of recyclables' markets, including regional junk shop operators
    - The city identifies specific people from the City or DoE to assist with recycling
    - Assisitng in recycling marginal reocerables, such as plastic bags

- Accept that the private sector and particularly the market will decide what items and how much is to be recycled
- Accept that the most efficient schemes are those operated by the private sector such as existing junk shops. The city needs to commit to working with and enhancing these operations, and being the backstop for geographical areas not serviced by junk shops and to recover any other recyclables not removed by the junk shop operators prior to collection.

Appendix D Waste Processing and Disposal Options

Incineration

1. Incineration of waste would considerably reduce the volume of waste for landfilling. A large facility would need to be constructed to burn waste material, thus converting carbon and hydrogen compounds to carbon dioxide, water and other residues. In the process of burning this waste it is possible to generate some energy. The proceeds from energy sale would not offset the entire running costs, let alone redemption on the capital investment.

2. The negative side of incineration is the need to sort the waste stream prior to burning as not all waste material can be burnt. The most significant disadvantage is the generation of exhaust gases (some potentially harmful gases) and the visual intrusion of the chimney stack. Specialist knowledge is required to operate and maintain an incineration facility which adds significantly to the life cycle costs.

3. Incineration was not considered a viable option due to the disadvantages and high capital and operating costs of such a facility. Costs of up to $100 a tonne for incineration would not be unusual, converting to about $90 per cubic metre at 900kg/cubic metre density. For example, the Perth Solid Waste Study reviewed incineration costs and determined that a new incinerator in Hawaii was operating at a cost of $105 per tonne. The proposal to eventually reuse greenwaste would significantly reduce the calorific value of thewaste, necessitating expensive fuel supplements, particularly in wet weather periods.

4. The incinerator is a very complex item of equipment requiring a trained operator or else incomplete combustion will almost certainly occur, resulting in the emission of carcinogens and toxins. The usual scrubber system includes activated carbon, which requires regular regeneration or else the toxins will simply escape to atmosphere. There are no functioning mixed waste incinerators in developing countries in the region. Some have never even been properly commissioned prior to being abandoned.

5. Unless the waste stream is very dry and clean, supplementary fuels will be required. Because it is planned to ultimately remove greenwaste which is the highest calorific feed source, there is no likelihood of energy recovery to offset costs. Overall incinerators are very costly to run.

6. In terms of Refuse Derived Fuels (RDF), tyres are the best option for burning in cement kilns as supplementary fuels. This is common globally.

7. In summary, incinerators are appropriate in places where land is very expensive such as in Japan, where space is tight and highly trained operators are available. Even New York landfills its waste so even these factors do not guarantee that incineration is the best option.

Pit Burners

8. Pit burners are used as a relatively low cost method of burning selected waste, building materials and timber. They are cheaper than incinerators, however the exhaust gases are less controllable. Pit burners can reduce the volume of waste requiring landfill significantly, however, not to the extent of incineration. Operation in protracted wet weather would be difficult.

9. Due to the difficulties in meeting exhaust gases emission requirements and expected public objection to the odours and visible plumes which would result, a pit burner system was not

considered viable for the total waste stream. It may be appropriate for large timber pieces and tree stumps, especially after a natural disaster where large quantities of tree waste requires disposal.

Baling

10. Baling domestic waste is a technique similar to compaction and uses pressure to bind the waste into a tight mass ready for disposal. This process significantly reduces the volume of waste and makes handling and transportation easier. However, baling plants are costly to purchase and operate. They are also prone to mechanical breakdown due to the highly variable nature of the waste stream, including items such as large metal off-cuts and rocks. The baled contents of the landfill take longer to degrade and stabilise, thereby making the aftercare and utilisation of the site more difficult.

11. It was considered that baling of waste was not an economically viable option in the study area.

Composting

12. See previous sections for details.

"Zero Waste" System

13. Typically the waste goes through many stages of separation and treatment as follows, based on a recently commissioned plant in Viet Nam:

- Mixed waste is delivered to the site and weighed in the onsite permanent weighbridge
- The mixed waste is then dumped into a receiving building, which is equipped with odour extraction equipment as well as mist sprays
- The waste is then pushed into a receivals pit with a chain conveyor installed at the base. Large items are prevented from entering the speed by a manually raked screen
- The waste then goes through of a bag breaker which is a series of cutting blades to open all plastic bags
- The inclined conveyor then takes the waste to the second bag breaker which also reduces the size of large materials
- The waste is then conveyed into a rotating trommel where the fine material passes through the trommel screen and is conveyed into the adjacent composting building
- The larger material passes through the trommel and then goes underneath the magnetic separator to remove the iron metals
- About a dozen waste pickers are positioned along the conveyor to remove any recyclables and especially plastic
- The material exiting this conveyor is then conveyed to the incinerator room
- Material sent to the compost building is then allowed to mature for 45 days.
- The compost building is also equipped with extractor vents as well as a misting system.
- A large self-powered composting vehicle is provided which will straddle the compost windrows and regularly turn them over to improve aeration and moisture consistency within the windrow
- Once the composting process is complete, compost is then transferred to a third building for packaging

- The composted material is dumped on the floor and then pushed into a receivals pit. The pit is equipped with a paddle drum mixer which also conveys the compost onto an inclined conveyor
- The compost is then conveyed into a rotating drum to dry out the compost. This rotating drier is heated by off gases from the incinerator.
- The dry compost is then conveyed to an inclined vibrating screen
- Oversize material is then sent back to the head of the plant for further processing. Much of this oversized material is inorganic waste such as plastics, glass and metal.
- The dry compost is then conveyed by another inclined conveyor taking the compost into a rotating mixing drum
- Compost exiting the mixing drum is then conveyed up to a bagging machine
- The bagging machine consists of a hopper with a mixing screw conveyor at the base which then conveys the compost into the weigher and bagging machine.
- Further conveyors then move the bags ready for stockpiling
- All residual waste is then sent to the incinerator building
- A four claw grab retrieves the incinerator feedstock from the building floor and loads it into an elevated hopper
- An inclined conveyor then takes the waste into a rotating trommel to remove any residual organic material
- Another conveyor then takes the material into a pulveriser and then a mixer
- Material is then introduced into a two chamber incinerator
- Ash is then transferred to the brick making building
- Incinerator ash is then mixed with pebbles by hand shovelled into a receiving hopper
- An inclined conveyor takes the mix to a rotating trommel
- The oversized material is rejected and the pass-through is then directed by another conveyor to a powered mixer
- The mix is then conveyed to the vibrating compactor making the bricks onto small timber pallets.
- The bricks are not fired in a kiln and are allowed to harden naturally
- Odour from the various buildings is pumped to an organic biofilter to remove malodours
- Gaseous emissions from the incinerator are pumped to a series of wet scrubbers in a lagoon format then an activated carbon bed prior to being discharged through the metal vent stack.
- Ground drainage and other leachates from the buildings are pumped to the leachate treatment plant which consists of a series of passively aerated lagoons.
- Adjacent to the buildings is a lined landfill. However this landfill is part of the superseded facility and will not be used in future.
- Therefore the Solid Waste Management facility is considered to be a zero waste operation

Comments on the Zero waste facility

14. The aim of such a facility is very clear, that is, to have a zero waste operation. Such zero waste facilities are the ultimate aim for all Waste Management operations but to date have not succeeded in a sustainable way anywhere globally in a traditional community setting. There have been many pilot and short-term trials which have the theoretically achieved a zero waste position, but none in a sustainable real world application. .

15. In reality however the long term expectations are not as positive especially in developing countries where land is relatively cheap and complex mechanised systems may not receive the maintenanc and operaitonal attaention required.. A number of issues raise real concerns about sustainability and some are listed below;

- For a 100 ton/day facility, the monthly power costs would be approximately USD7,000 a month. This is a substantial power bill and experience elsewhere has indicated that the operators are unwilling to spend such high amount in the long term on a facility that does not attract much public support compared with more high-profile items such as road development and water supply improvements.

- The operators advised that they had allowed USD17/tonne to operate the facility through the local government budget. This translates to about $1800 a day of financial support at present, but increasing as the waste volumes increase over time. If this level of support is forthcoming in the long term, then that would make the facility essentially financially sustainable. However experience elsewhere indicates long-term support for the proper operation of high technology waste management facilities often is not forthcoming.
- In terms of managing items such as car tyres, mattresses and other difficult wastes, operators advised that these will be shredded/chipped and then incinerated. But there was no shredding or chipping facility included which could handle such items prior to incineration. There will also be many other types of waste which cannot be incinerated, composted or converted into bricks. A functioning engineered landfill will eventually be required to supplement the recycling facilities for the residuals.
- The plan is to incinerate items such as paunch manure and intestines from abattoirs or slaughterhouses. In reality these materials are far too wet to incinerate and will require significant drying prior to burning efficiently, or the addition of supplementary fuels such as diesel.
- Demolition material such as timber and broken bricks and concrete will not be accepted into the site. However such material will still be produced and will merely be illegally dumped if not accepted at the recycling facility.
- One of the many reasons for centralised Municipal Solid Waste composting systems failing is lack of a sustainable market for the compost product. This is further exacerbated in countries where compost cannot be applied to agricultural crops for human consumption. This is a sensible approach but experience elsewhere indicates that the farmers lose interest in using the compost when they realise that the addition of artificial fertilisers is also most likely required.
- Centralised composting schemes for municipal solid waste have one other major drawback. Even with a large number of separation stages using trommels, vibrating screens, magnetic separation as well as Eddy Current separation at some facilities, there have been many cases where the final compost is still contaminated with glass shards, metal and sometimes even medical waste sharps. This has resulted in compost users suing local authorities (particularly in the United States) even though the product is given to the local community at no cost. The duty of care responsibility for the compost provider remains, even if the compost is given away.
- The operators intend to charge for the compost thereby generating a revenue stream to offset the high operations costs, and not simply give it away. Experience elsewhere suggests that few farmers are willing to pay a significant price for compost especially when it used on lower value crops such as rubber. In the Philippines, there is a stockpile of over 8000 tonnes of compost which the operators cannot even give away as local

farmers are insisting that the landfill operators pay the haulage and distribution costs of the compost throughout the farm.

