PROPOSED METHODOLOGY FOR SITING OF COMPOST FACILITIES IN VIENTIANE, LAO PDR

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Abstract

The choices made while siting a compost facility can greatly influence the success or failure of the facility and can affect the related environmental impacts, social impacts and economics. In this report, a methodology is proposed for siting compost facilities in Vientiane, Lao PDR. This methodology is based on a review of the literature on siting practices specifically for solid waste management facilities and was developed using the experience gained through field work in Vientiane during the summer of 2004. The methodology is detailed enough to allow for systematic and transparent decision making and flexible enough to allow for full incorporation of context into the siting process. The proposed methodology for compost facility siting has four steps: identification of objectives, criteria and constraints; identification of candidate sites; investigation of candidate sites; and, evaluation of sites. A case study using four sites from Vientiane is also presented to demonstrate the application of the proposed methodology.

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1 Introduction

1.1 Background

1.1.1 Lao People's Democratic Republic

Lao People's Democratic Republic (Lao PDR) is a landlocked country located in Southeast Asia and is bordered by China and Myanmar to the north, Thailand to the west, Cambodia to the south and Vietnam to the east. Lao PDR is 236,800 square kilometres and has a population of approximately 6,068,000 growing at a rate of 2.44% as of July 2004 (CIA, 2004). The Mekong River is the country's most important transportation route and runs from China in the north to Cambodia in the south as shown in Figure 1. The two main urban centres are Savannakhet in the south and Vientiane, the capital, toward the north.

Figure 1.1: Map of Lao PDR

Geographically, Lao PDR is mainly rugged and mountainous with some plains and plateaus. The Mekong flood plain is an important agricultural zone and accounts for much of the agricultural land in the country. The climate is characterized by the tropical monsoon with a rainy season stretching from May to November and a dry season from December to April. Much of Lao PDR is thickly forested and, as on of the most pristine ecologies remaining in Southeast Asia, the country is important for biodiversity (Cummings, 2002).

The main natural resources in Lao are timber, hydropower, gypsum, tin, gold and gemstones. Agriculture is very important to Lao's economy as 49.4% of the GDP is from the agricultural sector whereas 24.5% is due to industry and 26.1% is due to the service sector including tourism. Lao still has a relatively low level of infrastructure with no rail, rudimentary roads and limited telecommunications (CIA, 2004).

According to the 2004 UN Human Development Report, Lao PDR ranks 135th out of 177 countries on the human development index and therefore is at the low end of the medium developed countries, only 7 countries away from having a low level of development. The life expectancy is 54 years, the adult literacy rate is 66%, the infant mortality rate is 97 per 1000 live births and 63% still have no sustained access to potable water (UNDP, 2004).

1.1.2 Vientiane

The city of Vientiane is the capital of the Lao PDR and has a population of 500,000 (Lao Embassy, 1997). It is located on the bank of the Mekong River directly across from Nong Khai, Thailand. Vientiane receives between 1500 and 2000mm of rain annually and the temperatures can range from 15°C in the dry season to 38°C in the rainy season (Cummings, 2002). As the capital, it is the location of all of the foreign embassies as well as the Presidential palace, government offices and non-governmental organization headquarters.

There are a number of markets in Vientiane, differing in size, operating hours and type of products sold. Most citizens of Vientiane do the main part of their shopping at these markets. The largest markets in the centre of the city are Thalat Khuadin, Thalat Sao, Thalat That Luang and Thalat Thong Khankham ('thalat' meaning 'market'). All of these markets sell a combination of prepared food, raw food, packaged goods and clothing.

1.1.3 Solid Waste Management in Vientiane

Historically, solid waste in Vientiane has been burned and/or dumped in the Mekong. The burning of solid waste still does occur on a small scale in the city. The Lao Garbage Society (LGS), which was founded in 1994, offers residential and commercial pickup and transportation to the landfill. In 1997, the Japanese International Corporation Agency (JICA) founded the Urban Cleansing Service (UCS). JICA donated $2.7 million US to construct a building for UCS, upgrade the landfill, purchase vehicles and purchase large, metal solid waste bins. UCS currently contributes to 90% of the solid waste collection in Vientiane and LGS contributes to the remaining 10%. Vientiane's landfill is located 18 kilometres outside of the city and was constructed for a 15 year lifespan to be reached in 2010. A new site has been proposed at km 36 (36 kilometres outside of Vientiane) to be used after the km 18 site is full. A local non-governmental organization (NGO), the Participatory Development Training Centre (PADETC), set up a company that buys recyclable materials and ships them to Thailand. This has promoted the growth of recycling banks that buy recyclables from individuals and members of the informal sector (waste pickers and informal collectors) (Manivong, 2004).

1.1.4 The Waste-Econ Program

This research was carried out as part of the Waste-Econ Program, which is a 6-year (2000-2005) Canadian International Development Agency (CIDA) funded program involving partnerships with a number of government institutions, universities and non-governmental institutions in Vietnam, Cambodia and the Lao PDR. The program aims to explore methods for recycling, exchanging and reducing wastes in a way that will be beneficial to the economies of the partner countries, to people working in the waste sector and to the environment as a whole (Waste-Econ, 2004). In the Lao PDR, the University of Toronto has partnered with the National Science Council (NSC) at the Prime Minister's Office in Vientiane. As part of the Waste-Econ program, a pilot project has been carried out to study the feasibility of composting organic waste from markets in Vientiane.

A number of students from the University of Toronto have conducted research in Vientiane for this pilot composting project targeting market waste. Genevieve Wong has produced a report about current waste management practices in three of Vientiane's markets (Thalat Thong Khankham, Thalat That Luang and Thalat Khuadin) and possible source separation of organics (Wong, 2004). Sangeeta Chopra has conducted a waste audit on one of the markets (Early Morning Market) (Chopra, 2004). Kyoungsoo Kwon is currently completing a report about the economic feasibility of a compost facility (Kwon, 2004). Karline McCawley is producing a preliminary marketing study regarding the possibility of selling composted material (McCawley, 2004).

1.2 Purpose and Methodology

The purpose of this work was to develop a compost facility siting methodology that can be applied in Vientiane and other developing countries. This report aims to provide enough detail and clarity to allow the Waste-Econ partners in Lao PDR to carry out the proposed methodology. The methodology is flexible and general enough that it can be adapted for site assessment for other types of projects in Vientiane as well. This work ties into previous research and field work completed within the Waste-Econ project in Vientiane over the past few years and discussed in the preceeding section.

A literature review was conducted in order to obtain a background understanding of current facility siting practices and to form a basis for developing the methodology. There were no sources specifically dealing with compost facility siting, so sources related to facility siting in general as well as those dealing with solid waste management facilities (particularly landfills) were consulted.

Field work for this research was conducted mainly during June and July of 2004 in Vientiane, while working at the National Science Council (NSC) in the Prime Minister's Office. This field work was crucial as facility siting is extremely context dependent so a good idea of the context was needed. The context involves not only understanding the physical setting within Vientiane, but also understanding the priorities and issues of concern of the Lao people. Since NSC is the Waste-Econ partner in Lao, it was important to attend their meetings to understand what issues were important to the council. There was also a Technical Coordination Committee which included representatives from NSC, the Vientiane Municipality Cleansing Organizations, PADETC, the Department of Urban Development, the Institute of Environment Research Organizations, the Vientiane Municipality Women's Union and some others. These meetings were important to this research as many of the entities represented were stakeholders in the proposed composting project.

Outside of NSC, a number of meetings were organized including one with a PADETC representative and a number with market managers. The market managers in particular were able to give valuable information about their current solid waste management system.

A number of site walkthroughs were conducted during the month of July. The visited sites included the landfill site at Km 18, the area around Thalat That Luang and the area around Thalat Khuadin. The data collected during the site visits is presented in the case study in section 4 of this report.

Although the meetings and walkthroughs were crucial to understanding the context of the project, the greatest benefit to understanding project context was derived from living in Vientiane and with the Lao people.

1.3 Composting

1.3.1 Process

Composting is the enhanced biological decomposition of organic matter. Organic material and oxygen are converted by microorganisms into carbon dioxide (CO_2), water, heat and humus (dark, fertile soil). If not enough oxygen is present, the process can become anaerobic and produce odours as anaerobic microorganisms produce compounds such as methane (CH_4), hydrogen sulphide (H_2S) and organic acids. In the desired aerobic decomposition process, more oxygen is consumed at the beginning of the process and the consumption decreases as decomposition proceeds (Chopra, 2004).

1.3.1.1 Moisture

A moisture content of 50-60% is desirable for the composting process as moisture helps to dissipate heat produced during the process and aids in the distribution of nutrients for the microorganisms. If the moisture content is too low, decomposition slows and if the moisture content is too high the water can restrict aeration of the material causing the process to become anaerobic. Excess moisture can also produce added leachate. A high moisture content can be controlled by mixing in dryer material and a low moisture content can be increased by adding water to the pile (Chopra, 2004).

1.3.1.2 Nutrient Balance

The nutrients important to the composting process are carbon, nitrogen, phosphorous and potassium. The carbon to nitrogen ratio (C/N) is particularly important as carbon is necessary for microorganism energy and growth and nitrogen is necessary for proteins and for reproduction. A C/N ratio of 20/1 to 25/1 is desired for efficient composting. If the organic material used as feedstock for the composting process does not have the desired C/N ratio, other materials can be added to change the ratio (Chopra, 2004).

