

LANDFILL SITE SELECTION

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SUMMARY: This paper looks at how increased environmental awareness and the advent of new environmental legislation have affected the EIA process and consequently, the technical aspects of landfill site selection in the African context. It also looks at developments and pitfalls in negative mapping, the due consideration of alternatives and Candidate Landfill site ranking methodology.

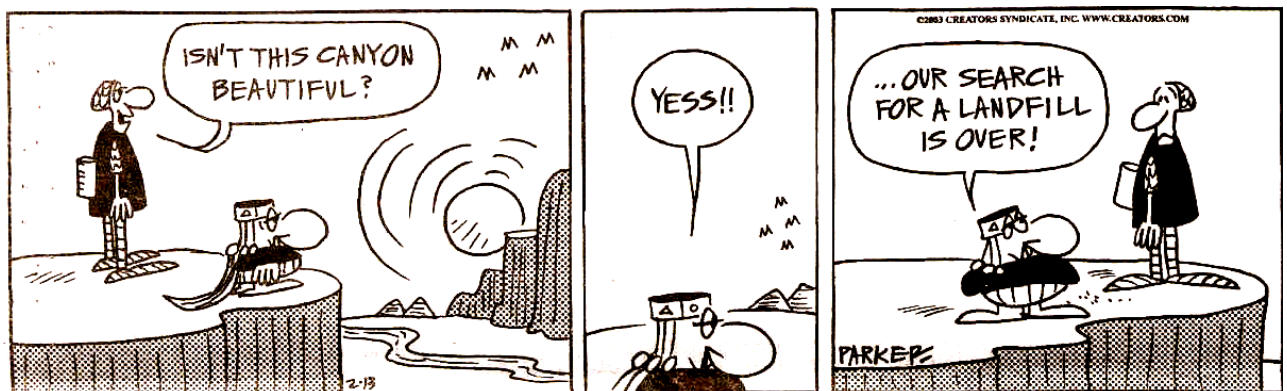
1. INTRODUCTION

In terms of the Integrated Waste Management approach, progressive authorities are making concerted efforts to reduce the amount of waste that goes to their landfills for final disposal. Notwithstanding this, waste disposal by landfill remains the way in which almost all waste in African and other developing countries is currently disposed. This is also the case in many developed countries. Consequently, landfills and the provision of landfill airspace remain essential elements in most waste management systems and strategies.

The Integrated Waste Management approach recognizes the above situation, so that the final step in the hierarchy is waste disposal by landfill. Landfilling is thus endorsed, provided appropriate standards are ensured to protect the environment, public health and quality of life.

THE WIZARD OF ID

Brant Parker, Johnny Hart



Proper landfill site selection is the fundamental step in sound waste disposal and the protection of the environment, public health and quality of life.

Proper landfill site selection determines many of the subsequent steps in the landfill process, which, if properly implemented, should ensure against nuisances and adverse long-term effects. For example, a well-selected landfill site will generally facilitate an uncomplicated design and provide ample cover material, which would facilitate an environmentally and publicly acceptable operation at a reasonable cost.

The criteria involved in landfill site selection include environmental, economic and socio-political criteria, some of which may conflict. With increased environmental awareness, new legislation and certain other developments over time, the landfill site selection process has become much more sophisticated, as new procedures and tools have been developed.

The author became involved in landfill site selection in 1975 and has remained active in the field ever since, siting hazardous and general waste landfills in South Africa and elsewhere in Africa. This paper is based on experience gained from numerous African case studies over a thirty-year period. The purpose is to illustrate the evolution of the science and process of landfill site selection in this context. It is felt that the content of this paper will be relevant elsewhere, particularly in developing countries, endeavouring to upgrade their waste disposal by landfill practices.

2. THE GENERIC SITE SELECTION PROCESS

In almost any document on landfill site selection, the general objectives are to ensure that the site to be developed is environmentally and socially acceptable, and thus sustainable. Specialist consultants are often used for this purpose. These are technical, but often include environmental consultants.

Early considerations in the technical process are the size (land area) and the strategic location of the proposed site, to ensure that the facility meets the disposal need. While the size depends on the waste stream over the predicted site life and provision for sufficient buffer zones, strategic location is determined by the waste generation areas to be served and transport routes. It is economically sound practice to establish the proposed facility as close to the generation areas as possible, with a view to minimising transport costs. Often an “economic radius” is determined, based on the existing or proposed mode of waste transport. This will define the initial area of investigation.

Once the “economic radius” or “study area” has been identified, a Public Participation Process (PPP) should be initiated and maintained throughout the site selection process. This may, however, be controversial, as making the public aware too early can compromise the results. It may stir up public and political resistance, i.e. the “not in my back yard” or NIMBY syndrome. It might also lead to land speculation and soaring land prices, or losing a competitive edge in the case of a private sector contractor. On the other hand, not to inform the public early on, or presenting them with a *fait accompli* is guaranteed to generate mistrust and even more resistance. Unless dictated by local regulations, therefore, informing the public is a case-specific issue.