- The facility obviously requires high levels of expertise to operate correctly, especially if environmental standards on gaseous emissions from the incinerator are to be met. Generally mixed plastic waste is not incinerated unless in a special incinerator designed to achieve a temperature of 1200° C and a burn time of at least 2 seconds. If these very rigorous standards are not met, then there is a real risk of only partial incineration of the plastics. This can result in the formation of toxic and hazardous by-products such as dioxins. In general, operation of an incinerator receiving a highly variable feedstock from municipal solid waste will require a very high level of expertise and the correspondingly high level of maintenance.
- The need for a high level of operator skill throughout the entire plant will be critical. The numerous motors, pumps, conveyors and other mechanical items will require a small team of fulltime electrical and mechanical fitters. Otherwise because of the serial nature of the operation, the protracted breakdown of any item will result in one of the main process trains being off line for extended periods. Without the backup redundancy afforded by an engineered landfill, this will inevitably result in significant stockpiling of untreated solid waste with associated odour, fly and vermin problems.
- Observation of the raw incoming waste and the “inorganic” waste on the sorting conveyors confirmed the very low amounts of recyclables in the waste stream. Therefore if the higher technology system can only be justified on the basis of segregating the compostable material from the inorganics, and not to maximise recyclables recovery, as the recyclables content is already extremely low.

System Sustainability

16. The key issues regarding sustainability are on-going funding and plant complexity. The operator advised that the on-going funding is guaranteed through the local government support, supplemented by the sale of compost. Experience indicates that such funding often tails away when higher priority local funding requests eventuate, usually associated with higher profile local authority activities.

17. In terms of complexity, a good example is that the incinerator was not working at the time of inspection. The reasons for this could not be ascertained after questioning, but it would be symptomatic of what could be expected in the future with frequent breakdowns of such high technology equipment burning such a highly variable waste stream.

18. As mentioned above, the facility has numerous electromechanical items operating in a very hostile environment. These will always be breaking down and there may be a degree of operator indifference associated with consistently repairing these items in the longer term, as well as instituting programmed maintenance/preventative maintenance activities such as replacing conveyor belts and roller bearings before they fail.

19. The operating environment is hostile because of the high humidity within the sheds as well as corrosive landfill gases. Significant corrosion was observed on some motor cooling vanes and steel frames even though the plant has only been operating for about one month. Programmed or preventative maintenance will be essential to avoid down time resulting from equipment failure.

20. In such a serial or linear waste management process, if one motor fails then that whole treatment train has to go offline. Given the close interdependencies of the various trains (waste

segregation, composting, incineration and brick making), failure in one processing train will impact on the entire operation soon thereafter.

21. Very well trained operators will be required for items like the incinerator operation and overall composting management. At the time of inspection, final compost was being returned to the head of the composting train for reprocessing due to contamination. There is nothing in the treatment train that will completely remove very small shards of glass caused by the bag breaking elements and other mechanical activity.

22. Even if the local operator does receive sustainable funding to the amount required, retain self-funding markets for over 2500 bags of compost a day and retain good trained operators and specialised maintenance staff, it is certain that a final disposal facility such as an engineered landfill will still be required. It is simply impossible to recycle or reuse every component of a real-world mixed domestic waste and industrial waste stream. Even internally to the SWM operation, composting is not a completely predictable activity. Compost facilities utilising more traditional waste streams like green waste or sewage sludges always have some batches that do not meet specification for some reason such as biological or due to contamination. These off-specification batches have to be dumped and there is no facility at this plant for such a large volume to be disposed of.

International Comparisons

23. Most centralised composting schemes have failed through a lack of a viable market for the product, lack of funds to continue operation (as they are not self-funding) or ultimately conversion to composting other more suitable material such as animal manure. A large scheme handling 1,000t/d operates in Lahore, Pakistan but that is a PPP arrangement where compost contamination is not an issue (as one of the PPP partners is the adjacent farmer using the compost and does not mind if the compost has foreign objects therein) and finally, compost is applied to high value food crops.

24. The NGO funded composting operation in Battambang only treates presorted market waste which is again hand sorted prior to composting. Compost is then run through a rotating trommel with 10mm apertures prior to hand sorting again and then bagging. About 2 tonnes/day of raw waste is composted. The scheme only survives based on NGO support.

25. Waste incineration is generally only practiced in locales where land costs are so high to preclude landfill development. They are banned in some counties like the Philippines because of concerns about the stack emission being environmentally damaging and even carcinogenic. The Government there does not believe that incinerator scrubber and filter systems will be maintained in the long term thereby allowing toxins to escape into the atmosphere.

26. The unfired bricks can only be used for local non-structural drainage projects which will eventually be fulfilled. Also incinerator ash can contain many contaminants such as heavy metals. Unless a pozzolanic material such as cement is added to the mix, then the heavy metals will be mobile and can leach out causing pollution.

Conclusion

27. Most of the above methods can be used for reduction of the volume of waste, however a landfill of some type is still required for some part of the waste stream. Given the cost of the above methods, landfill is considered the most appropriate method for disposal. It is proposed to divert greenwaste for mulching and re-use in the future, and encourage recycling of other waste stream components, such as plastic bags, bottles and cans.

28. Only the remnant wastes will be landfilled.

Appendix E Leachate Management

1. Leachate will be collected in the leachate collection drains located in the bottom of the cells. From there it will flow into a pumping station to allow the leachate to be returned to the top of the landfill for reinjection or sprayed on the external batters to encourage vegetation growth in dry weather. It can also be pumped from the pump well into the water tanker to be used to prevent excessive dust from access roads and tipping face areas.

2. An area can be set aside in the site layout to install possible future leachate treatment facilities.

Need for Leachate Treatment

3. With operational measures designed to reduce leachate production to a minimum, it is usual for leachate generation/absorption to be in balance for several years after which time leachate flow expresses itself near the "downstream" toe of the landfill area.

4. The drains will eventually intercept this flow and divert it by gravity to the deleaching wells. At the time of completion of each progressive stage of filling, the individual and combined fill areas will be capped and sealed.

5. Automatic pumps to be installed in the wells with integrated on/off float operated switches. Collected leachate will be pumped up to "dry wells" dug into the upper areas of the waste fill where the leachate is recycled through the waste, encouraging accelerated biodegradation, absorption and attenuation of many of the leachate chemical constituents. A "dry well" consists simply of a gravel filled trench dug two to three metres into the waste surface and covered. In this way, the lanfill mound is used as wet weather storage until it is possible to irrigate any excess leachate volumes.

6. Provided that the site is operated in a manner which inhibits direct rainfall entry, no excess leachate requiring additional leachate treatment will be required.

7. If the monitoring of the deleaching wells and performance of the "dry wells" indicates that leachate generation is excessive, there will be room on site to dispose of any excess through evapotranspiration on intermediate areas of the landfill area by spray irrigation. The use of leachate as a plant nutrient and water source has been used successfully both in Australia and overseas but needs to be checked by laboratory testing in each case to determine the site specific quality of the leachate being produced. This will be undertaken as part of the EMP leachate monitoring requirements.

8. If the leachate is unsuitable for irrigation, it can be treated to remove the contaminant of concern prior to irrigation. For example, if metals levels are excessive, lime dosing and sedimentation/filtration would be used to reduce the metal content. However untreated leachate has successfully been used many times for plant irrigation.

Leachate Water Balance

9. The average moisture content of municipal waste ranges from about 20 to 45 per cent, with most of the moisture being held in foodstuffs and green waste. Commercial and industrial waste mixed with non-putrescible municipal waste has a moisture content of less than 20 per cent.

10. The degradation of the organic component of the waste mass produces a small quantity of liquid leachate and gaseous by -products. The leachate produced is partially absorbed into the dry waste mass and partially lost as vapour due to the heat of the biodegradation process . Under these conditions virtually no free liquid is produced.

11. Due to unavoidable direct rainfall entry over operational areas of the landfill the volume of liquid within the waste mass increases. The direct entry of rain is expressed as a percentage of the rainfall on the site. Well run sites with excellent surface water controls have limited their annual leachate production to less than 5 per cent of annual rainfall. Poorly run sites where even external runoff water from adjoining catchments has not been excluded have an annual leachate production in excess of 100 per cent of annual rainfall.

12. Once the moisture content of the waste mass approaches 60 to 70 per cent or so the waste becomes saturated and any water excess becomes free to move by gravity. Under these conditions, leachate collects at the base of the landfill or above low permeability soil layers within the waste mass and expresses itself in springs around the toe of the landfill or even up the sides of the perimeter batters.

13. In physical terms at the end of Stage 1, the landfill will consist of 134,000m3 of waste and soil. With a porosity of about 30 per cent, it has the capacity to accept 40,000m3 of liquid into the voids prior to leachate flowing. This ignores the capacity of the paper, cardboard and some other components to absorb leachate.

Cell 1 Balance (for covered site)

Stage 1 surface area= 14,400m^2
Average annual rainfall= 1,569mm
Average annual pan evaporation= 1,650mm
Runoff coefficient (2.5H:1V)= 0.9

Infiltration = 14,400m^2 x 1,569mm x 0.1 => 2,260m^3

Evapo -transpiration = 14,400m^2 x 1,650 x 0.625 =>14,120m^3
(for vigorous / lush grass cover)
=14,400m^2 x 1,650 x 0.25 => 5,800m^3
(for moderate / just acceptable grass cover)
=14,400m^2 x 1,650 x 0.1 = >2,370m^3
(for no grass cover)

Net potential infiltration = zero for sealed, grassed site
(vigorous /lush grass cover)
= zero for sealed, grass site
(moderate grass cover)
= zero for sealed, non grass site

14. The completed Cell 1 has a theoretical physical capacity to retain 40,000m3 of leachate in refuse voids.

15. In practice, this physical retention does not occur since a very large amount of leachate is removed through absorption and vapour losses in landfill gas as part of the biodegradation process.

16. Thus for a “closed” landfill, the potential infiltration of rain water will be totally lost by evapotranspiration, retention in available pore space and absorption/vaporisation with landfill gas which is fully saturated.

17. In any case, there are extensive areas of future landfill cells which offer large tracts of land for leachate irrigation.

During Operation Phase of Cell 1

18. Landfills are more vulnerable to excess rain water infiltration during the operational stage when storms occur at times when areas of the landfilling operation are uncovered and / or the surface gradients are temporarily quite flat.

19. Assuming about two thirds of Cell 1 is complete and parts of the site are periodically uncovered or too flat, the following balance could apply:

- Area = 7 000m^3
- Runoff Coefficient = 0.75
- Infiltration = 7 000 x 1,569 x 0.25 => 2,700m^3
- Evapotranspiration = 7 000 x1,650 x 0.1 => 1,200m^3
- Net infiltration = 1,500m^3
- Capacity to retain in voids = 37 500m^3 x 0.3 => 11,200m^3

20. Thus, for an uncovered, flat partially completed Cell 1 landfill, the potential infiltration of rain water of 2,700 m3 will be “lost” by evapotranspiration, absorption/vaporisation and void filling.