1.3.1.3 Microorganisms and Temperature Regulation

Bacteria, fungi and actinomycetes are microorganisms responsible for the degradation of organic matter during composting. They fall into three categories depending on their optimal living temperatures: psychrophilic, mesophilic and thermophilic. Since the microorganisms function better at certain temperatures, different microorganisms are active during different stages of composting. The best microorganisms for composting are the mesophilic and the thermophilic which prefer temperatures of 35°C and 55°C respectively. Operating at high temperatures has the added benefit of killing pathogens although, if the compost gets too hot, the microorganisms may also be killed (Chopra, 2004).

1.3.1.4 Curing

After most of the organic material has been degraded to compost, it is important to let it mature and form stable compost. This curing allows decomposition of more resistant materials such as larger particles and organic acids to complete and it increases the concentration of the humus. It also allows for the compost to develop important disease suppressing properties. Mature compost no longer consumes large quantities of oxygen and will not deprive plants of either oxygen or nutrients. Compost is mature when its temperature stabilizes at the ambient temperature (Chopra, 2004).

1.3.2 Methods

There are a number of different methods for composting and each have their own advantages and disadvantages. The methods covered in this section are not technically intensive and are generally appropriate for application in the developing community context. It is important to understand the various methods as they have different space requirements and environmental impacts.

1.3.2.1 Windrows

The windrow method of composting involves forming piles with the organic waste. The piles must be turned on a regular basis in order to aerate the pile to keep the degradation aerobic, to break down larger particles, and to release heat, gases and water vapour. Turning piles can be extremely labour intensive so some windrows have a passive aeration system as well (Rytz, 2001). The Indonesian windrow system (see Figure 1.2), for example, uses bamboo frames to support the waste allowing for aeration of the bottom as well as the top of the pile. A roofed area is needed to protect the piles from direct rain and sunlight so that the moisture content can be regulated. It is also recommended to place the piles on a concrete slab to control leachate. Any leachate captured can be poured back onto the pile to maintain the moisture level (Rytz, 2001).

Figure 1.2: Bamboo frame for Indonesian windrow system in Dhaka, Bangladesh (Rytz, 2001)

1.3.2.2 In-vessel Composting

In-vessel composting is a semi-aerobic process and the odours are controlled by the vessel. No roof is needed as the vessels (see Figure 1.3) have lids to keep the rain out. The composted material is removed from the bottom of the barrel at regular intervals and is piled to be cured. A small roofed area should be provided for the curing piles as excess moisture from rainwater interferes with the curing and drying process (Rytz, 2001).

Figure 1.3: In vessel composting in Dhaka, Bangladesh (Rytz, 2001)

1.3.2.3 Vermicomposting

Vermicomposting, otherwise knows as vermiculture, uses worms to break down the organic matter. The worms and organic matter are placed into a ventilated container. The worms mix the compost and consume the matter leaving castings that are high in nitrates, potassium, calcium, phosphates and magnesium which can act as a valuable fertilizer. The compost must be kept within a temperature range of 13°C and 25°C which is difficult to maintain. Also the temperatures are not high enough to ensure the inactivation of pathogens (Chopra, 2004).

1.3.2.4 Aerobic vermi-bacterial system (AVB)

Energy Tech Solutions Ltd in Pune, India has designed a hybrid method of composting that involves both microorganisms and worms. All of the information presented here on AVB technology is directly from representatives of Energy Tech Solutions Ltd (Singh, 2004) and has not been thoroughly verified. AVB uses microorganisms to degrade the organic material and deep-burrowing worms to ensure even mixing. Seven large basins are prepared, one for each day of the week as the compost takes a week to stabilize. Each bin is large enough that one day's worth of organic material can be spread out such that all of the matter is aerated. For seven bins and a waste flow of 1 tonne per day, approximately 500-600 m^2 are needed. The bins are essentially low concrete walls enclosing the compost and are open directly to the ground. A more detailed description of the AVB system can be found in Appendix 1.

1.4 Organization of Report

This remainder of this report is divided into four chapters: the literature review, proposed site methodology, case study, and conclusions and recommendations. The main purpose of each chapter is outlined below.

Literature Review – This chapter gives background and current methodology regarding facility site assessment.

Proposed Siting Methodology - This chapter outlines the proposed facility site assessment process developed during the course of the research. Objectives, sub-objectives and criteria are outlined and a method of data collection and analysis is suggested.

Case Study – A case study demonstrates the application of the proposed siting methodology outlined in the previous chapter to some sample sites.

Conclusion and Recommendations – The conclusion summarizes the research presented in the report. The recommendations outline suggested future areas of study or action.

2 Literature Review

This chapter summarizes different approaches to waste facility siting and outlines a generalized site assessment procedure.

2.1 Siting Approaches for Waste Facilities

There are a number of general approaches that can be used to site waste facilities. These approaches are not specific to a type of waste facility and provide different options that can be applied to match the context of the site assessment in question. Three main approaches are outlined by Lawrence (1996): the environmental suitability approach; the social equity approach; and, the community control approach. Each of these approaches places an emphasis on certain impacts of siting a waste management facility. These approaches can be applied in a number of ways and can also be combined in order to suit the needs and goals of the particular assessment.

2.1.1 The Environmental Suitability Approach

The environmental suitability approach (ESA) follows a rational process of alternative site identification, screening and comparison. The main goal of this approach is to minimize the adverse impacts on the environment and maximize the positive ones. There are three main ways in which this can be achieved: constraint minimization, opportunity maximization and service maximization (Lawrence, 1996).

Constraint minimization is a comprehensive, step-by-step method of choosing sites. The area in question is first screened and the sites that meet certain constraints are identified. These sites are then put through another screening process to identify candidate sites which are subsequently compared with one another to choose the final site (Lawrence, 1996).

Opportunity maximization is not as rigorous or comprehensive as constraint minimization and seeks to benefit from existing opportunities. This approach gives precedence to sites with highly suitable physical characteristics, existing facilities, available properties and co-use with industrial areas in order to minimize adverse effects on the environment. This method is easier to apply than constraint minimization and can therefore be less costly (Lawrence, 1996). Opportunity maximization contributed to the addition of a gypsum mine to the list of candidate sites in a landfill siting process for Halifax County, Nova Scotia, as the land was inexpensive and the site had already been used for an industrial purpose (Lawrence, 1996).

Service maximization is used when severe consequences can arise from service related issues such as increased travel time, transport risks and impacts are of great concern or if accessibility will greatly limit the use of the facility. Transportation distances and site accessibility are often controlling factors in this method of site assessment. For example, when the city of Edmonton, Alberta was siting a municipal landfill they constrained the search area to 16 km as this was viewed as the maximum economic haul distance (Lawrence, 1996).

2.1.2 The Social Equity Approach

The social equity approach (SEA) focuses on procedural and substantive fairness for communities and other stakeholders. Of particular concern are vulnerable or underrepresented parties. This approach aims for fairness in the distribution of waste facilities and even distribution of the costs and benefits in order to avoid and redress imbalances. Procedural fairness is also important and this is ensured through direct community and stakeholder involvement in the siting process, conflict resolution and consensus building. Funding assistance may also be provided to encourage the vulnerable parties to fully participate (Lawrence, 1996).

2.1.3 The Community Control Approach

The community control approach (CCA) aims for a high degree of process and outcome control by the potentially affected parties. This can be achieved by locational, procedural and facility control by communities and stakeholders. Locational control includes the use of volunteer communities and may even give local communities veto in decision making. Procedural control is often carried out by a citizen siting authority or through partnerships and citizen advisors to allow communities direct involvement with the siting process.

Facility control entails that communities have a say in the technologies used and the day to day operations of the proposed waste facility (Lawrence, 1996).

2.2 The Facility Siting Process

The facility siting process is essentially a decision making process. The goal of a facility site assessment is to aid decision makers in fulfilling certain requirements and/or objectives when choosing a site. This process is often iterative and has four main steps as outlined in Figure 2.1.

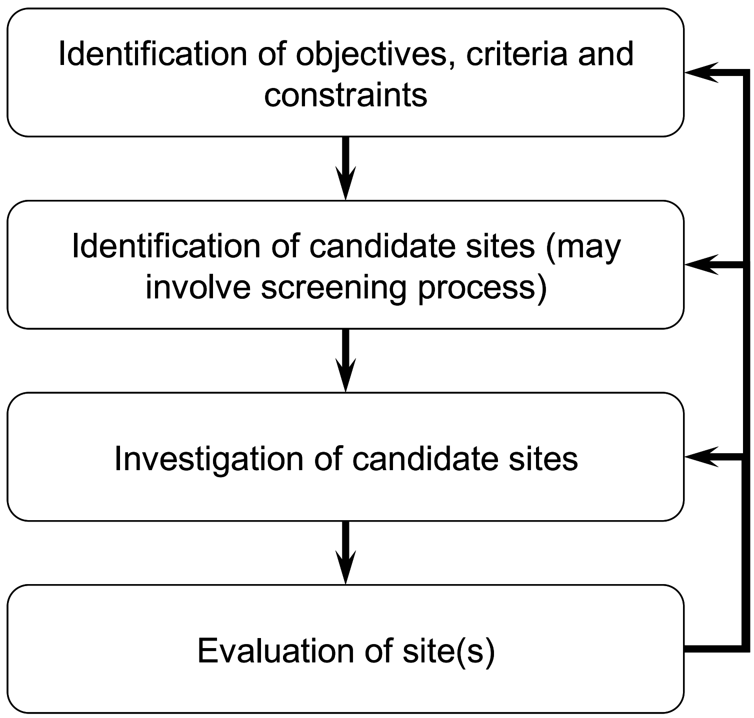

Figure 2.1: Facility Site Assessment Process

The process or framework for facility siting is generally the same regardless of the siting approach used. The differences in approach will manifest themselves in the objectives chosen, weightings of criteria assigned and the method and level of stakeholder involvement.

