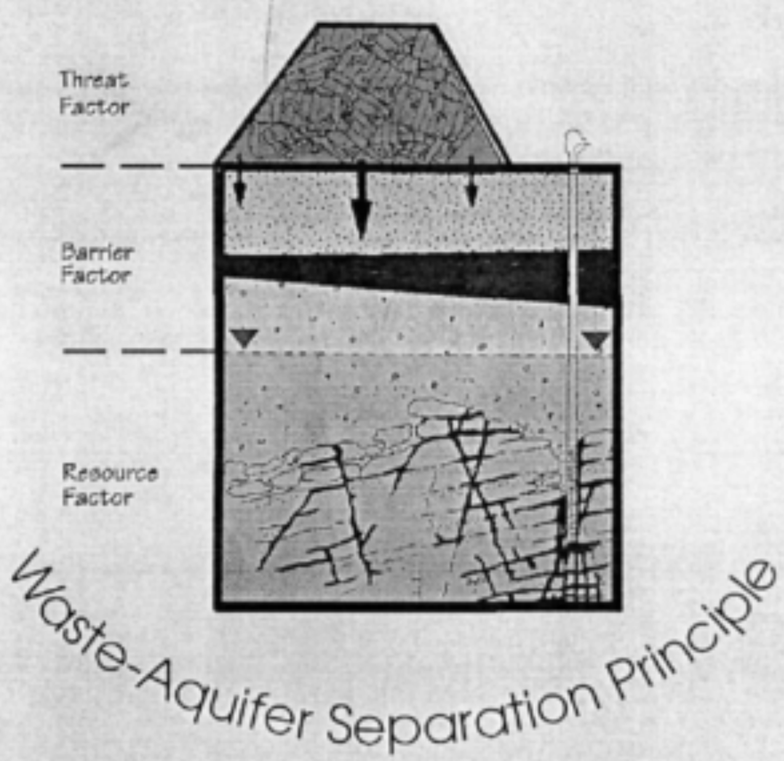
A systematic method for evaluating site suitability for waste disposal based on geohydrological criteria

WASP MANUAL



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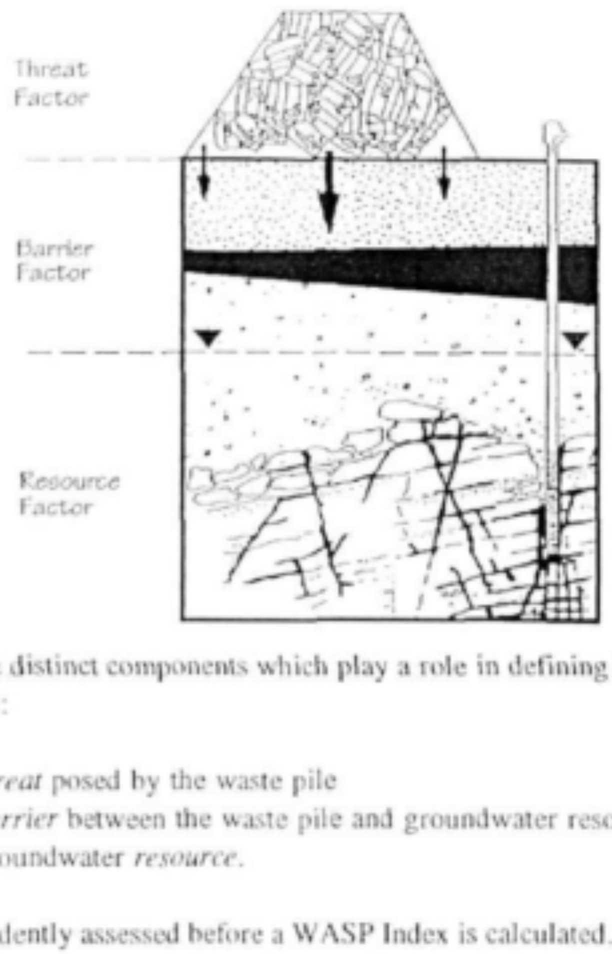
PREAMBLE

The Waste - Aquifer Separation Principle, or WASP, is a tool for assessing the suitability of both existing and proposed waste facilities in terms of geohydrological criteria. The development, verification and validation of WASP are described in detail in a report by Parsons and Jolly (1994) entitled:

> *The development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria.*

The Executive Summary of the report is included in this manual. The research was funded by the Water Research Commission of South Africa and carried out by CSIR and the Department of Water Affairs and Forestry. Copies of the research documents and the WASP software are obtainable from the Executive Director, Water Research Commission, PO Box 824, Pretoria 0001, South Africa. All users of WASP are urged to read these documents in order to gain a deeper understanding of the assumptions of the procedure as well as to be aware of the application and limitations of the tool.



WASP considers three distinct components which play a role in defining the suitability of a particular site for waste disposal:

- the *threat* posed by the waste pile
- the *barrier* between the waste pile and groundwater resources
- the groundwater *resource*.