21. The obvious implications of this are to progressively develop a landform that will shed surface water, cover waste on a daily basis and promote grass growth as external batters are developed. Improving the runoff coefficient from 0.75 to 0.85 alone will control leachate production to levels which can be readily managed by absorption/vaporisation and evapotranspiration, and not relying on the finite limit of filling void spaces.

Leachate Management Strategy

22. The basics of the management strategy are as follows:

- eliminate seepage of leachate from beneath the site by installing a compacted clay liner.
- eliminate lateral movement of leachate by grading the base of the site to the central area and intercepting this seepage in interceptor/collector drains.
- reducing the volume of leachate generated by using filling, compaction, shaping and covering procedures which severely inhibit direct rainfall entry.
- reducing the volume of leachate generated by intercepting and by-passing all upstream surface water catchment areas around the fill area in surface drainage channels.
- progressively pumping leachate from deleaching wells and recycling it through the waste by means of “dry wells”, irrigating on previously worked areas to sustain grass and plant growth and irrigating future cell areas prior to development if required.
- monitoring the groundwater quality within and adjoining the site.

23. With the available size of the site and the many years that will be associated with each stage of the development of the final landform there is ample time available to modify the system if required, and monitoring programs will be sufficient to detect problems on site before they become a potential problem for downstream users.

24. If leachate volumes during the life of the landfill do become excessive for dry well injection and irrigation, the leachate well pumps could be upgraded to convert the landfill into a controlled bioreactor. This is being undertaken in the USA where the landfill is purposely saturated and the leachate recirculated through the refuse mound to accelerate biodegradation of the refuse organics and conversion of microbial activity from the acid forming stage to the methanogens. During the methane forming stage, the leachate is biotreated and the pH stabilised near neutral. The leachate becomes benign after a number of years (rather than decades usually required in conventional landfills) and can be released to local receiving waters, possibly after further treatment, such as chemical precipitation.

25. However given the extensive areas of vacant land available during the early stages of the controlled dump development which can be used for leachate irrigation, and then the extensive waste mound volume in later stages which can be used to “store” the leachate by reinjection, then leachate management and disposal problems are not expected at any atge of operation.

Appendix F Landfill Gas Management

Background

1. Gases found in landfills are composed mainly of carbon dioxide and methane but can include minor amounts of ammonia, carbon monoxide, hydrogen, hydrogen sulphide, nitrogen and oxygen as well as many other trace constituents.

2. Aerobic decomposition continues to occur until the oxygen in the air initially present in the compacted wastes is depleted. Thereafter, decomposition will proceed anaerobically producing mainly methane. The gas production rate and composition is a function of many parameters, such as landfill moisture content, age, and biodegradability.

3. Biological activity is directly responsible for methane generation from landfilled organic wastes. The biological decomposition phase takes place in three stages that are not distinctly separated.

4. The presence or absence of oxygen is the principal determining factor. When solid waste is initially deposited, oxygen is trapped in the fill materials by the landfilling operation. While this oxygen is available, organic wastes are decomposed into CO2, water, residual organics and heat by aerobic micro-organisms. Aerobic decomposition occurs relatively quickly. CO2 content can reach 90%. Some carbon dioxide dissolves into any available water, resulting in decreased pH levels, while the balance remains in the gaseous phase.

5. The oxygen consumed by aerobic micro-organisms is not generally replaced, due to the presence of a low permeability soil cover. This results in a gradual decrease in the aerobic micro-organisms population and a corresponding increase in the facultative micro-organism population which are tolerant to oxygen but do not depend on it. The characteristic products of this second stage biological decay are carbon dioxide and partially degraded organics, including organic acids which cause a further reduction in pH levels.

6. As all of the available oxygen is consumed, the anaerobic methane forming micro-organisms (methanogens) become dominant. The methane forming bacteria are relatively slow, producing water and methane with very little production of heat. This group of micro-organisms efficiently decomposes organic matter, including organic acids, into gaseous end products, mostly methane. The reduction of organic acid content and the lower production of carbon dioxide promotes an increase in the leachate pH to near neutral values.

Gas Generation Rates

7. Generation rates from other sites have been assessed and used to estimate the likely landfill gas generation rate at the site. This was done by comparing sites in terms of depth of waste, total volume of waste and waste stream components. The calculations are for the completed Cells 1 to 4, as well as the overfill at landfill completion.

8. These comparison sites are as follows:

- University of Massachusetts Campus, Boston, USA. The measured flow rate into a crawl space beneath a building site was 0.3 m3/m2.day of surface area. This translates to a flow rate of about 13,000m3/day locally. The average depth of waste will be about 50 per cent less than at Boston, but the age of the waste will be younger and the organic content will be at least double and hence it is likely that the generation rate (over a 10 year period) would be at least 24,000m3/day.

- Sheldon-Arleta Landfill, Los Angeles, USA. The measured flow rate at the 30m deep landfill (3 million ton refuse content) at Sheldon-Arleta was about 96,000m3/day. It is estimated that the local flow rate (based on comparative depths, volume and waste stream content) would be about 29,000m3/day over a 10 year period.
- A theoretical analysis of typical refuse in the USA (based on chemical composition and capacity for methane generation) gave a peak estimate of 12m3/minute/million ton of waste. This would translate to about 19,7000m3/day. This assumes biodegradation of all waste.
- LandGEM USEPA Landfill gas model: Based on the project waste masses, the gas generation rate using default values is 19,200 m3/day when the final overfill is completed and gas generation rates peak some 8 years later..

9. In summary, the gas volume per day is likely to be around a maximum of 20,000 cubic metres per day. This is far too small to warrant considering power generation or other productove reuse optiosn sich as gas scrubbing for making CNG as an option at this time.

Passive Release

10. Most species of tree cannot grow successfully over landfills which produce sufficient gas to lower the soil oxygen level below about 6%.

11. Small shallow rooted trees may survive on landfills with a conventional 600mm soil cover or relatively short lived species like acacias may thrive, die and naturally regenerate with no apparent difference in appearance to the landfill landscape with time.

12. Future development on the completed landfill is restricted (apart from problems with settlement) in a passive, gravity landfill gas system in that any man made or other voids can fill with the gas which in certain proportions (CH4 content between about 5 and 15% with air) is potentially explosive.

13. Walking paths, seats, open shelters and the like would be suitable.

14. Good quality, healthy grass cover with shrubs should be capable of development on a 600mm growing medium placed on top of the 600 mm clay final cover cap across the landfill.

15. Some landfill gas control systems include a flare whereby the gas is sucked out of the collection zone by means of a blower fan which creates a small negative head and the collected gas is burnt at the outlet. This suction and burnoff method (flaring) removes any odours.

16. To be effective, the methane content needs to be consistently high and the burner designed to prevent snuff outs by wind. There are a variety of designs available on the market and cost in the order of USD350,000 for a landfill of this size.

17. The inclusion of a blower and burner to the system would remove any gas odour.

Active Collection/Deep Wells/Utilisation of Energy

18. The extraction of landfill gas from waste fill sites by means of a field of deep wells and thence using this gas as a fuel source has been successfully carried out in numerous locations around the world.

19. The standard design for these vertical wells is to have them at about a 50 metre grid pattern spacing over the site. They are usually formed by a 200 millimetre diameter slotted pipe placed vertically in a 600 millimetre diameter gravel wick. These are usually not installed until at least after two or three years operation when there is sufficient waste on site to generate useful quantities of gas and the earlier acid forming stages of the aerobic and anaerobic breakdown have finished and methane forming bacteria dominate. Also the vertical wells usually only extend into the top 2/3 of the landfill height. The bottom third of the landfill is usually not penetrated by the gas pipes so as to avoid contact with any ponded leachate. Therefore with the landfill design being proposed there were be only 4 gas wells that could be installed in the first cell.

20. Also in the early stages of landfill development, there is a risk that the gas wells, which are operated under negative pressure, would draw in oxygen as there is only daily and intermediate cover on two faces of the cell.

21. The landfill gas may be totally cleaned so that it can be pumped directly into an existing natural gas grid or it can be improved (cleaned) to a variety of levels and used to fire gas burners for direct heat, to boil water for indirect heating or to fuel gas turbines for electricity generation.

22. The technology for the various energy utilisation approaches is well established and there are several examples of these technically successful approaches.

23. The proposed landfill will be small and will be filled relatively slowly. With the likelihood of long-term reduction in organic matter entering the landfill, this landfill will not be a particularly efficient landfill gas producer.

24. If outside parties have an interest in collecting and utilising the landfill gas from the site, then it can be made available for their independent assessment and development within the framework of the final rehabilitation plans.

25. A small royalty to the City on the gas extracted could offset costs associated with the blending of the gas extraction/utilisation system into the overall rehabilitation plan.

26. The evidence available appears to indicate that the income from sales of landfill gas or electricity generated from landfill gas does not cover the consultancy, investigation, installation, running, maintenance, piping and other overhead costs.

27. There are however, small operators who do not need to completely clean the gas and who burn it directly in existing adjacent site facilities such as brick kilns who can take advantage of a cheaper fuel source and hence make a profit.

28. However the controlled landfill will very small and unlikely to attract any commercial interest.

29. Therefore there is no little merit in installing the gas wells until the over-topping stage is underway for Cells 1 and 2, and even then the yield will be too small for commercial purposes.

30. Landfill gas will continue to be generated up to 20 years after placement.

Global Warming/Greenhouse Effect

31. The biodegradation of organic matter within a landfill produces mainly methane and carbon dioxide gases, both of which are “greenhouse” gases in that they let the warming rays of the sun penetrate the earth’s atmosphere and thence tend to restrain that warmth from passing back into space.

32. However, the organic matter which is concentrated in landfills will biodegrade in any case, at a faster rate under aerobic conditions (in air) than under the anaerobic conditions (without air) that exists within a landfill once it is placed, compacted and sealed.

33. The volume of methane and carbon dioxide that is produced in landfills is a fraction of one per cent when compared to that produced by volcanoes, deep sea geysers, fossil fuel burning, forest burning, industry, termites, cattle, rice paddies, warming of the northern hemisphere tundra and so on. The net effect of the production of methane gas and carbon dioxide gas in landfills with respect to the environment is negligible. However, landfill represents a significant fraction of the anthropogenic associated greenhouse gas emissions, and as such appropriate systems must be installed.

34. Technically, any of the above potential treatment/design options are available and a decision on the final rehabilitation details should not be made at this stage. Economic conditions, particularly in relation to energy costs, are almost certain to change over the next 10 to 15 years and beyond and hence flexibility in relation to the use or otherwise of the methane gas is preferred at this stage.

35. Since any one or a combination of all of the above described treatments/controls can be implemented at a later date without detrimental effects there is no need at this stage to make a final decision on this matter.