2.2.1 Identification of objectives, criteria and constraints

The first step in the site assessment process is to identify the objectives, criteria and constraints that will be used to screen and evaluate sites. *Objectives* are general goals to be achieved through the assessment process. Ultimately, the site that best meets the objectives is the optimal choice. These objectives are stated as something to be maximized or minimized and are broken down into *sub-objectives*. The sub-objectives, although they are more specific than objectives, are still too broad to be evaluated directly so they are further broken down into *criteria*. For example, an objective to minimize environmental impact may have sub-objectives such as: minimize water contamination; minimize loss of ecologically important areas; and, minimize air pollution. The sub-objective to minimize loss of ecologically important areas may be broken down into criteria such as: minimize destruction or vegetation on site; and, minimize disruption of wildlife on site. The criteria can be evaluated directly through data gathered and the ratings produced can be used to determine which site best meets the overall objectives. *Constraints* are limits placed on the site and are related to one or more of the objectives. For example, the sub-objective to minimize transportation costs may demand a maximum transportation distance which becomes a constraint.

The objectives, criteria and constraints will differ depending on the country or community involved. In Ontario, Canada, for example, the objectives for compost facility siting are outlined in guideline documents and must satisfy certain legal requirements including legislation such as the Environmental Protection Act, the Ontario Water Resources Act and the Environmental Assessment Act (MOE, 1998). In the province of Ontario, the siting process should ensure the following: compliance with local zoning by-laws; sufficient space availability on-site; adequate separation between the facility and adjacent land uses and environmentally sensitive areas; and, adequate access to transportation routes (MOE, 1998). In other parts of the world, the requirements for a landfill are not explicitly stated in government documents. Site assessment is equally important in these areas and the requirements should be defined by the authority carrying out the assessment through consultation with stakeholders.

2.2.2 Identification of Candidate Sites

The second step in facility site assessment is to identify candidate sites to be evaluated more thoroughly. This is usually done through a screening process based on the objectives, criteria and constraints outlined in the previous step. The siting approach or approaches used will also influence this screening process.

A commonly used systematic technique for area screening is constraint mapping as described by McAllister for use in Land-Suitability Analysis (LSA) (1980). Constraint mapping is a method that applies constraints over a large area. The constraints are plotted onto a series of maps by blocking out areas that do not meet the constraint. These maps are then overlaid on one another essentially leaving only areas that meet all constraints uncovered. The blank areas become the candidate sites and go on to be evaluated in more detail. The map overlays can be done physically with areas blocked off on transparent layers of the map. If the geographical information is available in a Geography Information System (GIS)-compatible format , such a system can also be used to perform constraint mapping. If the areas identified are too large or too plentiful, more constraints may need to be added to generate a suitable number of candidate sites. If no areas meet all of the constraints either the search area must be enlarged or one or more of the constraints must be relaxed in order to find suitable sites.

Lawrence categorized constraint mapping under the Environmental Suitability Approach (1996). This method can, however, bring in elements of the Social Equity Approach and the Community Control Approach as well by using the principle of social equity as one of the guiding constraints and by allowing communities direct input into the screening process. The other methods that he suggested such as opportunity maximization, service maximization or the use of volunteer communities may not be as systematic but can be easier to apply, more cost-effective and can result in the best candidate sites being chosen. The method of screening should be chosen according to resources available and overall objectives of the siting process.

2.2.3 Investigation of Candidate Sites

Depending on the method of screening used to choose the candidate sites, a second screening may be necessary at this stage to remove from consideration any sites that do not meet constraints. The remaining sites can then be evaluated in more detail.

Detailed data is required about each candidate site in order to determine how well they meet each sub-objective and objective. New information may also arise during detailed data collection that shows that a site does not meet constraints and should therefore be eliminated from the candidate list. Detailed data can be collected from a number of sources including interviews, published data and walkthroughs (McNally, 2003).

2.2.4 Choice of Site(s)

The last step in facility site assessment is to move from data collected in step three to an evaluation and finally a choice of site or sites. The data are used to rate each site with respect to the criteria. This can often be done directly but may require input from stakeholders or experts. The ratings can be either numerical (using a scale of 1 to 10) or qualitative (using descriptors such as high, medium or low acceptability) (McNally, 2003). A matrix can be used to display the ratings and help with the overall evaluation.

The ratings assigned to the sites with respect to the criteria are used in combination to determine the overall suitability of the sites. If there are few enough criteria to consider, this can be done by looking at the site comparison matrix, weighing ratings and their relative importance, and assigning an overall rating. This can also be done numerically by assigning a rating of importance to each sub-objective which when combined with the rating of the site within the sub-objective can produce a weighted rating. These weighted ratings can then be combined to produce an overall rating of the site. Stakeholders and experts can help with assigning weightings to the criteria.

2.3 Possible Environmental Impacts of Composting

Most of the papers written about the siting of a solid waste management facility refer to the siting of a landfill. Compost facilities are associated with somewhat different environmental concerns. The operation of the facilities themselves is of concern because of odours, dust, litter and noise (MOE, 1998). These will differ depending on the method of composting used and may be reduced with certain mitigating measures. A compost facility may also be a source of water contamination as the water used to maintain the desired moisture content in the organic material can often leach contaminants (MOE, 1998). Transportation issues are important for compost operations as trucking of wastes is not only costly but can also have negative environmental impacts. This is particularly important when siting the facility, as the location of the facility determines the amount of transportation needed.

3 Proposed Siting Methodology

The suggested approach for facility siting in Vientiane combines aspects of the environmental suitability approach, the community control approach and the social equity approach. ESA provides the framework for the method of screening and evaluating sites and CCA and SEA is important in stakeholder involvement.

This chapter outlines the proposed facility site assessment methodology for a composting project in Vientiane. The methodology follows the 4-step procedure outlined in the literature review. The siting approach guides the manner in which this procedure is carried out and will be referred to throughout this chapter.

3.1 Objectives, Criteria and Constraints

The first step in facility site assessment is to determine objectives, criteria and constraints. This section outlines suggested objectives for compost site assessment in Vientiane as well as their associated criteria and constraints. The objectives and criteria were developed based on the literature review and experience gained through field work. During a meeting at the end of July, 2004 with the Technical Coordinating Committee at the National Science Council in Vientiane, the objectives and criteria were presented and the stakeholders in attendance acknowledged their importance. The objectives and criteria are presented in Table 3.1.

3.1.1 Objectives

The overall objectives for this facility site assessment are to minimize negative environmental impacts, minimize negative social impact and maximize economic feasibility.

Minimize negative environmental impacts - It is important to protect environmental and ecological resources when embarking on any engineering project. This involves protecting water and air from contamination and maintaining existing ecosystems as much as possible. Environmental impacts should be considered, as damage to the environment not only affects wildlife and vegetation but also may have ramifications for human health.

Minimize negative social impacts - It is important to ensure that a compost facility has minimal impacts on society and particularly on the neighbouring community. This objective inherently overlaps somewhat with the environmental objective because of the human health aspect. There are also other possible social impacts that must be considered in facility site assessment.

Maximize economic feasibility (minimize costs, maximize benefits) - This is particularly important in the context of the developing world and therefore in Vientiane as outside forms of financial support such as government subsidies are not likely even if there are environmental benefits to the compost facility. The facility cannot operate if the site chosen makes it financially unfeasible.

3.1.2 Sub-objectives

Since the objectives are broad and cannot be measured directly they are broken down into sub-objectives. These are more specific and are easier to measure than objectives either quantitatively or qualitatively by evaluating data gathered about the site. The sub-objectives are used in combination to determine how well the objectives are being met. For example, for the objective to maximize financial benefit, a sub-objective may be to minimize land cost.

Table 3.1: Objectives, Sub-objectives and Criteria

Objective	Sub-Objective	Criteria	Data Required
Minimize negative environmental impacts	Minimize air pollution from transport	Minimize distance to waste source	distance to waste source
		Minimize distance to compost buyers	distance to compost buyers
	Minimize water pollution	Maximize distance to nearest water body	description of and distance to water bodies
		Minimize disruption of water features on site	description of water features on site
	Minimize loss of ecologically important/sensitive areas	Minimize destruction of vegetation on site	current vegetation on site
		Minimize disruption of wildlife on site	current wildlife on site
Minimize negative social impacts	Minimize odour impact	Minimize marginal impact on current odour level on site	current odour level on site
		Maximize distance to sensitive receptors	distance to nearest residence
			distance to nearest school
			distance to nearest public building
			distance to nearest businesses/shopping areas
			any other sensitive receptors
	Minimize noise impact	Minimize marginal impact on current level of noise on site	current noise level on site
		Maximize distance to sensitive receptors	distance to nearest residence
			distance to nearest school
			distance to nearest public building
			distance to nearest businesses/shopping areas
			any other sensitive receptors
	Minimize loss of socially important areas	Minimize disruption to land use around site	land use around site (proximity to and description of nearby buildings, areas etc.)
		Maximize use of vacant land	current use of site

Maximize economic feasibility	Minimize land cost	Minimize capital cost of land	price of site
	Minimize transportation costs	Maximize access to site	accessibility of site (roads?)
		Minimize distance to waste source	distance to waste source
		Minimize distance to compost buyers	distance to compost buyers
	Minimize construction costs	Maximize suitability of land for construction	description of land layout (flat, hilly...)
	Maximize revenue from site	Maximize size of site	size of site

3.1.2.1 Objective A – Minimize negative environmental impact

Minimize water pollution – It is important to protect water resources because water contamination can have a number of negative ecological and human health impacts. In meetings with the Technical Coordination Committee of the National Science Council of Lao PDR, many expressed concern regarding impacts on water resources indicating that this is an important issue to the Lao people. This sub-objective can be achieved by using criteria such as minimize the distance to the nearest water body and minimize the disruption of water features on site.