Once working in the study area, the next phases are the elimination of all areas with associated Fatal Flaws. In this instance, Fatal Flaws are defined as phenomena that prohibit the development of an environmentally or publicly acceptable waste disposal facility except at excessive cost. In the South African Minimum Requirements 1998, eighteen such fatal flaws are listed, including sensitive environments, water resources, development and unsuitable geological and soil conditions.

Once all areas with associated Fatal Flaws have been eliminated from the study area, a number of candidate sites have to be identified. This process is based on numerous economic,

environmental and public acceptance criteria, and ensures the *due consideration of alternatives*, which represents a fundamental element of any Environmental Impact Assessment (EIA) process.

Once all the candidate sites have been identified, they must all be compared and technically evaluated. Unsuitable sites must be eliminated and the best sites must be short listed for further consideration. The short listed sites are then ranked in order of suitability. The ranking process is, however, controversial and is often open to criticism because it may be seen as subjective, which in some instances is the case.

The top-ranking site is then subjected to a more detailed investigation by means of a Feasibility Study, to confirm that it has no Fatal Flaws and is environmentally and publicly acceptable. The Feasibility Study may comprise many administrative and technical aspects, which depend on local legislation. It should, however, include a preliminary Geohydrological Investigation, as well as a preliminary Environmental Impact Assessment (EIA). If Fatal Flaws emerge in the investigations the site is discarded and the next best site is investigated. Otherwise, a conceptual design is drawn up, which addresses any critical factors associated with the site, and this, together with the investigation results, is submitted to the authorities and usually to the public.

In the event that the authorities find the site feasible, further detailed investigations must be undertaken. These should involve detailed Geohydrological Investigations, a detailed Environmental Impact Assessment (EIA) and a detailed design. If Fatal Flaws emerge in the investigations the site is discarded and the next best site is investigated. If the site is sound, however, it may be developed.

Depending on local legislation, sophistication and know-how of the authorities or fund donors, the generic landfill siting process may vary. Some countries have permitting systems in place, which require landfill site permitting before development, while others have nothing. Any professional working in the latter environment should work according to suitable guidelines, such as the South African Minimum Requirements or USEPA Guidelines for landfilling in developing countries.

3. THE GENERIC EIA PROCESS

Landfilling can have a significant adverse effect on the environment and quality of life of adjacent communities, if not properly sited, developed, operated and closed. Consequently, all these aspects should be addressed during the Environmental Impact Assessment (EIA), which should take place during the landfill site selection process.

The EIA process includes not only the impact assessment, which involves specialist technical issues, but also the associated Public Participation Process (PPP). In essence the PPP involves liaising with the authorities, identifying the Interested and Affected Parties (IAPs), informing them of the project and process and obtaining their input, which is taken into consideration by addressing their issues and concerns. Where it occurs, *justified* public resistance to a proposed landfill site should be regarded as a Fatal Flaw.

As noted, the initiation of the PPP is controversial and case-specific, but as a general rule, the sooner the PPP is initiated the better, and it should be maintained throughout the landfill site selection process. In practice, the actual EIA process will vary from case to case, but should follow the basic principles of EIA, which are not addressed in detail in this paper.

In some cases, increased environmental awareness has led to more stringent EIA regulations, often based on developed country models. Occasionally the process almost becomes an end in itself and allows IAPs to use delay tactics to lengthen the process. There is also an ever-present threat of litigation. The waste management consultant must therefore ensure that everything done

during the site selection process is defensible, and must sometimes be prepared to defend it in court. Finally, the *due consideration of alternatives* requires consideration of all other waste management options. Thus, to be completely transparent, both the technical and the EIA processes have to be thorough, consistent and defensible. However, in the end analysis, this conservative approach is usually vindicated because, even though it may take longer, it does ensure proper landfill site selection.

On account of the EIA process, a general trend observed is that more detailed investigation is often carried out earlier in the process. An example is that in order to rank the best Candidate Landfill sites objectively and defensibly, one may embark on more detailed studies, normally reserved for the Feasibility Study and even the EIA specialist studies.

4. SOME TECHNICAL ASPECTS OF LANDFILL SITE SELECTION

4.1 Negative mapping

Negative mapping is a preliminary tool used in the identification of Candidate Landfill sites. It is used early in the study to eliminate the unsuitable areas in a study area and to identify “positive window areas” for further investigation. This can be done on a small or large scale and makes use of overlay technology to exclude the unsuitable areas. Such unsuitable areas are often associated with the Fatal Flaws and unsuitable conditions, termed “exclusion criteria”. Some of these appear below:

- Existing land use, development and population density (current and future).
- Unsuitable topography, drainage areas and areas of vulnerable to water pollution.
- Unsuitable geology (e.g. dolomites in South Africa) and soils.
- Existing and potential agricultural land use.
- Identified areas of environmental sensitivity (e.g. nature conservation areas).