36. If gas reuse becomes economic or mandatory in the future, then wells can be retrofitted into the mound to maximise gas recovery rates for destruction by flaring or commercial reuse.

Appendix G Remediation of Existing Dump Sites

Existing Fires

1. In addition to the obvious environmental damage caused by waste fires at the current operating dumpsite at Srah Srang, they also present a serious health and safety risk. Incomplete combustion of the various plastic types at the landfill can result in the formation of carcinogenic by-products such as dioxins. These airborne pollutants are being breathed in by the compactor truck drivers, landfill staff and waste pickers at the site.

2. There are also many safety issues associated with such fires at the disposal site. There may be pressure vessels (gas tanks, pressure cans, etc.) deposited at the site which can explode at the elevated temperatures associated with combustion.

3. Any heavy smoke also presents a major safety problem by severely limiting sight distances. As a result, there is a much greater risk of collisions between vehicles or vehicles and people.

4. The presence of the fire, and also the associated intensity of smoke generation, appears to have been accepted by the local community as a normal aspect of waste management. This is not the case and urgent effort will be required to address this perception problem prior to attempting to remediate the site.

5. In summary, urgent action is required to prevent new fires starting in the old dumping areas and to stop the fires in previously worked areas. Initially the surface fires should be extinguished and then deeper fires progressively excavated and extinguished as part of the initial activities leading to eventual full remediation.

6. There were no active fires at the closed dumpsite at Toul Makak Lech.

7. **Existing Leachate**

8. A number of drains and contiguous water courses were inspected in and around the two dumping sites.

9. While there was some obvious leachate contamination of the water courses and impoundments, the visual extent of the leachate contamination appeared only minor. The water courses and impounded water in the closed dump cell were not black and anaerobic with gasification occurring, but rather just showed some colouration of the water column.

10. Some of the nearby water ponds appeared aerobic/oxic and were visually uncontaminated by leachate.

11. As it was the end of the dry season at the time of inspection, leachate migration from the waste piles would be minimal unless the mound was fully saturated. It is also noted that most of the organics at the site have either degraded due to natural decomposition processes or been incinerated. Therefore there is very little organic material in the refuse mounds to produce a high biological strength leachate.

12. Whilst the leachate may be weak organically, it may still of course contain inorganics such as heavy metals and biocides.

13. In general, the amount of leachate flow and peripheral contamination was apparently low for such uncontrolled facilities but this is no reason to accept this ongoing pollution.

Other Existing Environmental Issues

14. Very few vermin were observed on the sites, probably because of the extent and intensity of the fires

15. There were a number of birds present, but the infestation was not of grave concern.

16. Flies were generally at fairly low densities for such uncontrolled dumping, again due to the burning of putrescible organics such as food scraps.

17. Based on these various impacts, as well as the aesthetic and public health issues, the dumping site requires either in-situ remediation or hauling to the proposed controlled landfill site.

Remediation and/or Relocation Option

18. There are two options for managing the existing dumping areas.

- If the area is small and remote from sensitive areas such as water courses, then the previously deposited waste can be pushed into a suitable mounded shape, compacted and then covered with soil. (In the case of the current dumping site on private land, this option will only be possible if the land owner accepts this protocol.)

- If the waste amount is significant and potentially environmentally and socially damaging, then the waste needs to be excavated and extinguished, placed into trucks and hauled to the new landfill once it is operational.

19. It is proposed that both the closed and current sites should be remediated insitu and the waste not transferred to the proposed new site because:

- the separation of the closed and current sites from the proposed site is significant
- the volumes of waste are relatively small
- the waste has been burnt so the leachate will be of lower strength organically
- there is no hazardous industry in the city which would result in significant quantities of heavy metals and biocides in the waste, leading to a hazardous leachate potential
- The soil profile contains some clay limiting leachate migration and providing attachment sites for any heavy metals in the leachate
- The waste mound will be shaped, compacted, covered with clay and then a growing medium to limit rainwater infiltration leading to minimal leachate generation
- The sites are flood free

Closure Protocols

20. In most cases unless the waste pile is extensive and causing local environmental, social or aesthetic concern, it should just be shaped, compacted and covered with soil as per normal landfill operating procedures.

21. A key factor in limiting on-going leachate generation from any remediated secondary dumping sites will be providing reasonable slopes for the final mound shape.

22. The external batters should be graded at the usual 1V:2.5H and the crown should still have a minimum of 5% slope. This is to allow for differential settlement throughout the waste mass over time which can result in ponding of rain water in settled areas if the surface is flat, resulting in excessive infiltration and subsequent leachate formation. Applying cover material is then essential.

Landfill Gas Systems

23. Most remediated dumps just allow landfill gas to escape passively through the cap. This is a very common approach and has few drawbacks in terms of safety or environment. This does not present a safety risk as methane concentrations are minimal in the open atmosphere even relatively close to the final cap.

24. Landfill gas is toxic to tree growth and so if vegetation such as large trees have roots penetrating through the cover material into the waste mass, then they will be stunted or even die. A common alternative to a gas interception system is just to provide an extra depth of soil over the impermeable layer for any locations where large trees are proposed.

25. One option for gas management includes installing a rubble layer on the top 1/3 of the final mound surface to facilitate landfill gas migration to passive vents. The gas would then be freely vented to atmosphere through a number of six metre high passive stacks. This system facilitates a path for methane rich landfill gas to vent to atmosphere, which has climate change considerations. However most of the organics in the landfill have already been removed by fire so the quantities of landfill gas to be emitted will not be large.

26. Overall the inclusion of a gas blanket is not considered necessary as:

- The sites are very small
- the gas quantities will be relatively small because of the fires on site to date have removed most of the historically-deposited waste organics;
- there will not be any buildings with basements constructed on the site which could lead to explosive gas pockets forming, and
- the growing media plus clay cap will provide sufficient root depth for grasses and small shrubs to survive. If larger trees are to be planted, a localised thickening of the surface growth media will provide sufficient root protection against landfill gas impacts on tree vitality.
- The site will eventually be incorporated into the new controlled landfill

Leachate Management

27. The proposed final cover design and batter slopes will minimise rainfall infiltration and therefore leachate generation. Given that the local soil at both sites has some clay content, and the dumping sites are small, it is considered appropriate not to require the installation of a liner under the entire waste mound. Retrospectively installing such a liner would require that all waste is removed and then replaced. This will be a huge cost for what is considered to be of little environmental benefit.

28. To minimise the amount of leachate entering the water table under the site, it is important to minimise the leachate forming within the mound. This is firstly done by profiling the mound and providing suitable final cover as described below, which minimises the volume of leachate generated.

29. An option for further reducing the leachate head would be to provide a peripheral leachate interceptor drain. However this would usually only be required for large dumps and not the locally small size. The interceptor would usually consist of a gravel filled drain under the toe of the final cover. Within the gravel drain would be a 200mm diameter slotted pipe laid at grade. The pipe may be encased with geotextile to limit the intrusion of silt.

30. The pipe would drain to one or more leachate pumping stations. The leachate pumping stations would lift the leachate to irrigate newly planted areas in the dry weather encouraging vegetation cover. This would involve running a permanent pipe to the top of the mound and then having a relocatable pipe attached to this outlet. The relocatable pipe would be moved around the areas to be irrigated as required.

31. Escaping landfill gas is fully saturated and this also passively removes leachate.

32. Given the relatively small disposal sites, it is recommended that compaction, shaping and application of soil cover should be sufficient without the need for leachate interceptors and pumping stations.

33. **Fire Control**

34. Fires at waste disposal sites are extremely hard to manage.

35. Small areas of surface combustion can be controlled with water and subsequent application of the soil cover material. However areas which are smoking due to underground combustion cannot be extinguished just by applying water at the location of smoke egress. Landfills are anisotropic and the smoke plumes resulting from fires at depth often surface some distance laterally from the actual subsurface fire source. Therefore no matter how much water is applied at the point of smoke emission, there is no guarantee that this water will reach the combustion source.

36. The only way to extinguish subsurface fires is to excavate until the combustion source is reached. The combusting material can then be removed, spread and watered until the fire is extinguished, and the waste then returned to the cell only once it has returned to ambient temperature.

37. Even for small spot fires, this can be a very time consuming and expensive activity.

38. This fire control program will also need to include an education component to remove any belief that merely applying soil as final cover will extinguish all fires in the long term, especially in the upper parts of the waste piles. Any new fires starting in the fresh waste piles, or restarting in the previously worked areas, should be immediately and fully extinguished as the highest priority. This may require the preparation of a temporary cleared area or intermediately covered existing waste area for placement and management of excavated burning waste.

Environmental management

39. To support such a remediation scheme for a large closure activity, it will usually be necessary be necessary to install a number of groundwater monitoring wells. Such wells may have to be installed for the existing sites but this is unlikely given the small size of the dumping sites. They would be located in such a way as to provide hydrogeologically appropriate upslope and downslope sampling locations for the final mound footprint.

40. If the sampling indicates that groundwater contamination is occurring, then deleaching wells can be installed retrospectively within the waste mound. Groundwater contamination is considered extremely unlikely if the waste is placed correctly, compacted, shaped appropriately, covered and equipped with leachate interceptors systems, in accordance with the general specifications above.

41. Given the small size of the site involved, and the future installation of monitoring wells for the controlled landfill, these additional monitoring wells are not considered necessary.

Immediate Action Required

42. The biggest cost associated with remediation will be the excavation of burning/smouldering waste at depth, carting to a prepared area and spreading, extinguishing the fires, reloading the waste, transferring it to the new cell location and finally compacting it at the current dumpsite. Minimising the quantity of waste that has to be extinguished will greatly reduce the overall remediation costs.

43. Therefore the following activities should be commenced as soon as possible:

- Advise the city staff that fires are unacceptable and are to be extinguished as the highest priority
- Provide the operators with cover soil and spreading equipment, as well as a water truck and excavator.
- Do not allow any more fires to be started.
- Remove any burning tyres or other larger items on fire and extinguish
- Put intermediate soil cover (300mm thick) over all previously worked areas which are not currently smoking or burning to prevent fires spreading
- Progressively excavate burning/smouldering waste at depth, cart to a prepared area and spread, extinguish the fires, reload the waste and transfer to the active cell location and then apply intermediate cover soil
- Compact waste properly by pushing up a slope and having at least 3 passes
- start trimming back the perimeter batters to a 1v:2.5h slope if required (or just develop the replaced waste into a 5% plateau if no mounding is required) ready for final capping in accordance with the final mound profile and footprint.
- Cover with intermediate cover soil to prevent fires restarting

Remediation Costs

44. The bulldozer, excavator and body tipping truck are proposed to be purchased prior to controlled landfill commissioning. These vehicles can then be used to remediate the existing dumping site. With some preplanning by the city, the site could be progressively remediated and closed within the current operating budget of the Municipality

45. This approach will also provide some training opportunities for the new plant operators prior to operating new controlled landfill.