Minimize air pollution from transport – The pollution due to transportation of waste and compost to and from the site is mainly due to emissions from trucks. The best scenario with regard to this sub-objective is for the site to be so close to the source that the waste can be transported by handcart. If the waste must be transported by truck, the aim should be to locate the site as close to the source as possible. The transportation of the composted material to the buyers should also be considered although the amount of composted product and therefore the frequency of trucks needed is far less than for the original waste. This sub-objective is broken down into the following criteria: minimize distance to waste source; and, minimize distance to compost buyers.

Minimize loss of ecologically sensitive/important areas – Ecologically sensitive areas are those that are easily damaged whereas ecologically important areas are those that contain important vegetation or fauna and that would disrupt the ecosystem if they were to be damaged. Wetlands, for example, are both ecologically sensitive and important as they are sensitive to change and provide a habitat for diverse flora and fauna. This sub-objective may not be as important as others in the city of Vientiane but should still be considered. The criteria that should be met in order to satisfy this sub-objective are to minimize the destruction of vegetation on site and minimize the disruption of wildlife on site.

3.1.2.2 Objective B – Minimize negative social impact

Minimize odour impacts – A major social concern, particularly with solid waste management systems, is the presence of odours from the facility. The extent of the odours produced depends on the type of compost facility constructed but will be present in any case because organic solid waste will be transported and stored on site. In order to determine the impact of odours from a facility, the locations of sensitive receptors and their proximity to the site must be known. Sensitive receptors to be considered include residents, schools, public buildings and local businesses. The current level and type of odours on or near the site should also be known in order to determine the marginal effect that the odours from a compost facility may have on the sensitive receptors. The criteria associated with this sub-objective are: minimize the marginal impact on odour level on site and maximize distance to sensitive receptors.

Minimize noise impacts – Noise from a compost facility can be irritating and disruptive to sensitive receptors in the area and therefore should be considered when determining social impact. Although this is more of a concern when the planned facility is highly mechanized, noise impacts should be considered even for small facilities. The level of noise impact can be determined by the same methods as were used for odour impacts. The proximity of sensitive receptors and the background noise already present around the site must be known. The criteria associated with this sub-objective are: minimize the marginal impact on noise level on site; and, maximize distance to sensitive receptors.

Maintain socially important areas – Socially important areas refer to those areas that are used either formally or informally by people. Some such areas may be green spaces used as gathering places, parks or even areas that people walk through during the day. In order to determine if an area is socially important information must be gathered about the current land use of the site and land uses around the site. If possible, the site should be visited at different times during the day and on different days of the week to understand how people are using the site. The criteria to be satisfied in order to meet this sub-objective are to minimize disruption to land use on and around the site and to maximize the use of vacant land.

3.1.2.3 Objective C – Maximize economic feasibility

Minimize land cost – Land cost can be a large part of the capital cost of the facility and must be considered in a facility site assessment. The land purchase or rental cost and any details about possible donation of the site should be established.

Minimize transportation costs – Transportation costs include transportation of organic solid waste to the site and transportation of the finished product to the buyers. These costs must be paid on an ongoing basis and therefore are crucial to determining the desirability of a site. In order to estimate transportation costs the proximity of the organic solid waste source and the compost buyers to the site must be known. Within a certain proximity to the site the cost of transportation is drastically reduced as materials can be moved by handcarts instead of trucks. The proximity of the waste source is more important than that of the compost buyers as the volume of organics is drastically reduced during the composting process. Access to the site is also important because if trucking is necessary, trucks must be able to go to and from the site. If an access road is not available, one would need to be constructed before facility operations which would increase the capital cost of the facility. The criteria, therefore, are to minimize the distance to the waste source and minimize the distance to compost buyers.

Minimize construction costs – The site can affect construction costs if the site preparation for construction is costly. For example, if the site is hilly, it will need to be graded before construction for the compost facility can begin. The criterion for this sub-objective is to maximize suitability of the site for construction.

Maximize revenue from the site – The capacity of the site is primarily determined by the size of the site. Higher capacity sites can be used to process more organic waste and can therefore be more financially attractive. In order to process large amounts on a small site, different, more expensive composting methods would need to be employed. A large site also allows for flexibility as future growth of the operation is less restricted. The only criterion is to maximize the size of the site.

3.1.3 Constraints

Certain criteria or objectives may need to be met to a certain level or standard so constraints may need to be applied. For example, if the objective is to maximize financial benefit a constraint may be that the site must allow the facility to be financially viable and constraints to the associated criteria may be a maximum economic haul distance or a maximum land cost.

3.1.4 Interrelationships Between Sub-objectives

It should be recognized that there are interrelationships between certain criteria as the satisfaction of one may satisfy or change the importance of another. For example, minimizing transportation costs requires a site that is close to the waste source and therefore also satisfies the minimization of pollution from transportation sub-objective. Also, if the transportation costs are minimizes this may make the land costs less important as the compost facility may be financially beneficial even at a high capital land cost. These interrelationships should be acknowledged when deciding on overall ratings where a number of criteria are considered simultaneously.

3.2 Choosing Candidate Sites

The environmental suitability approach forms the basis of the proposed method to choose candidate sites. Service maximization and opportunity maximization are applied first to limit the search area. Then constraint mapping is applied to choose candidate sites.

Constraint mapping could technically be applied instead of service and opportunity maximization. Although this is probably the most systematic method for choosing candidate sites it is currently infeasible to carry out in the context of Vientiane. First of all, constraint mapping relies on accurate and detailed maps which may be difficult to obtain. Second, enough information must be available about the entire search area to determine which areas meet the constraints. For these reasons, constraint mapping is only applied after service maximization and opportunity maximization when the search area is small enough to allow for the data required for constraint mapping to be gathered.

The economic feasibility of the compost facility is crucial and the reduction of transportation costs are key in the economics of the proposed project. This makes sense intuitively and is also supported by the work of Kyoungsoo Kwon who conducted an economic assessment on the proposed project (Kwon, 2004). Service maximization is therefore very important to the project and is an appropriate method to begin with when choosing candidate sites.

Using service maximization to screen for candidate sites limits the search area to within a certain distance of the waste source (markets). This limitation can be determined by conducting a preliminary economic assessment to determine the maximum feasible haul distance. Opportunity maximization is also applied alongside service maximization in order not to miss potentially feasible sites outside of the search area defined by service maximization. These opportunities can be found by asking stakeholders to suggest or volunteer pieces of land for the facility. For example, a large piece of donated land may be an important opportunity even if it falls outside of the search radius.

The search area defined by service maximization and the sites identified through opportunity maximization are then subjected to a preliminary constraint minimization to narrow the area to a set of candidate sites. The constraints to be applied at this point must be easy to evaluate from a walkthrough of the site. Other constraints that require more data may be applied later in the process. At this stage the search area will be studied for sites that satisfy the following constraints: empty or unused; not a wetland; reasonable size for compost facility (not simply a few square metres). These sites become the candidate sites and are then investigated and evaluated to choose the best site(s).

3.3 *Investigation of Candidate Sites*

The candidate sites now must be evaluated with respect to the sub-objectives previously determined. Information regarding criteria relevant to such an evaluation must be gathered about each of the sites. The criteria are listed in Table 3.1. In order to gather this information, certain questions must be asked of the person who suggested the site (if any), landowners, as well as be posed during walkthroughs or while studying maps of the candidate sites and their surrounding areas. For example, in order to determine the water features on site walkthrough of the site can be performed to list the water features, take pictures and to draw them on a map. The questions that follow can, if answered, provide the necessary data to evaluate the candidate sites according to the criteria in Table 3.1. The questions have been divided into three groups according to how the questions may be asked.

3.3.1 Questions for Data Gathering

To ask during site walkthrough

1. Describe the land layout of the site. Are there many hills? Is it relatively flat? Sloped?
2. How big is the site?
3. Describe the vegetation present on the site. Is the site important for wildlife?
4. Describe the presence of water on the site. Ponds? Rivers?
5. How does the current use of the site affect the physical aspects of the site?
6. Are there currently sources of odours in or around the site? Describe the level of odours.
7. Is the site located in a noisy area? Describe.
8. Is the site accessible? Describe.
9. Draw map of the site with a focus on on-site details.

To ask while using maps/GIS and walkthrough

1. How close is the site to residences?

2. How close is the site to schools?
3. How close is the site to public buildings? Which ones?
4. How close is the site to shopping areas? Markets?
5. Are there other places nearby that will be impacted by a compost facility on this site? How far are they from the site?
6. How far is the site from the source of the organic solid waste?
7. Is the site accessible by truck? Is the site accessible by other means?
8. How far is the site from water bodies? Describe the water bodies in the area.
9. Obtain map of the site context and add details of its surroundings.

To ask person who suggested site or land owner

1. What is the current/future use of the site?
2. Who currently owns/is responsible for the site?
3. Are they willing to donate the site?
4. Are they willing to sell the site?
5. If so, how much do they ask for?
6. Do they have any concerns about putting a compost facility on their site?

3.4 Evaluation of Candidate Sites

After all of the questions have been answered to an appropriate level of detail, the constraints must be applied again. New or more specific information may make it clear that some sites do not meet the constraints. If none of the sites are found to meet all of the constraints, one or more constraints should be relaxed.

A matrix can be used to compare and rate candidate sites using the information gathered by answering the questions. Each objective has its own matrix with sites listed on one axis and criteria on the other. Each site can be rated for its appropriateness with respect to each criterion using descriptive ratings (e.g. very good, good, adequate, poor, very poor)[1]. Descriptive ratings are useful as they can be easier to assign than numerical ratings and they cannot be mistaken for being quantitative. An example matrix is shown in Table 3.2.