Initially, manual overlays were used with a high degree of success. However, this methodology was slow and tedious. Notwithstanding this, it remains the appropriate technology in developing countries where normal and digitized maps are often scarce. In countries where digitized maps are available, Geographical Information Systems (GIS), for which overlay technology is the ideal application, is now the state of the art. When using GIS and digitised data for negative mapping, however, one must proceed with caution, as there are at least two associated pitfalls, as follows:

- The quality of the result depends on the quality of the input data used. Much of the soils and geological data for instance is mapped on a scale of 1:250 000, whereas one really needs to work on a scale of 1:50 000, particularly in the remaining positive “window areas”. If the scale is not sufficient to provide detail, certain aspects can be overlooked.
- Another possible pitfall is when GIS specialists, (who can achieve spectacular presentations on the computer, but have little or no insight into science of landfill site selection) carry out the GIS negative mapping. There are examples of studies that, based on this and a lack of field validation, have resulted in erroneous conclusions, sometimes with far reaching implications.

To ensure better accuracy and a good understanding of actual conditions on the ground, therefore, negative mapping must always be carried out in parallel with field validation, involving direct observation. Since field validation in effect provides a scale of 1:1, it is always more conclusive than GIS data in this context. For example, the type and depth of soil observed in a road cutting, is far more reliable than information obtained off a 1: 250 000 or even a 1: 50 000 soil map. This “ground truthing” has sometimes resulted in areas ruled out by GIS negative

mapping, yielding prime Candidate Landfill sites. Conversely, it often reveals that the remaining positive “window areas” are not that good after all. It has been found that excellent results can be obtained with GIS when done in conjunction with ground truthing.

4.2 The due consideration of alternatives

Since the *due consideration of alternatives* is a fundamental principle in Integrated Environmental Management (IEM) and the EIA process, and is also a fundamental principle in landfill site selection. By presenting numerous alternatives and comparing them, the approach goes a long way towards providing objectivity and a defensible approach.

One mistake that has frequently been made by the consultant (the author included) is that one tends to view “alternatives” as Candidate Landfill sites. As soon as the IAPs become involved, however, it soon becomes evident that (as indicated in the EIA section), “alternatives” also mean other waste management solutions. These will include composting, recycling and possibly even the latest “black box” technology that has been “sold” to the politicians. These issues have to be addressed and the necessity of a new landfill confirmed, before the process can proceed. Similarly, the IAPs may present alternative Candidate Landfill sites. While these are usually intended to move the proposed landfill away from the area under consideration, they must be taken seriously and considered on the same basis as the other Candidate Landfill sites.

In a landfill site selection exercise, generally the more alternatives identified, the better. In the recent project to identify a new regional landfill site for the City of Cape Town, some 75 potential sites in total were considered. These were reduced to about 30 Candidate Landfill sites, of which only 4 were short-listed and ranked. This example possibly represents an extreme case, on account of it being a high profile project in an extremely sensitive environment.

Regarding the Cape Town project, it is of interest to note that, notwithstanding the number of alternatives considered, the EIA process dictated that the top *two* sites both be considered for further investigation. This was based on an *interpretation* of the National Environmental Management Act of 1998 and is contrary to the South African Minimum Requirements approach and that of many developed countries, including the USA, which require specialist studies to be carried out on only the top ranked site. This approach has significantly increased the complexity, size and cost of the project and delayed the process, which at the time of writing had been going for five years.

While in most site selection processes, one should endeavor to identify as many alternatives as possible, few will result in the number of Candidate Landfill sites considered in the Cape Town project. For sites in South Africa, the number has ranged from 15 to 30, while in other African countries, where transport distances are usually restricted by vehicle type, this has ranged between 12 and 15. Examples are Sekondi Takaradi in Ghana, Soyo in Angola and Jwaneng in Botswana.

There are also situations where the due consideration of alternatives may not always represent the most logical approach. Such situations could result when existing factors and/or historical planning may strongly favor a given site. In such instances, the situation should be made known to the authorities from the start, and a directive obtained as to what would be considered to represent an appropriate approach.