Appendix H Detailed Costings Spreadsheets

Pursat CAPEX (STAGE 1)

No	ITEM	UNIT	QUANTITY	RATE (USD)	RATE (Riel)	COST (USD)	COST (Riel)	COMMENTS
	LANDFILL CONSTRUCTION COST					**1,136,987**	**4,547,948,000**	
A	**EARTHWORKS**					**74,650**	**298,600,000**	
	Bulk earthworks for landfill Cell	m^3	20,160	2.50	10,000	50,400	201,600,000	Cut, carry and dump as future cover material or encircling bund
	Trimming of landfill cell	m^2	14,400	0.75	3,000	10,800	43,200,000	
	Bulk earthworks for roads, building pads, pump station, monitoring wells and leachate exit pipe.	m^3	700	2.50	10,000	1,750	7,000,000	60 m2 of buildings with 1 metre deep pads, parking areas 250m2. plus leachate pipe (60m by 4m2), pump well and monitoring wells each 10m3
	Levelling and trimming of recycling area, building footprints and roads	m^2	5,600	0.75	3,000	4,200	16,800,000	Assume 160m internal access road to cell then extend to 3000m2 recycling area at end of Cell 1.
	Construction of stormwater drains	Item	1	7,500	30,000,000	7,500	30,000,000	Road drainage included in road costs. This is just for general drains around cell bund and recycling area.
B	**BUILDINGS**					**30,900**	**123,600,000**	
	Administration, ablution, laboratory and storeroom	m^2	60	350.00	1,400,000	21,000	84,000,000	Includes fit out and lighting, etc.
	Generator building	m^2	20	250.00	1,000,000	5,000	20,000,000	Assumes connection to local power lines is not possible
	Gatehouse	m^2	14	350.00	1,400,000	4,900	19,600,000	
C	**ROADS, HARDSTAND and TREE SCREEN**					**675,400**	**2,701,600,000**	
	Access road from Main Road to landfill entry (5.3m wide double lane bitumen sealed with 1 metre shoulders, and elevated 1.5 metres)	m	1,600	300.00	1,200,000	480,000	1,920,000,000	Elevation earthworks involves 7.5m wide crest with 1V:2H batters 1.5m high making a cross section of 16 Sq m by 1600m long makes 25,600m3. at $2.50/m3. making $40/m or $64,000 in total. Allow the top 600mm to be fully compacted at $1/sq.m. in 200mm layers, with basic compaction in the lower layers, making $35,000 or $22/L.m. The road pavement costs $220 lin.m including allowance for the 1m wide shoulders ($15/m2) and bimumen seal ($20/m2) on 5.3m width,. Allow for culverts every 500 m at a cost of $10,000 each making $30,000, or $18/lin.m. Total cost is $300/linear metre.
	Main access road within the landfill (2 lanes, Asphalt both lanes)	m	160	280.00	1,120,000	44,800	179,200,000	
	Road to the cell (2 lane gravel permanent)	m^2	1,130	20.00	80,000	22,600	90,400,000	Outside of Cell 1 back to main access road - 8m wide
	Temporary road (2 lane gravel temporary)	m^2	2,400	15.00	60,000	36,000	144,000,000	Between Cells 1 and 2 and 3 - covered over eventually - 8 m wide

No	ITEM	UNIT	QUANTITY	RATE (USD)	RATE (Riel)	COST (USD)	COST (Riel)	COMMENTS
	Gravel parking areas	m^2	250	20.00	80,000	5,000	20,000,000	For site equipment such as dozers and workers and visitors cars
	Site perimeter bund (1.5 high)	m	1,350	60.00	240,000	81,000	324,000,000	Bund will have a crest width of 2.5m giving cross section of 8sq.m. for 1350m making 10,800 cu.m. or $27,000 at $2.5/m3. Allow for compaction every 200mm making 40 m2./linear metre on average, making $40/lin.m. at $1/m2 for compaction. Cost per lin.m. is $60 average.
	Tree screen in buffer plus general site landscaping	m^2	6,000	1.00	4,000	6,000	24,000,000	Visual barrier between landfill and mainly the resettlement area.
D	**SITE INFRASTRUCTURE**					**356,037**	**1,424,148,000**	
	Compacted clay liner	m^3	8,640	13.00	52,000	112,320	449,280,000	Assume clay is purchased offsite from clay borrow pits and carted to the cell ($8/m3), reworked and compacted in 3 by 200mm layers ($1./m2 per layer)
	Leachate collector pipe - 200 dia PVC slotted laid in a 600sq trench	m	105	40.00	160,000	4,200	16,800,000	1 main drain plus connector. Allow $5/m extra for slotting the pipe
	Leachate exit pipe - 200m dia PVC solid wall to pump station	m	90	35.00	140,000	3,150	12,600,000	Deep trench therefore extra costs to lay.
	Gravel backfill around leachate pipe	m^3	38	15.00	60,000	567	2,268,000	600mm by 600mm trench to be backfilled
	Leachate pump station and pump	Item	1	10,000	40,000,000	10,000	40,000,000	Includes a 5L/S submersible pump, running power lines to the pump, and power board/control electrics at pump station
	Irrigation and reinjection relocatable pipe (75mm HDPE)	m	200	3.50	14,000	700	2,800,000	Includes allowance for drilling holes in a 100m section of the pipe for irrigation purposes
	Construction of Groundwater Monitoring wells	Item	3	7,500	30,000,000	22,500	90,000,000	Includes lockable cap and bentonite or concrete waterproof collar
	Enclosure fence surrounding ultimate site	m	1,300	75	300,000	97,500	390,000,000	Fence 2m high plus 3 strand barbwire top - around cell 1 and all buildings
	Movable litter fence	m	50	100	400,000	5,000	20,000,000	2 m high in 3 m long panels set into relocatable concrete feet pads
	Electric generator 20kVA	item	1	10,000	40,000,000	10,000	40,000,000	To power leacahte and dewatering pump as well as security lighting and aircon and lighting in buildings
	Lighting column and High-pressure sodium lamps	Item	6	1,100	4,400,000	6,600	26,400,000	Street and security lighting for buildings and equipment, as well as portable lights for night operation
	Lighting cable	m	200	25	100,000	5,000	20,000,000	
	Electrical control cabinets (low and high voltage)	Item	1	5,000	20,000,000	5,000	20,000,000	
	Non potable water supply (well	Item	1	7,500	30,000,000	7,500	30,000,000	Bore water well with pump and elevated header tank for non-

No	ITEM	UNIT	QUANTITY	RATE (USD)	RATE (Riel)	COST (USD)	COST (Riel)	COMMENTS
	with pump and header tank)							potable water and fire fighting purposes.
	Potable water supply (Rainwater tank and pump)	Item	1	3,000	12,000,000	3,000	12,000,000	Building gutters and rainwater tank with pump for drinking water
	Sanitation (Septic tank and leach field)	Item	1	3,000	12,000,000	3,000	12,000,000	
	Portable dewatering pump for open cells and water inside the perimeter bund	Item	1	5,000	20,000,000	5,000	20,000,000	Diesel powered trolley mounted pump with 20L/s capacity. To be used in celss and enclosed bunded area as required .
	Weighbridge 60T	Item	1	55,000	220,000,000	55,000	220,000,000	Including civil works and installation
	LANDFILL OPERATING EQUIPMENT COST					**482,000**	**1,928,000,000**	
	Dozer (Caterpillar D5/6 or equivalent with landfill blade)	item	1	250,000	1,000,000,000	250,000	1,000,000,000	Essential equipment.
	Excavator/ end Loader - assume Caterpillar D320 or equivalent	Item	1	150,000	600,000,000	150,000	600,000,000	For loading cover soil and any waste to be relocated. Drain cleanouts.
	10 wheeler tipping dump truck	Item	1	70,000	280,000,000	70,000	280,000,000	Carting cover soil and waste to be relocated
	8,000L Water tank with pump	Item	1	12,000	48,000,000	12,000	48,000,000	For watering gravel roads and fire control
	LAND CLEARANCE COMPENSATION					**-**	**-**	
	Land purchase	ha	-	0.00	0	-	-	Assume land is government owned
	WASTE COLLECTION FLEET AND EQUIPMENT					**609,000**	**2,436,000,000**	
	Waste compactor collection trucks (20m3 capacity - 10t)	Item	2	80,000	320,000,000	160,000	640,000,000	All equipment prices are based on purchasing high quality units from internationally recognised suppliers. Much cheaper equipment is available but with substantially reduced working life.
	Waste compactor collection trucks (5m3 capacity - 2.5t)	Item	5	35,000	140,000,000	175,000	700,000,000	
	10 wheeler tipping dump truck	Item	1	70,000	280,000,000	70,000	280,000,000	
	Hook lift waste collection trucks (prime mover)	Item	1	70,000	280,000,000	70,000	280,000,000	
	Hook lift bins (12 m3 or 3 tonnes on average)	Item	30	3,000	12,000,000	90,000	360,000,000	Low side, rear entry door walk-in bins for easy access for individuals and also pushcart emptying. Sizes from 2 cubic metres to 12 cubic metres (6m by 2.2m by 900 high making about 3 tonnes capacity)
	Small motorised carts	Item	2	8,000	32,000,000	16,000	64,000,000	
	Pushcarts	Item	40	700	2,800,000	28,000	112,000,000	
	TOTAL					**2,227,987**	**8,911,948,000**	

Source: TA 7986-CAM consultants

Pursat Waste Collection OPEX (2022)

Item	Number	Hours/ year	Cost/hr. (USD)	Total (USD)	Total (Riel)	Loads /day	Tonnes/ Load	Tonnes/day
Waste compactor collection trucks (20m3 capacity say 10t/load and 1 loads/day)	2	2,496	15	74,880	299,520,000	1	10	20
Waste compactor collection trucks (5m3 capacity say 2.5t/load and 2 loads/day)	5	2,496	8	99,840	399,360,000	2	2.5	25
Waste body-tipper collection trucks (say 3t/load and 2 loads/day)	1	2,496	12	29,952	119,808,000	1	5	5
Hook lift waste collection trucks (prime mover - say 1.5t/load and equivalent to 6 loads/day) May be more trips using smaller bins as required, or less if moving the larger bins	1	2,496	12	29,952	119,808,000	5	2	10
Hook lift bins - 1 at each secondary dumping location initially	30			-	-			
Small motorised carts (primary collection to secondary sites)	2	2,496	3	14,976	59,904,000	**Total tons capacity /day**		**60**
Pushcarts	40				-			
Item	**Number**	**Months/ year**	**Cost/Mth. (USD)**	**Total (USD)**	**Total (Riel)**			
Sanitary Inspector Wages	1	12	300	3,600	14,400,000			
Truck and vehicle drivers	12	12	250	36,000	144,000,000			
Garbage Collectors/Sanitary Worker Wages. Assume 3 garbage collectors per large vehicle (in addition to the driver) plus 20 pushcart and general sanitary workers	46	12	200	110,400	441,600,000			
TOTAL OPEX/YEAR				**$ 399,600**	**1,598,400,000**			

The actual cost per domestic Household will be lower as commercial facilties, such as restaurants and hotels, as well as institutions such as schools and offices, will pay a higher charge for waste removal. This additional cost for non-domestic waste removal will reduce the net cost to a domestic household.