Table 3.2: Example comparison matrix

Sub-objective	Site A	Site B	Site C
Minimize air pollution from transport	poor	v. good	adequate
Minimize water pollution	good	v. good	adequate
Minimize loss of ecologically important/sensitive areas	good	poor	good

The ratings presented in the matrix can be used to determine a rating for each site with respect to each objective. The sites can be rated simply by considering the overall impact of the individual criteria ratings and balancing the ratings with the relative importance of the criteria or sub-objectives. The sites are now rated for each objective and the final suitability rating of the sites can be determined.

3.5 Stakeholder Involvement

The assessment should include stakeholders at many points during the process. The stakeholders should be identified before the assessment is carried out in order to avoid making important decisions before consultation. For the proposed compost facilities in Vientiane, stakeholders may include government departments, the Women's Union, non-governmental organizations (NGOs) working in solid waste management, market managers, market vendors, and people who live or work near potential sites. Stakeholders

[1] Sites can also be rated numerically (e.g. on a scale of 1 to 10). The numerical ratings are based on qualitative assessment, despite appearing quantitative, and are not any more or less accurate than the descriptive ratings. Numerical ratings can be useful when many criteria are involved and the ability to add or multiply ratings is important. These ratings can be weighted according to the importance of the associated sub-objective and the sum of the weighted ratings can be taken to arrive at a composite or overall rating

should be consulted at the following steps: deciding on objectives, sub-objectives and criteria; determining constraints; suggesting sites; evaluating sites particularly with respect to ratings and weightings assigned to criteria; and, considering areas and methods of mitigation.

4 Case Study

The purpose of this case study is to demonstrate how the proposed siting methodology can be applied. The sites used for illustration are real sites and much of the information presented in this study regarding the sites is from field work conducted during the summer of 2004. However, the gaps in the information gathered were filled with hypothetical data for illustrative purposes. In order to emphasize the illustrative nature of this case study the sites are referred to by letter (Site A, Site B etc).

4.1 Identification of objectives, criteria and constraints

The objectives and criteria used for this case study are taken directly from the proposed site methodology outlined in chapter 3. The constraints identified are as follows:

- the land must be unused so that no businesses or residents are displaced from their land;
- the site must be of a reasonable minimum size for a compost facility (~ 200 m^2);
- the site cannot be a wetland;
- the maximum haul distance for the waste must be approximately equivalent to a 5 minute walk (such that waste can be hauled by handcart instead of by truck).

The constraints above were chosen by the author of this report for illustrative purposes. When actually carrying out this siting methodology, constraints should be determined through consultation with stakeholders.

4.2 Identification of Candidate Sites

Service maximization was used first to limit the search area for candidate sites. This step uses the constraints identified in the first step. One of the constraints chosen was that the site needed to be within a 5 minute walk of the waste source (market). The search area was then limited to that area around the market. A walkthrough of the area around Thalat Khuadin and Thalat That Luang was performed. The candidate sites needed to satisfy all of the other constraints (reasonable size, vacancy, not a wetland) and 3 sites were identified.

There was also an opportunity that added another site to the list of candidates. A large site 18 kilometres outside of Vientiane was offered as a possibility for the compost facility. This was possibly a good opportunity because the land area was large, the trucks that take the waste from the markets to the landfill already drove past the site and the owners of the site were willing to offer the site free of charge.

While the case study is based on real sites, the sites are not identified because some of the data presented was created for illustrative purposes.

4.3 Investigation of Sites

Information now must be gathered about the candidate sites A through D. The questions outlined in the proposed methodology can be asked and answered through walkthroughs, interviews and the use of available maps. The data gathered regarding the candidate sites are presented in tables 4.1, 4.2 and 4.3 for comparison purposes. The tables are organized according to the data requirements outlined in Table 3.1.

Diagrams, maps and photographs of sites can be found in Appendix 2.

Table 4.1: Data from site investigation regarding environmental impacts

	Site A	**Site B**	**Site C**	**Site D**
Proximity to waste source (length of route)	adjacent to market	adjacent to market	250 metres from market along dirt road (unless shortcut of 100 m through small parking lot)	18 kilometres away from Vientiane
Proximity to shopping areas	adjacent to market	adjacent to market	50m from market	none nearby
Water features on site	none	none	none	none
Proximity to other water features	bordered on 2 sides by sewage canal, pond north of site beyond palm trees	none nearby	small pond to north of site (bordering site)	none nearby
Vegetation on site	small, young trees	tall grass, leafy plants at one end of site, trees on perimeter of site	tall grasses	short grasses, small shrubs
Fauna on site	none noticed	none noticed	none noticed	none noticed

Table 4.2: Data from site investigation regarding social impacts

	Site A	Site B	Site C	Site D
Current odours on site	weak odours from nearby market	strong odours from nearby market and adjacent garbage area	no particular odours present	some odours from adjacent landfill
Proximity to residences	across busy paved street from nearest residences, other residences 120 m to north across pond	residences border site to west, south and east	residences border site to north and south	residences about 50 m away from site
Proximity to schools	none nearby	none nearby	none nearby	none nearby
Proximity to public buildings	post office 120 m away, across busy street	none nearby	none nearby	none nearby
Proximity to shopping areas	adjacent to market	adjacent to market	50m from market	none nearby
Proximity to other places of note	site is part of land set aside for future public park	none nearby	none nearby	none nearby
Current noise levels on site	noisy due to busy street 30m away an adjacent market	some noise from adjacent market, some intermittent noise from unpaved road on east side of site	background Vientiane noise, some intermittent noise from unpaved road on west side of site	noise from adjacent highway
Current use	small part of new park for ASEAN summit in 2004	vacant	vacant	vacant

Table 4.3: Data from site investigation regarding economics

	Site A	**Site B**	**Site C**	**Site D**
Owner of site	Government department	privately owned	privately owned	Vientiane cleansing association
Price of site	assumed low if department willing to donate part of their site in question	assumed to be standard price of land in Vientiane	assumed to be standard price of land in Vientiane	owner willing to donate
Concerns of current owner regarding compost facility	unknown	none	none	none, supportive of initiative
Accessibility of site	one lane dirt road that can accommodate large vehicles, or longer route along paved road	directly adjacent to garbage storage area of market	one lane dirt road that can accommodate large vehicles	turn off highway along dirt road built for large trucks
Proximity to waste source (length of route)	adjacent to market	adjacent to market	250 metres from market along dirt road (unless shortcut of 100 m through small parking lot)	18 kilometres away from Vientiane
Proximity to shopping areas	adjacent to market	adjacent to market	50m from market	none nearby
Land layout	flat	flat	flat	flat
Size of site	5,000 – 6,000 m^2	~ 450 m^2	~600 m^2	~ 8,000 m^2

4.4 Evaluation of Candidate Sites

The evaluation process involves rating sites first with respect to the criteria, then the sub-objectives, then objectives and finally by assigning an overall rating. Each step requires that the previous ratings assigned be considered as a whole in order to assign the ratings for the more general objectives. The ratings of very good, good, adequate, poor and very poor refer to the suitability of the site with respect to the criteria, sub-objective or objective. These ratings are absolute, not relative to the other candidate sites. For example, when rating sites with respect to distance to the nearest water body, a "very good" rating is given where the distance to the nearest water body is such that there is negligible risk of contamination and is not simply the farthest distance when compared with the other candidate sites. Stakeholders should be consulted when assigning ratings.

4.4.1 Evaluation of Criteria and Sub-Objectives

The data gathered in the previous step are used to rate the sites with respect to the criteria. The correspondence between data and constraints is shown in Table 1. Each overall objective has its own matrix that allows for a comparison between the sites within each criterion and sub-objective. The ratings of the criteria are taken as a whole to arrive at a rating for how well the sites meet the sub-objectives. The ratings on the various sub-objectives are then used to arrive at a rating for each site with respect to each objective. The cumulative ratings take into account not only the individual ratings but also the relative importance of the criterion or sub-objective in question to the overall objective. Stakeholders can be called in for consultation in this step as value judgements and personal heuristics are used to compile overall ratings.

4.4.1.1 Minimize Negative Environmental Impacts

The matrix in table 4.2 displays the ratings for the overall objective to minimize negative environmental impacts.

Table 4.4: Ratings with Respect to Environmental Impacts

Sub-Objectives	**Criteria**	**Site A**		**Site B**		**Site C**		**Site D**	
Minimize air pollution from transport	Minimize distance to waste source	v. good	v. good	v. good	v. good	v. good	v. good	v. poor	v. poor
	Minimize distance to compost buyers	v. good		v. good		v. good		poor	
Minimize water pollution	Maximize distance to nearest water body	poor	adequate	v. good	v. good	v. poor	poor	v. good	v. good
	Minimize disruption of water features on site	v. good		v. good		v. good		v. good	
Minimize loss of ecologically important/sensitive areas	Minimize destruction of vegetation on site	poor	adequate	v. good	v. good	v. good	v. good	v. good	v. good
	Minimize disruption of wildlife on site	v. good		v. good		v. good		v. good	
	Overall Rating	**good**		**v. good**		**adequate**		**adequate**	

Site A is found to be ‘good’ with respect to minimizing environmental impacts. There is some loss of vegetation as there are newly planted trees on the site. The site is close to water bodies but since the water bodies ultimately consist of wastewater. The site is very good for reducing impacts due to transportation. Therefore, the site is rated to be good.

Site B is ‘very good’ overall as the vegetation and wildlife on site are minimal, the site is within the city, it is directly adjacent to the garbage collection area for a market and it is not near any water bodies.