At this point, it is interesting to note the trends. Historically, it was land availability that counted. Basically, the nearest piece of vacant land would suffice for the “tip” or the “dump”, whether in a wetland or a canyon, as in the cartoon. Then as we became more aware and the science of landfill site selection evolved, land suitability became the main criterion. For example, a landfill had to be situated on deep clays and had to have an adequate buffer zone around it. Now, with the NIMBY syndrome, environmental awareness and associated stringent constraints, the adequate buffer zone has become the key criterion. Availability of a site with a suitable

buffer zone becomes a prime consideration. Consequently, even if a site is not ideal in terms of underlying geology and soils, provided it has the adequate buffer zone and is close enough to the waste generation areas, it will be considered, allowing for more costly liner engineering to overcome inherent site shortcomings.

4.3 Ranking of short listed Candidate Landfill sites

Once Candidate Landfill sites have been identified, they must be evaluated to eliminate unsuitable sites and to help determine the top ranking or short-listed sites. If there are a number of sites, the “course screening” can usually be achieved by inspection and consensus, within an objective team of experts, in a process similar to a Delphi method. Alternatively, a simple matrix comprising the candidate sites on the one axis and selected criteria on the other may be used. The criteria must then be appropriately weighted to reflect their relative importance. Scores are assigned for each criterion for each site and added together to provide a site total. Thereafter, sites are ranked from the lowest to the highest, and the latter are compiled into the short-list for further consideration.

Once a short-list of the top ranking sites has been established, these must be compared with one another in a “fine screening” exercise. For this process the above simple site-ranking matrix may again be used. However, assigning numerical values is seen as very subjective, so at this level variations may be used. One is a more detailed matrix based on an ABC system, where for each criterion, the site rated best would receive an A, second best B and the worst, a C. This is fine for three sites, but not for more sites or close ranking criteria. Another variant is to use colours.

While it was found that in some instances, the public would accept simple ranking matrices, this was not always the case, particularly with sophisticated IAPs. In such instances the ranking of Candidate Landfill sites can become a controversial issue, especially when using the simplistic methods described above. This is because different people have different perspectives. For example, whereas a waste manager will want to minimize transport costs, the IAPs are not concerned with transport costs and are (understandably) only interested in ensuring that their quality of life is not compromised. Frequently therefore, the objectivity of the ranking process is brought into question. Consequently, a more sophisticated methodology is required to rank the short-listed sites, to ensure defensible objectivity, especially in the face of public resistance and potential for litigation.

Various methods have been considered and the most successful methodology used to date is that based on the Analytic Hierarchy Process (AHP), a multi-criteria decision-making approach, (Saaty 1994). Using pair wise comparisons and the eigenvector, this facilitates the scientific evaluation of alternatives in terms of a set of difficult-to-quantify criteria, such as aesthetics, risk, social impact, etc. The method first determines the weight of importance of each criterion, and then the relative scores of the alternatives under consideration for each criterion.

To carry out this exercise in the Cape Town project, an objective multidisciplinary team of experts was selected. Although in this case, the team comprised only consultants, it may include fund donors, members of authorities and even members of the public, provided they are seen to be objective and to have a recognizable level of expertise in a given field. First, each team member was requested to submit his or her list of landfill site ranking criteria. These lists were then work-shopped with the client and various EIA consultants, before being consolidated into a single list.

Since the criteria do not all have equal importance in the ranking process, AHP and pair wise comparison were used to assign a weighting to each criterion by the multi disciplinary team. Using the same pair wise method, each short-listed site was compared to its competitors for each criterion. The weighted criteria scores were then tallied for each site and compared to provide a

ranking.

The above complex methodology, using pair wise comparisons to provide objectivity, was found to be far more defensible than using simplistic matrices, which are seen as being very subjective. However, it must be noted that even complex models do not completely eliminate individual subjectivity, so that apart from professional honesty on the part of the individual, the best guard against subjectivity is the involvement of a high caliber, diverse and multidisciplinary team.

5. CONCLUSIONS

Based on the background and observations presented in the paper, the following general findings are presented for consideration:

- Regardless of trends in some developed countries, landfills and landfill airspace remain essential elements in waste management system in many countries, particularly in developing countries.
- Proper landfill site selection process is fundamental to sound waste disposal practice.
- Because of IAP involvement, waste management consultants should make provision to defend their work, in the event that it will be challenged - possibly in court. This will increase the workload and lengthen the landfill site selection process. It also promotes the trend that more detailed investigations are undertaken earlier in the process to ensure defensibility.
- Negative mapping is well served by the use of GIS. However, quality of input data, insight into the science of landfill site selection and continual field validation are essential for good results.
- The due consideration of alternatives should include waste management solutions other than landfill. Generally, the more alternative Candidate Landfill sites identified, the better.
- Generally, the simple ranking matrices in the Minimum Requirements are inadequate and prone to subjectivity. However, even the most sophisticated methodologies cannot completely eliminate subjectivity. The best way of addressing this is by using a high caliber multidisciplinary team.

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