Source: TA 7986-CAM consultants

Pursat CAPEX (2046)

No	ITEM	UNIT	QUANTITY	RATE (USD)	RATE (Riel)	COST ($ USD)	COST (Riel)	COMMENTS
	LANDFILL CONSTRUCTION COST					**2,461,240**	**9,844,958,000**	
A	**EARTHWORKS**					**492,063**	**1,968,250,000**	
	Bulk earthworks for landfill Cell	m^3	171,875	2.50	10,000	429,688	1,718,750,000	Cut, carry and dump as future cover material or encircling bund
	Trimming of landfill cell	m^2	62,500	0.75	3,000	46,875	187,500,000	
	Bulk earthworks for roads, building pads, pump station, monitoring wells and leachate exit pipe.	m^3	2,750	2.50	10,000	6,875	27,500,000	94 m2 of buildings with 1 metre deep pads, parking areas 250m2. plus leachate pipe (60m by 4m2), pump well and monitoring wells each 10m3
	Levelling and trimming of recycling area, building footprints and roads	m^2	1,500	0.75	3,000	1,125	4,500,000	Assume 50m access road to cell then extend to 3000m2 recycling area at end of Cell 1.
	Construction of stormwater drains	Item	1	7,500	30,000,000	7,500	30,000,000	Road drainage included in road costs. This is just for general drains around cell bund and recycling area
B	**BUILDINGS**					**30,900**	**123,600,000**	
	Administration, ablution, laboratory and storeroom	m^2	60	350.00	1,400,000	21,000	84,000,000	Includes fit out and lighting, etc.
	Generator building	m^2	20	250.00	1,000,000	5,000	20,000,000	Assumes connection to local power lines is possible
	Gatehouse	m^2	14	350.00	1,400,000	4,900	19,600,000	
C	**ROADS, HARDSTAND and TREE SCREEN**					**800,000**	**3,200,000,000**	
	Acces road from Main Road to landfill entry (5.3m wide double lane bitumen sealed with 1 metre shoulders, and elevated 1.5 metres)	m	1,600	300.00	1,200,000	480,000	1,920,000,000	Elevation earthworks involves 7.5m wide crest with 1V:2H batters 1.5m high making a cross section of 16 Sq m by 1600m long makes 25,600m3. at $2.50/m3. making $40/m or $64,000 in total. Allow the top 600mm to be fully compacted at $1/sq.m. in 200mm layers, with basic compaction in the lower layers, making $35,000 or $22/L.m. The road pavement costs $220 lin.m including allowance for the 1m wide shoulders ($15/m2) and bimumen seal ($20/m2) on 5.3m width,. Allow for culverts every 500 m at a cost of $10,000 each making $30,000, or $18/lin.m. Total cost is $300/linear metre.
	Main access road within the landfill (2 lanes, Asphalt both	m	160	280.00	1,120,000	44,800	179,200,000	

No	ITEM	UNIT	QUANTITY	RATE (USD)	RATE (Riel)	COST ($ USD)	COST (Riel)	COMMENTS
	lanes)							
	Site perimeter bund (1.5 high)	m	1,350	60.00	240,000	81,000	324,000,000	Bund will have a crest width of 2.5m giving crossection of 8sq.m. for 1350m making 10,800 cu.m. or $27,000 at $2.5/m3. Allow for compaction every 200mm making 40 m2./linear metre on average, making $40/lin.m. at $1/m2 for compaction. Cost per lin.m. is $60 average.
	Road around finshed cells (2 lane gravel permanent)	m^2	6,160	20.00	80,000	123,200	492,800,000	Outside of Cell 1 back to main access road - 8m wide
	Temporary road (2 lane gravel temporary)	m^2	4,000	15.00	60,000	60,000	240,000,000	Between Cells 1 and 2 and 3 - covered over eventually - 8 m wide
	Gravel parking areas	m^2	250	20.00	80,000	5,000	20,000,000	For site equipment such as dozers and workers and visitors cars
	Tree screen in buffer plus general site landscaping	m^2	6,000	1.00	4,000	6,000	24,000,000	Visual barrier between landfill and main road is main component
D	**SITE INFRASTRUCTURE**					**1,138,277**	**4,553,108,000**	
	Compacted clay liner	m^3	37,500	13.00	52,000	487,500	1,950,000,000	Assume clay is purchased offsite from clay borrow pits and carted to the cell ($7/m3), reworked and compacted in 3 by 200mm layers ($1.50/m3)
	Leachate collector pipe - 200 dia PVC slotted laid in a 600sq trench	m	380	40.00	160,000	15,200	60,800,000	1 main drain plus connector. Allow $5/m extra for slotting the pipe
	Leachate exit pipe - 200m dia PVC solid wall to pump station	m	320	35.00	140,000	11,200	44,800,000	Deep trench therefore extra costs to lay.
	Gravel backfill around leachate pipe	m^3	137	15.00	60,000	2,052	8,208,000	600mm by 600mm trench to be backfilled
	Leachate pump station and pump	Item	2	10,000	40,000,000	$ 20,000	80,000,000	Includes a 5L/S submersible pump, running power to the pump, and power board/control electrics at pump station
	Irrigation and reinjection relocatable pipe (75mm HDPE)	m	350	3.50	14,000	1,225	4,900,000	Includes allowance for drilling holes in a 100m section of the pipe for irrigation purposes
	Construction of Groundwater Monitoring wells	Item	3	7,500	30,000,000	22,500	90,000,000	Includes lockable cap and bentonite or concrete waterproof collar
	Enclosure fence surrounding	m	1,300	75	300,000	97,500	390,000,000	Fence 2m high plus 3 strand barbwire top - around cell 1 and all buildings
	Movable litter fence	m	50	100	400,000	5,000	20,000,000	2 m high in 3 m long panels set into relocatable concrete feet pads
	Electric generator 20kVA	item	1	10,000	40,000,000	10,000	40,000,000	To power leacahte and dewatering

No	ITEM	UNIT	QUANTITY	RATE (USD)	RATE (Riel)	COST ($ USD)	COST (Riel)	COMMENTS
								pump as well as security lighting and aircon and lighting in buildings
	Lighting column and High-pressure sodium lamps	Item	12	1,100	4,400,000	13,200	52,800,000	Street and security lighting for buildings and equipment, as well as portable lights for night operation
	Lighting cable	m	300	25	100,000	7,500	30,000,000	
	Electrical control cabinets (low and high voltage)	Item	1	5,000	20,000,000	5,000	20,000,000	
	Portable dewatering pump for open cells	Item	1	5,000	20,000,000	5,000	20,000,000	Diesel powered trolley mounted sludge pump with 5l/s capacity.
	Non potable water supply (well with pump and header tank)	Item	1	7,500	30,000,000	7,500	30,000,000	Bore water well with pump and elevated header tank for non-potable water and fire fighting purposes.
	Potable water supply (Rainwater tank and pump)	Item	1	3,000	12,000,000	3,000	12,000,000	Building gutters and rainwater tank with pump for drinking water
	Sanitation (Septic tank and leach field)	Item	1	3,000	12,000,000	3,000	12,000,000	
	Weighbridge 60T	Item	1	55,000	220,000,000	55,000	220,000,000	Including civil works and installation
	Landfill gas vent pipes	m	340	40	4,000	13,600	1,360,000	200dia slotted pipes in gravel surround at 50m centres over site to 2/3 depth of waste mound.
	Landfill gas collection manifold	m	1,100	3	300	3,300	330,000	75mm dia HDPE above ground
	Landfill flare	Item	1	350,000	35,000,000	350,000	35,000,000	
	LANDFILL OPERATING EQUIPMENT COST					**1,572,000**	**6,288,000,000**	
	Compactor (Landfill Compactor Caterpillar D826 or equivalent) plus prime mover and low loader shared between all landfill sites	Item	1	520,000	2,080,000,000	520,000	2,080,000,000	Assume a 826 model compactor which is mid size and approporiate for this ultimate daily tonnage
	Dozer (Caterpillar D5 then D6 or equivalent with landfill blade)	Item	2	300,000	1,200,000,000	600,000	2,400,000,000	Essential.
	Excavator/ end Loader - assume Caterpillar D320 or equivalent	Item	2	150,000	600,000,000	300,000	1,200,000,000	For loading cover soil and any waste to be relocated. Drain cleanouts.
	10 wheeler tipping dump truck	Item	2	70,000	280,000,000	140,000	560,000,000	Carting cover soil and waste to be relocated
	8,000L Water tank with pump	Item	1	12,000	48,000,000	12,000	48,000,000	For watering gravel roads and fire control
LAND CLEARANCE COMPENSATION						**-**	**-**	
	Land purchase	ha	-	0.00	0	-	-	Assume land is government owned
	WASTE COLLECTION FLEET AND EQUIPMENT					**1,745,000**	**6,980,000,000**	
	Waste compactor collection trucks (20m3 capacity - 10t)	Item	6	80,000	320,000,000	480,000	1,920,000,000	All equipment prices are based on purchasing high quality units from internationally recognised suppliers. Much cheaper equipment is available
	Waste compactor collection trucks (5m3 capacity - 2.5t)	Item	15	35,000	140,000,000	525,000	2,100,000,000	

No	ITEM	UNIT	QUANTITY	RATE (USD)	RATE (Riel)	COST ($ USD)	COST (Riel)	COMMENTS
	10 wheeler tipping dump truck	Item	3	70,000	280,000,000	210,000	840,000,000	but with substantially reduced working life.
	Hook lift waste collection trucks (prime mover)	Item	3	70,000	280,000,000	210,000	840,000,000	
	Hook lift bins (max of 12 m3 or 3 tonnes)	Item	75	3,000	12,000,000	225,000	900,000,000	Low side, rear entry door walk-in bins for easy access for individuals and also pushcart emptying. Sizes from 2 cubic metres to 12 cubic metres (6m by 2.2m by 900 high making about 3 tonnes capacity)
	Small motorised carts	Item	4	8,000	32,000,000	32,000	128,000,000	
	Pushcarts	Item	90	700	2,800,000	63,000	252,000,000	
	TOTAL					**$ 5,778,240**	**23,112,958,000**	