Site C is ‘adequate’ overall. Although the site is effectively located to reduce transportation impacts and does not have much vegetation, there is a pond adjacent to the site increasing the risk of water contamination.

Site D is also ‘adequate’ in terms of environmental impacts. Despite not containing important vegetation and being far from water bodies, the site is very far from the waste source and therefore is very poor with respect to transportation impacts.

4.4.1.2 Minimize Negative Social Impacts

The matrix shown in Table 4.5 displays the ratings for the overall objective to minimize negative social impacts.

Table 4.5: Ratings with Respect to Social Impacts

Sub-Objectives	Criteria	Site A		Site B		Site C		Site D	
Minimize odour impact	Minimize marginal impact of odours on site	good	good	v. good	good	v. poor	poor	good	v. good
	Maximize distance to sensitive receptors	good		poor		poor		v. good	
Minimize noise impact	Minimize marginal impact of noise on site	v. good	v. good	good	adequate	poor	poor	v. good	v. good
	Maximize distance to sensitive receptors	good		poor		poor		v. good	
Minimize loss of socially important areas	Minimize disruption to land use on/around site	poor	adequate	v. good	v. good	v. good	v. good	v. good	v. good
	Maximize use of vacant land	adequate		v. good		v. good		v. good	
	Overall Rating	**good**		**good**		**adequate**		**v. good**	

Site A is 'good' with respect to social impacts as it is already located in an area with some organic odours and high noise levels. It is, however, also part of a new park which could be of some social importance.

Site B is also 'good' with respect to social impacts. Although it is in a residential area, the land is unused and vacant and the area already has high levels of organic odours from the neighbouring market.

Site C is 'adequate' with respect to social impacts. The area is relatively quiet and does not have strong odour sources nearby. But since the land is unused and vacant the use of this area as a compost facility does not contribute to much loss of socially important areas.

Site D is 'very good' with respect to social impacts as the land is unusable since it is reclaimed from a landfill, the area already has high levels of odours from the landfill and noise from the highway and the site is far away from sensitive receptors.

4.4.1.3 Maximize Economic Feasibility

The matrix shown in Table 4.6 displays the ratings for the overall objective to maximize economic feasibility. In practice, these rankings would be determined with the help of the economic analysis framework developed by Kyoungsoo Kwon (2004).

Table 4.6: Ratings with Respect to Economics

<table>
<tr><th>Sub-Objectives</th><th>Criteria</th><th colspan="2">Site A</th><th colspan="2">Site B</th><th colspan="2">Site C</th><th colspan="2">Site D</th></tr>
<tr><td>Minimize land cost</td><td>Minimize capital cost of land</td><td>good</td><td>good</td><td>adequate</td><td>adequate</td><td>adequate</td><td>adequate</td><td>v. good</td><td>v. good</td></tr>
<tr><td rowspan="3">Minimize transportation cost</td><td>Maximize access to site</td><td>good</td><td rowspan="3">v. good</td><td>good</td><td rowspan="3">v. good</td><td>good</td><td rowspan="3">v. good</td><td>v. good</td><td rowspan="3">v. poor</td></tr>
<tr><td>Minimize distance to waste source</td><td>v. good</td><td>v. good</td><td>v. good</td><td>v. poor</td></tr>
<tr><td>Minimize distance to compost buyers</td><td>v. good</td><td>v. good</td><td>v. good</td><td>poor</td></tr>
<tr><td>Minimize construction cost</td><td>Maximize suitability of land for construction</td><td>v. good</td><td>v. good</td><td>v. good</td><td>v. good</td><td>v. good</td><td>v. good</td><td>v. good</td><td>v. good</td></tr>
<tr><td>Maximize revenue</td><td>Maximize size of site</td><td>v. good</td><td>v. good</td><td>poor</td><td>poor</td><td>good</td><td>good</td><td>v. good</td><td>v. good</td></tr>
<tr><td colspan="2">Overall Rating</td><td colspan="2">v. good</td><td colspan="2">adequate</td><td colspan="2">good</td><td colspan="2">poor</td></tr>
</table>

Site A is very beneficial for the economics of the proposed compost facility. Waste could easily be transported by handcart to the site from the nearby market, drastically reducing transportation costs, and the site is quite large so it can accommodate a large amount of organic waste. The land is owned by a government department and the possibility of obtaining the land at a low cost is a favourable feature.

Site B is ‘adequate’ with respect to economics. Although the site is small and may need to be bought from a private owner, it is directly adjacent to the market allowing for transportation of organic waste by the waste collectors in the market, drastically reducing transportation costs which could otherwise be significant.

Site C receives a rating of ‘good’ with respect to economics as the situation is similar to that of Site B except that the site is larger and therefore may be able to generate more revenue.

Site D is ‘poor’ with respect to economics. Although the land is free and large, the transportation costs are significant which could severely compromise the feasibility of the facility.

4.4.2 Overall Ratings of Sites

The ratings for each site with respect to the three objectives obtained from tables 4.4 to 4.6 are displayed in table 4.7 for comparison purposes. Each site is also given an overall rating obtained by weighing the relative importance of the objectives. In this step, it is also important to note and take into account critical or important ratings. For example, a rating of ‘poor’ or ‘very poor’ for any of the objectives may result in an overall rating of ‘poor’ since the goal is to meet all of the objectives.

Table 4.7: Overall Site Ratings

	Site A	**Site B**	**Site C**	**Site D**
Minimize negative environmental impacts	good	v. good	adequate	adequate
Minimize negative social impacts	good	good	adequate	v. good
Maximize economic benefit	v. good	adequate	good	poor
Overall Rating	***good***	***good***	***adequate***	***poor***

Sites A and B are ‘good’ as they manage to reasonably satisfy all three objectives. Site C is ‘adequate’ because, although it is good economically, it is only adequate with respect to social and environmental impacts. Site D is ‘poor’ because, although it reasonably satisfies social and economic objectives, the economic benefit derived from the use of this site is poor mainly due to transportation costs.

5 Conclusion and Recommendations

Facility siting can affect the success or failure of compost facilities in terms of the associated environmental, economic and social impacts. This report has outlined a siting methodology that is appropriate for siting compost facilities within the context of Vientiane but is also flexible enough to be used in facility siting in other parts of the world.

This proposed methodology should be used when making decisions about siting compost facilities in Vientiane. The methodology encourages decision makers to acknowledge explicitly the basis of the decisions being made which should result in better decisions and a more transparent decision making process.

It is important for decision makers to recognize that this methodology heavily depends on consultation with stakeholders. At the beginning of the siting process, stakeholders should be identified and then should be consulted at each stage of the assessment. The objectives and criteria outlined in the methodology are meant as guidelines or starting points and when the methodology is applied, the objectives and criteria should be identified through discussion and consultation with stakeholders.

6 Works Cited

Ambrose, J.A., 1983. "Developments in the composting of refuse". *Practical Waste Management*.

Central Intelligence Agency (CIA). November 30, 2004. The World Factbook – Laos. Available at HTTP: http://www.cia.gov/cia/publications/factbook/geos/la.html. Accessed November 2004.

Chopra, S., "Quantification and Composition Audit of Waste Generated at the Early Morning Market in Vientiane, Lao PDR", M.Eng. thesis, Department of Civil Engineering, University of Toronto, 2004.

Cummings, J., *Laos*. 2002. Victoria, Australia: Lonely Planet Publications.

Frantzis, I., "Methodology for Municipal Landfill Sites Selection". 1993 *Waste Management & Research* 11: 441-451.

Kwon, K., M.Eng student, personal communication, Vientiane. July 2004.

Lao Embassy, Washington. 1997. Vientiane Municipality. Available at HTTP: http://www.laoembassy.com/discover/sites/vientianecity.htm. Accessed November 2004.

Lawrence, D.P., 1996. "Approaches and Methods of Siting Locally Unwanted Waste Facilities". *Journal of Environmental Planning and Management* 39(2): 165-187.

Manivong, K., Management Committee PADETC. Interview. Vientiane, Lao PDR. June 17, 2004.

McAllister, D.M., 1980. *Evaluation in Environmental Planning Assessing Environmental, Social, Economic, and Political Trade-offs*. Cambridge, Massachusetts: MIT Press.

McCawley, K., Canadian Coordinator, Waste-Econ, Lao PDR, personal communication, Vientiane. July 2004.

McNally, L., “Protection of Water Resources in Landfill Siting in Vietnam”, M.Eng. thesis, Department of Civil Engineering, University of Toronto, 2003.

Ministry of the Environment, Ontario (MOE), “Draft Guideline for Aerobic Composting Facilities and Compost Use”. May, 1998.

Rushbrook, P., 1999. “Getting from subsistence landfill to sophisticated landfill”. *Waste Management & Research*. 17: 4-9.

Rytz, I., 2001. “Assessment of a decentralised composting scheme in Dhaka, Bangladesh”. Zurich, Switzerland: Waste Concern.

Singh, N., Project Director, Energy Tech Solutions Ltd. Presentation and personal communication. Vientiane, Lao PDR. June 21, 2004.

United Nations Development Programme (UNDP), 2004. Human Development Reports, Lao People’s Democratic Republic. Available at HTTP: http://hdr.undp.org/statistics/data/cty/cty_f_LAO.html. Accessed November 2004.

Waste-Econ, 2004. About Waste-Econ. Available at HTTP: http://www.utoronto.ca/waste-econ/abo-was.html. Accessed November 2004.

Wong, G.R., “Analysis of Separation Options for Composting Market Waste in Vientiane, Lao PDR”, M.Eng. thesis, 2004.

Appendix 1 Aerobic Vermi-Bacterial Composting

The following is a description of the Aerobic Vermi-Bacterial Composting system (AVB) as described by Navin Singh (2004).

The bins first have to be prepared to create the necessary ecosystem of microorganisms and worms. Once the ecosystems are stable, regular composting can begin. Each day, the grass or rice straw covering the compost to prevent excessive evaporation is pushed to the side, the waste is spread in the bin, and the bin is re-covered with grass. All of the bins are watered to maintain moist conditions. The next day, the same procedure is repeated with the next bin. By the time the first bin is needed again, the last instalment of waste has become stable compost and could be removed for sale. Usually, however, the compost is stored in the bins and is only removed twice a year when the farmers and fertilizing their fields and need the compost material.

Due to the spreading of the waste, the compost never becomes anaerobic and therefore does not produce unpleasant odours. The ecosystem is so stable and robust that the C/N ratio does not need to be controlled and the system can accept meat products, unlike conventional composting methods. The AVB system is not as labour intensive as windrow composting as the material does not need to be turned. No harmful leachate is produced since the process is purely aerobic and the water that enters the bins is filtered by the layers beneath before the water seeps into the ground. No roof is necessary as rainwater can percolate through the material and into the ground without causing any problems.

AVB systems have apparently been successful in a number of different areas in Pune, India and have been working for seven years so far. The AVB systems seems like a promising alternative to conventional windrow, in-vessel or vermiculture but may need to be studied further before it is implemented in Vientiane.

Appendix 2 Diagrams, Maps and Photographs of Sites

A 2.1 Site A

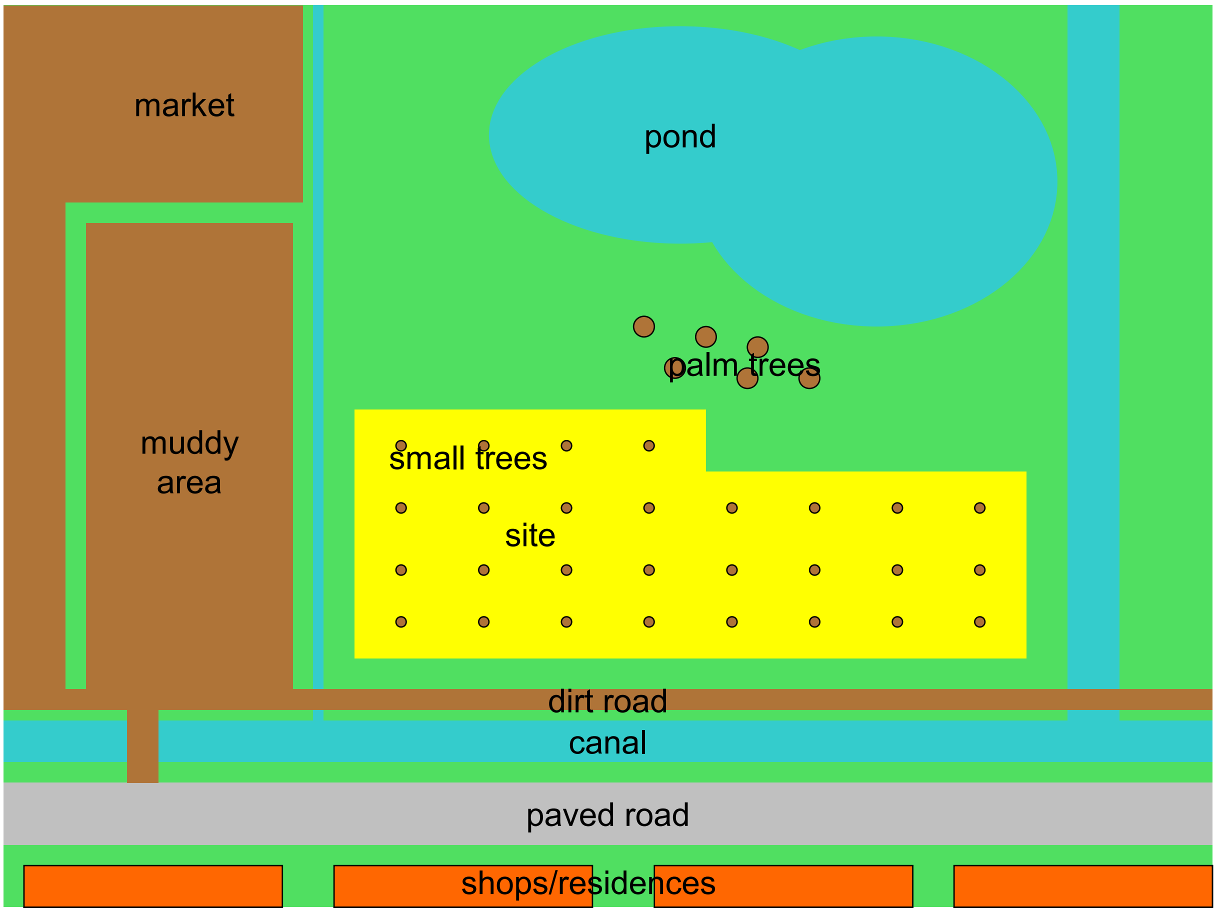

Figure A.1: Diagram of Site A (not to scale)

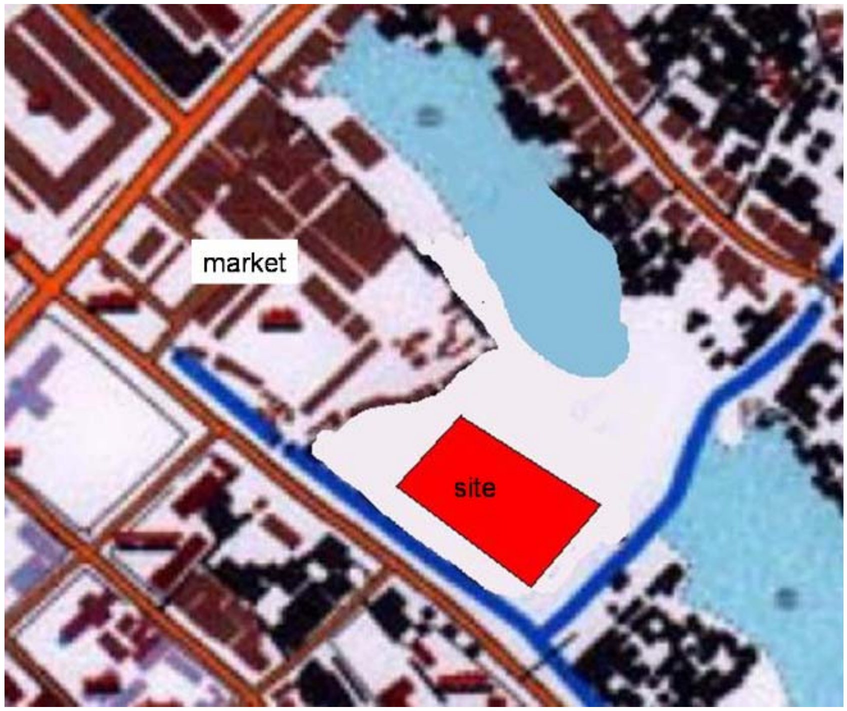

Figure A.2: Map of relative location of Site A

Figure A.3: Photograph of Site A

A 2.2 Site B

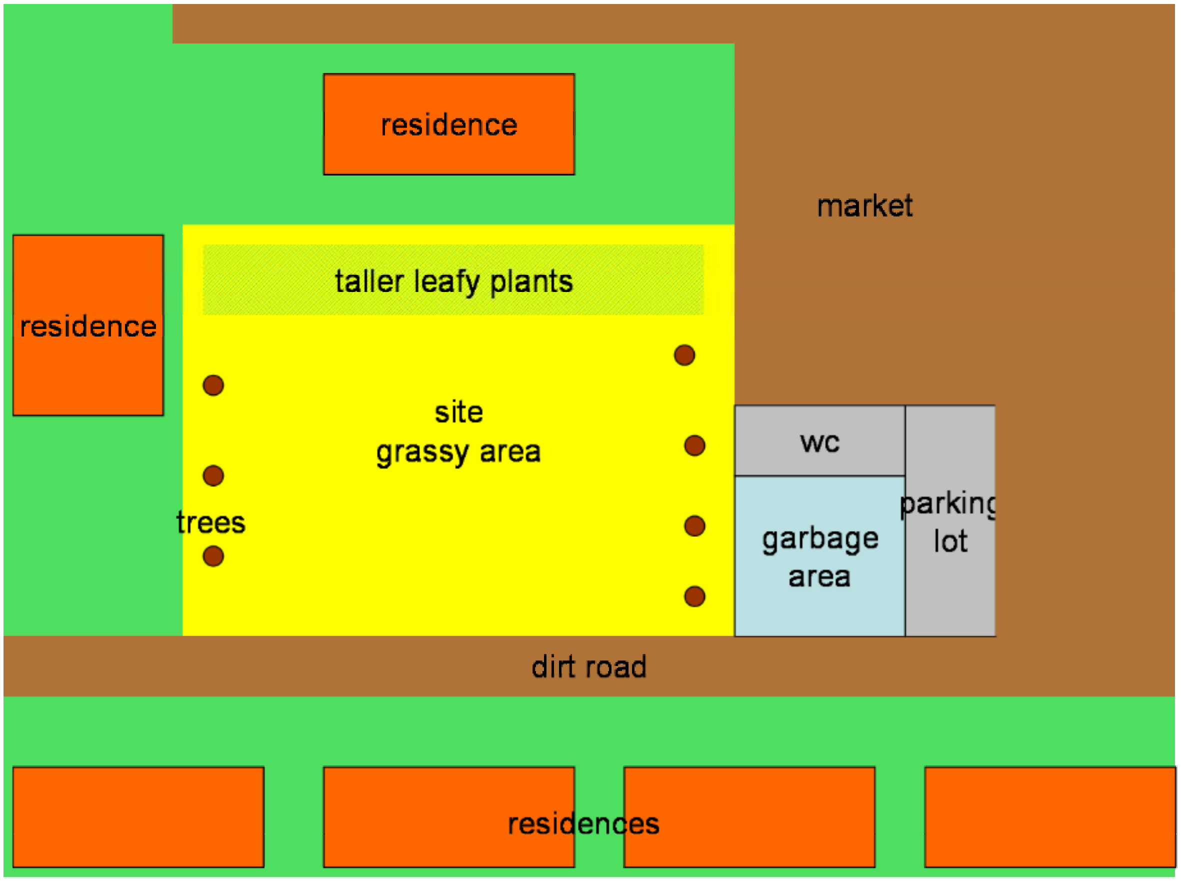

Figure A.4: Diagram of Site B (not to scale)