Source: TA 7986-CAM consultants

Appendix I Implementation Schedule

Solid Waste Management Component – Implementation Schedule

Item	2015	2016	2017	2018	2019	2020	2021	2022
2.3 Improved Solid Waste Management								
Conduct topographical and soil surveys								
Update feasibility study and prepare appraisal report for ADB and government approval.								
Transfer of O&M responsibilities and tariff collection for solid waste management to USU								
Issue bids, evaluate bids and submit to ADB for no objection								
Submit external resettlement M&E report to ADB (continuous, as per agreed RPs)								
Award contract for landfill construction								
Procure landfill equipment								
Remediation of old dumpsites at Srah Srang and Toul Makak Lech								
Landfill construction and supervision								
Procure collection equipment								
Final handover of works								
Internal monitoring of safeguards, including RPs and EMPs (continuous, as per agreed safeguard documents)								
Defects liability period								

Source: TA 7986-CAM consultants

Appendix J Drawings

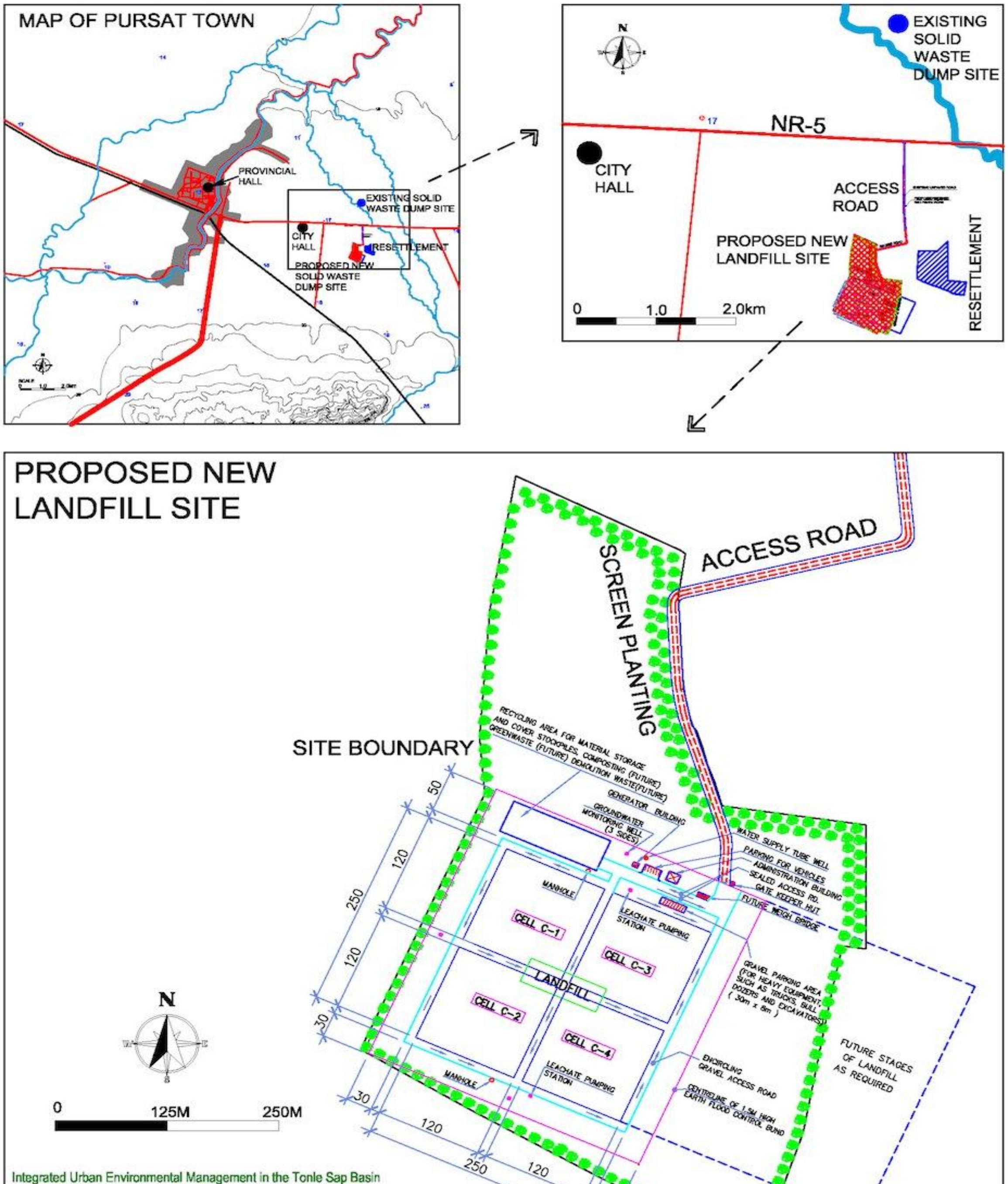


Figure D.1
Pursat Landfill Site Plan

Source: TA 7986-CAM consultants

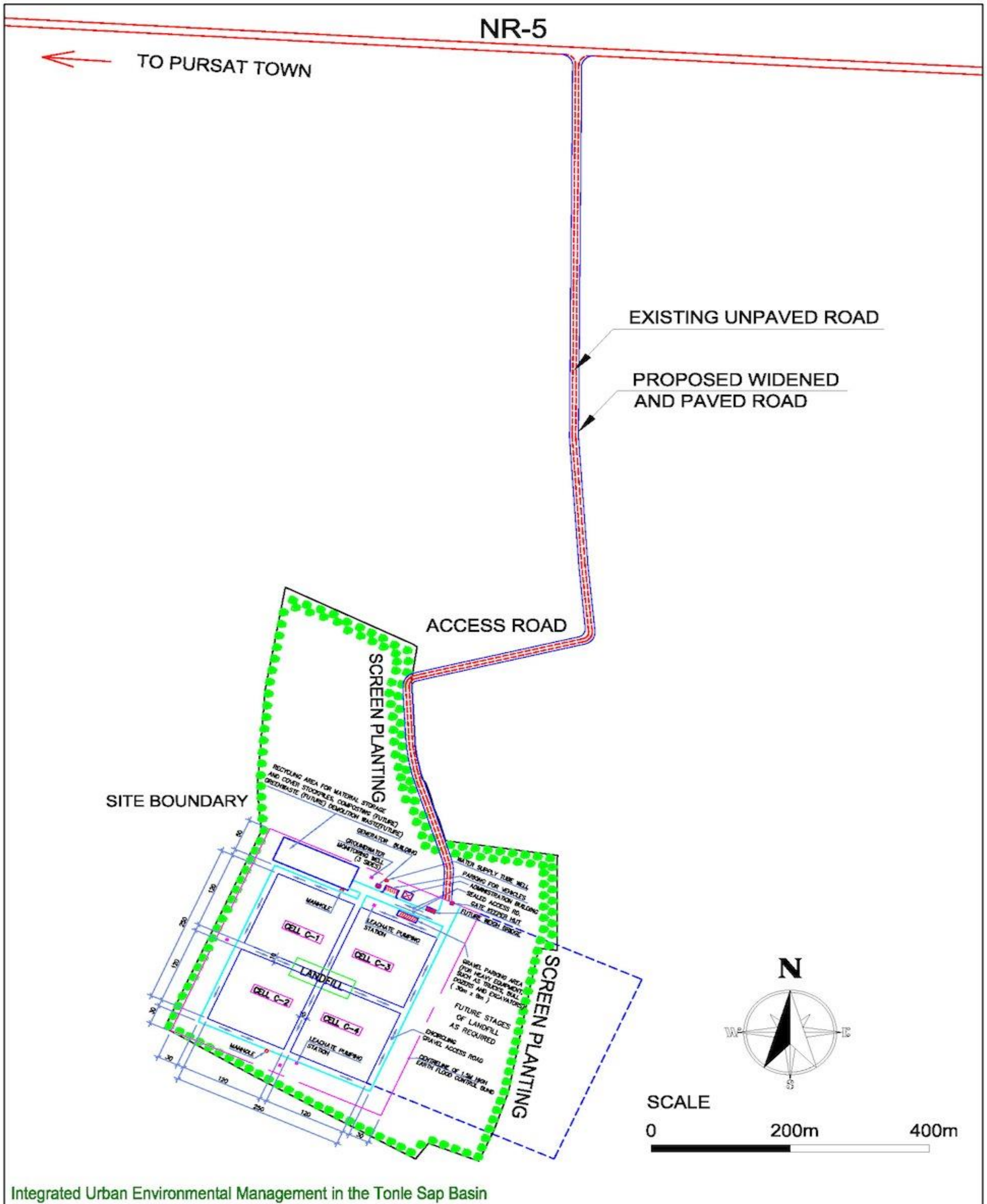


Figure D.2
Pursat Landfill Site Plan

Source: TA 7986-CAM consultants

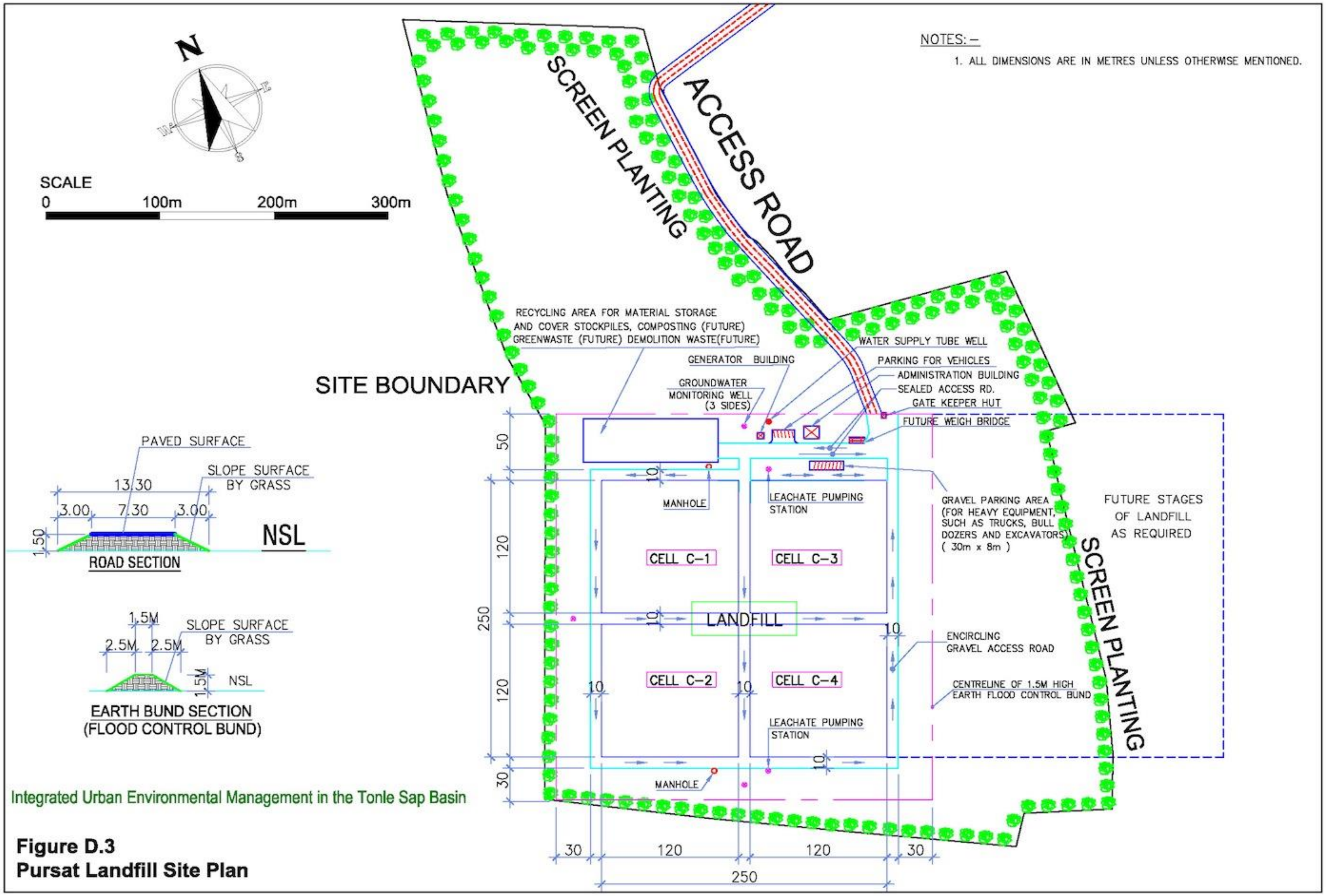
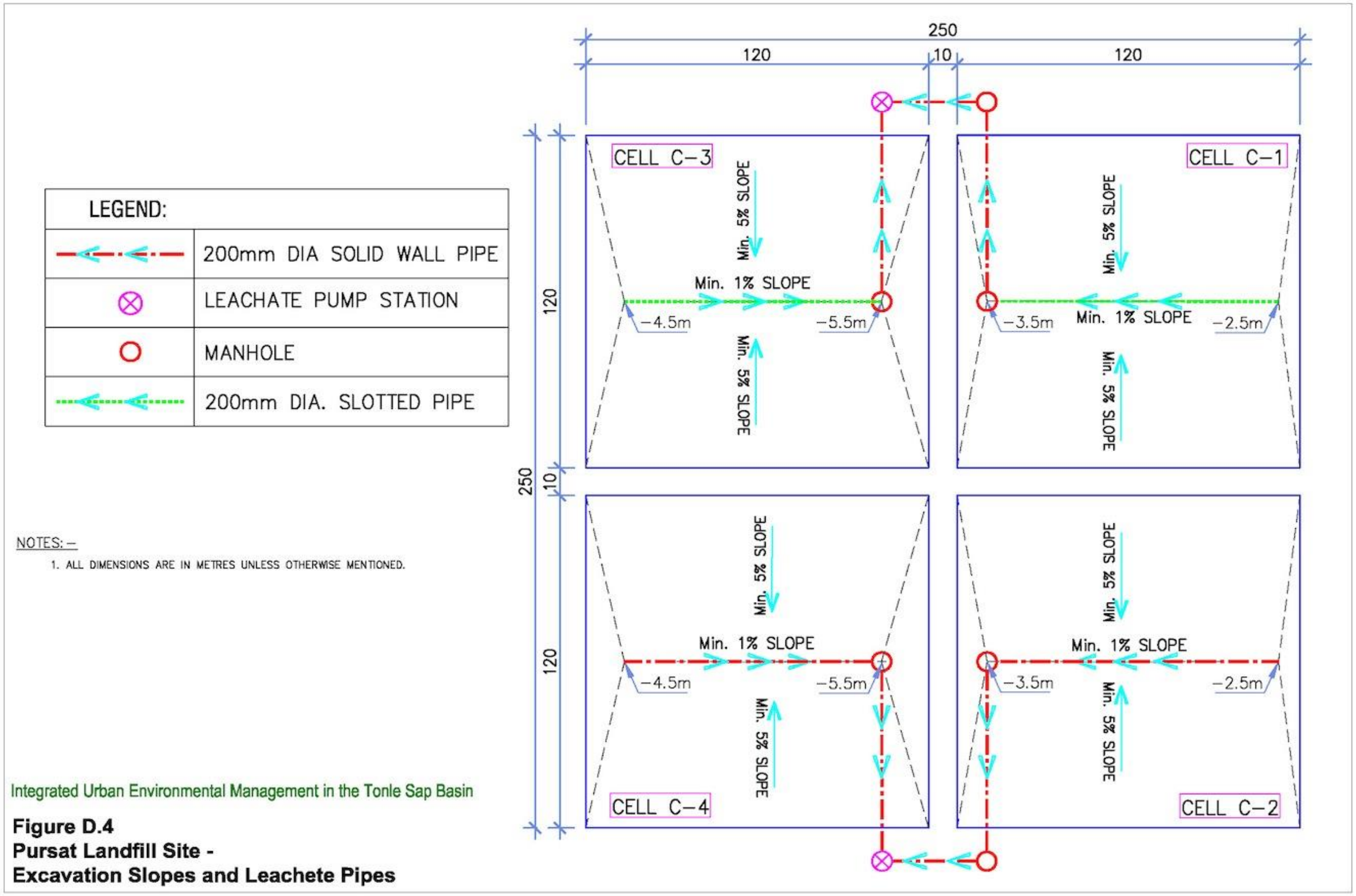


Figure D.3
Pursat Landfill Site Plan

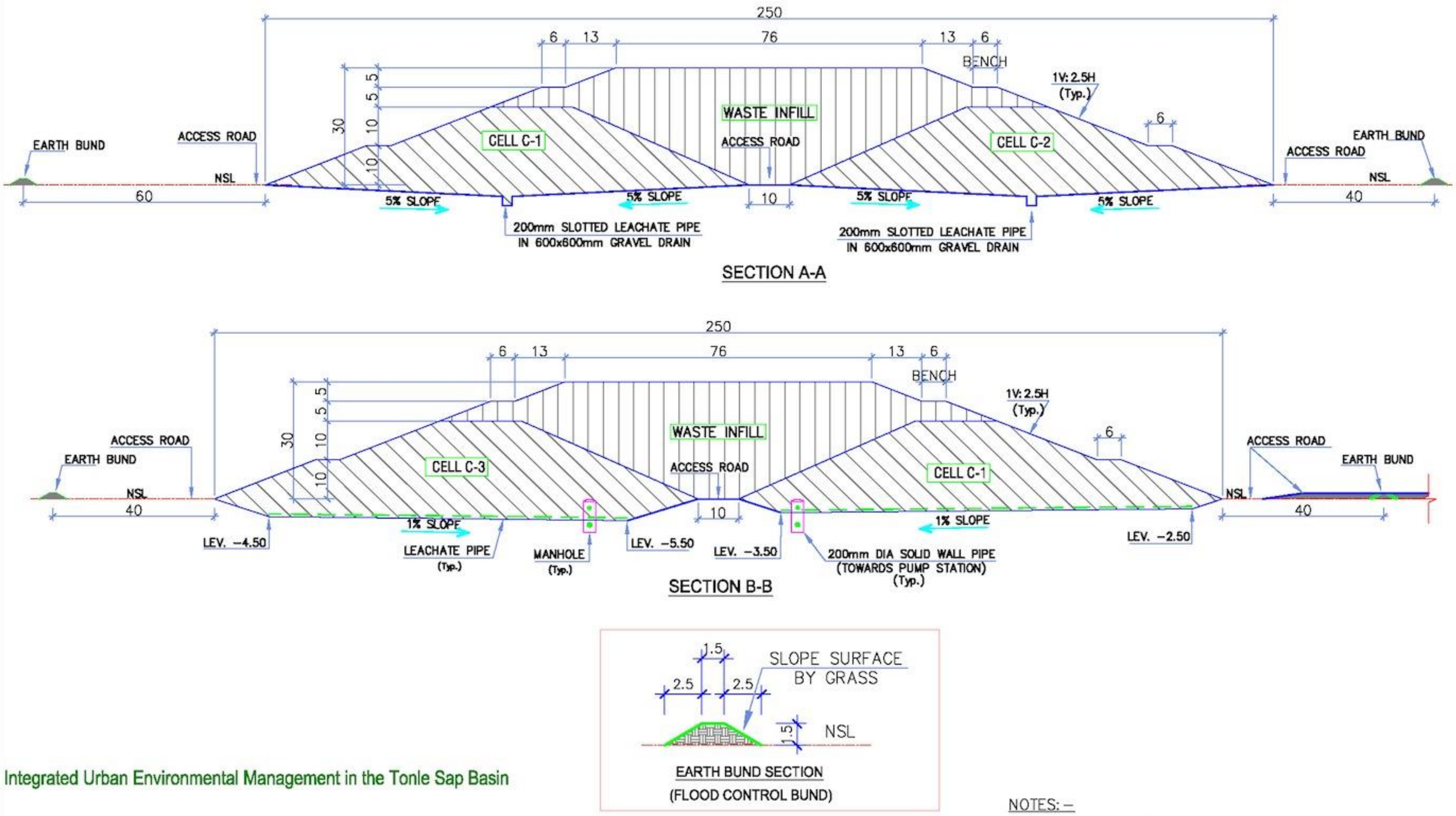
Source: TA 7986-CAM consultants



Integrated Urban Environmental Management in the Tonle Sap Basin

Figure D.4
Pursat Landfill Site -
Excavation Slopes and Leachete Pipes

Source: TA 7986-CAM consultants



Integrated Urban Environmental Management in the Tonle Sap Basin

Figure D.5
Pursat Landfill Site - Sections Plan

NOTES: –

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE MENTIONED.
2. FOR LOCATION OF SECTION A–A AND B–B REFER FIGURE D.2

Source: TA 7986-CAM consultants