Figure A.5: Map of relative location of Site B

Figure A.6: Photograph of Site B

A 2.3 Site C

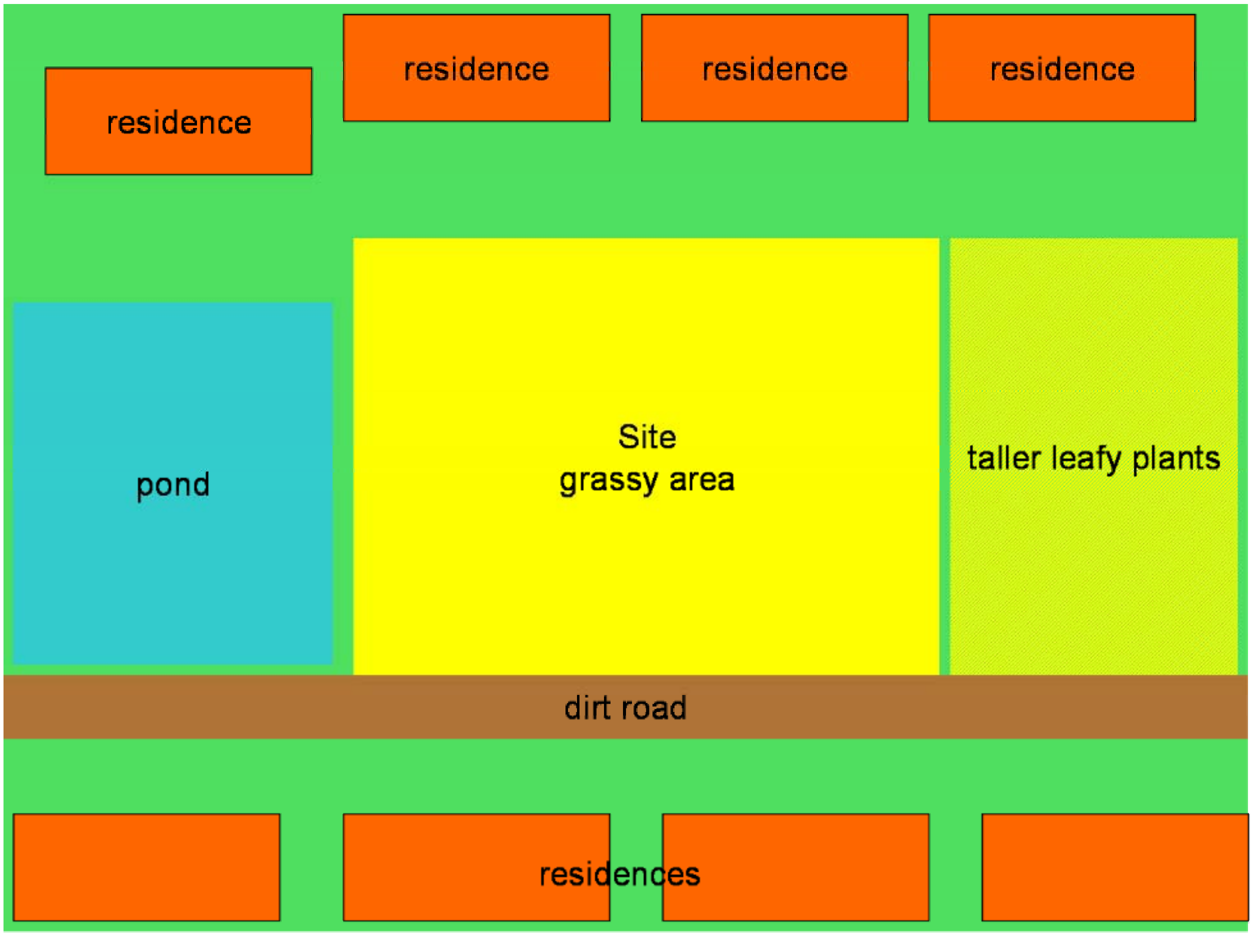

Figure A.7: Diagram of Site C (not to scale)

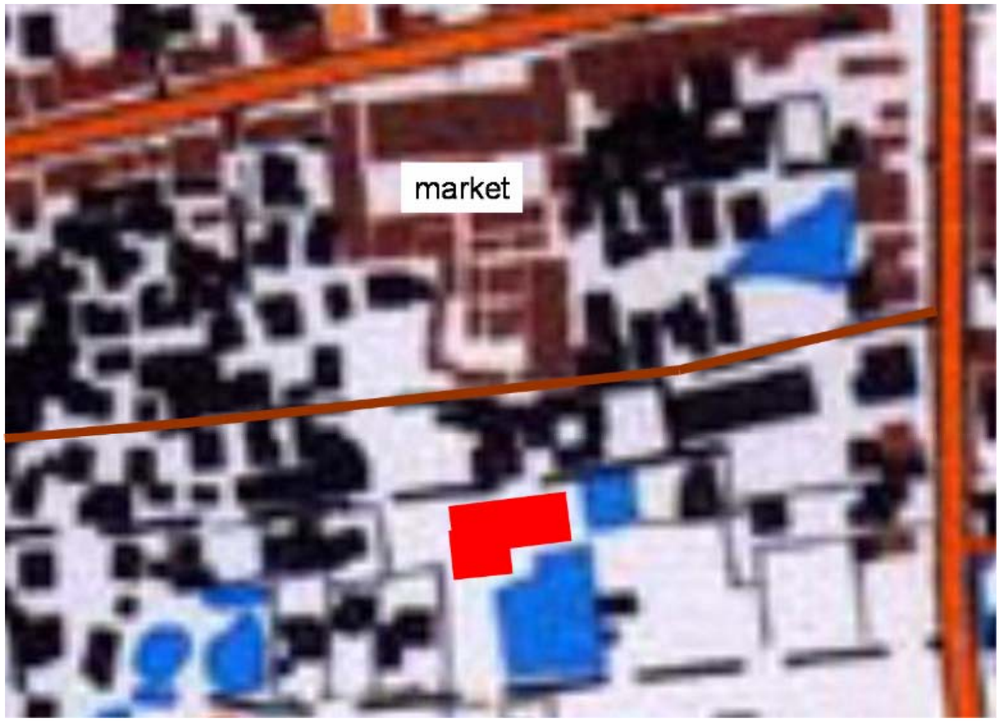

Figure A.8: Map of relative location of Site C

Figure A.9: Photograph of Site C

A 2.4 Site D

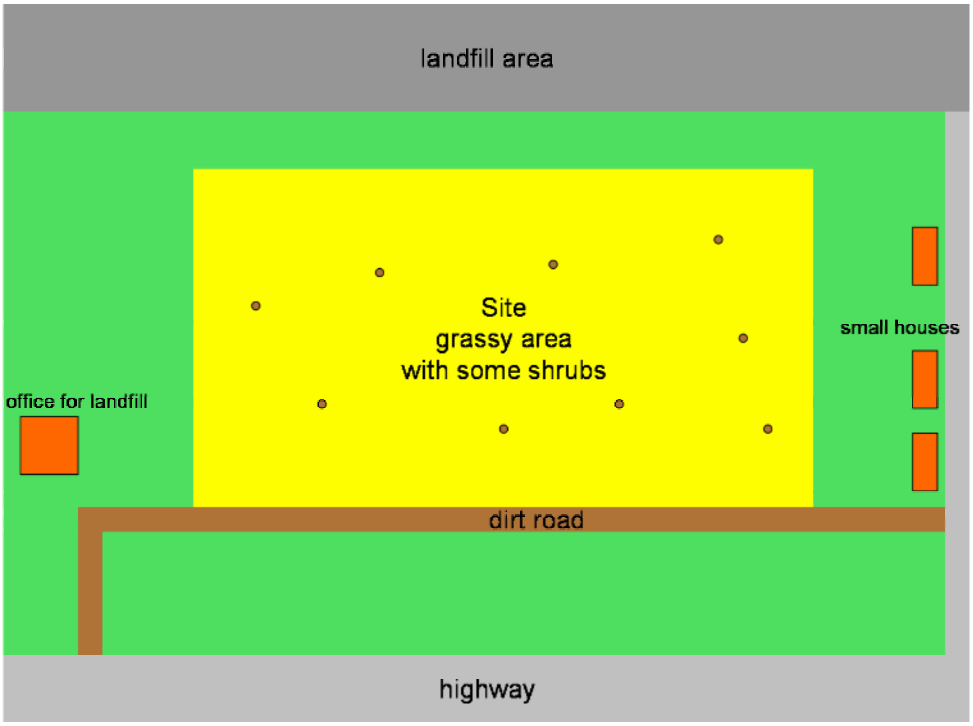

Figure A.10: Diagram of Site D (not to scale)

Figure A.11: Photograph of Site D