Each factor is independently assessed before a WASP Index is calculated. The Index is then compared with a calibrated interpretation scale in order to define suitability. Coupled to each factor is a data reliability rating process. The data reliability ratings of each factor are determined and then averaged. The rating is then recorded, in parenthesis, behind the WASP Index in order to provide a measure of the degree of detail of information used to calculate the WASP Index.

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EXECUTIVE SUMMARY

PROBLEM STATEMENT

Much of South Africa experiences a semi-arid climate. Due to an increasing water demand, sedimentation in dams and a limited number of suitable dam sites, the country will soon face serious water shortages. Even though groundwater only accounts for some 13 % of the total national water supply, approximately 65 % of the area of the country relies on this water source to one degree or another. The predicted inability of surface water resources to meet future water demands and the growing cost of developing these resources suggest that groundwater resources could help meet these requirements, either in conjunction with surface resources or as a sole source. Latest estimates are that over 280 towns and smaller settlements use groundwater to one degree or another.

The disposal of waste has been shown throughout the world to be a major contributor to the degradation of aquifers. Wastes are an unavoidable by-product of all man's activities and the disposal thereof is a growing problem. Approximately 95 % of all solid waste in South Africa is disposed of by landfilling or landbuilding. It is further estimated that 1 400 solid waste disposal sites exist in South Africa. The infiltration of leachate from these sites into groundwater bodies is hence of major concern.

No formalised systems or standard approaches are used to assess the impact that waste disposal sites have, or could have, on South Africa's aquifers. This has led to variable results being obtained and inconsistent conclusions being reached in those geohydrological studies that have been undertaken at waste disposal sites. In response to this, Hall and Hanbury (1990), Jolly and Parsons (1991) and Van Tonder and Muller (1991) all proposed some form of site evaluation based on international literature. However, all were literature-based and the methods have not been tested or validated under South African geological and geohydrological conditions.

RESEARCH OBJECTIVES

The objective of the investigation was to develop and field-validate a South African-based methodology which addressed the geohydrological components of waste site selection and suitability evaluation. The developed method was to be suitable for initial site screening and planning, setting of data requirements and final site suitability determination. Further, a set of required characteristics were identified at the outset. The method was to be:

a. valid, appropriate and accurate under South African conditions;
b. systematic, physically based, objective and the results repeatable;
c. suitable for site specific investigations;
d. an easy-to-use system based on readily available geohydrological data; and
e. the methodology was to be suitable for use by the central government permitting authority, local authorities and private companies entrusted with waste disposal as well as consultants undertaking waste disposal site selection and suitability determination studies.

RESEARCH METHOD

Information concerning site evaluation techniques used elsewhere in the world were collected by means of a WATERLIT literature search, a South African study tour and a short visit to Europe. The study tours were undertaken in order that in-depth discussions could be held with people active in the field of waste management and groundwater as well as with researchers and developers of other site assessment methods. A total of 29 different site or regional assessment tools were identified and studied. The positive and appropriate features of these methods were then used to develop a conceptual method which took account of South African conditions.

Information from 106 waste site permit applications, submitted to the Department of Water Affairs and Forestry, was examined. Owing to the nature of data presented and the reliability of the data, information from only 71 of these sites could be used in the development of the method. Data pertaining to the type and volume of waste disposed of and the prevailing geological and geohydrological conditions was then collected and used in the verification of the developed method. Information from ten well-studied waste disposal sites, spread throughout South Africa, was used in the validation of the method. Additional fieldwork was required at six of these sites to obtain the required information. The data used in the development, verification and validation of the method are regarded as the best data currently available.

WASTE - AQUIFER SEPARATION PRINCIPLE

It is widely argued in the literature that most waste can be landfilled without any unacceptable detriment to the public or the environment **if the sites are carefully selected**. Further, if expensive and technically difficult groundwater contamination clean-up is to be avoided, waste facilities and aquifers must be kept apart. This separation concept is central to the method developed and led to the name **Waste - Aquifer Separation Principle**, abbreviated as **WASP**.

Three factors were identified as being important in the assessment of site suitability for waste disposal (Figure 1), namely:

- the Threat Factor
- the Barrier Factor
- the Resource Factor.

Many of the methods studied subscribed to a similar concept. One of the major differences between WASP and vulnerability mapping techniques is that vulnerability mapping does not consider the actual threat posed by the waste pile. The fact that the three elements were so distinct and easily differentiated between, in terms of both role played and actual physical boundaries, made this approach attractive.

Threat Factor

All waste disposal sites produce leachate and, as such, pose a threat to groundwater resources. The threat posed is essentially some product of the volume of leachate produced and the quality of that leachate. Both components are extremely difficult to quantify or predict with any certainty. After due consideration was given to international trends and current South African practice, it was decided that a Threat Factor score could be obtained using the designed final area of the site and the type of waste being disposed of.

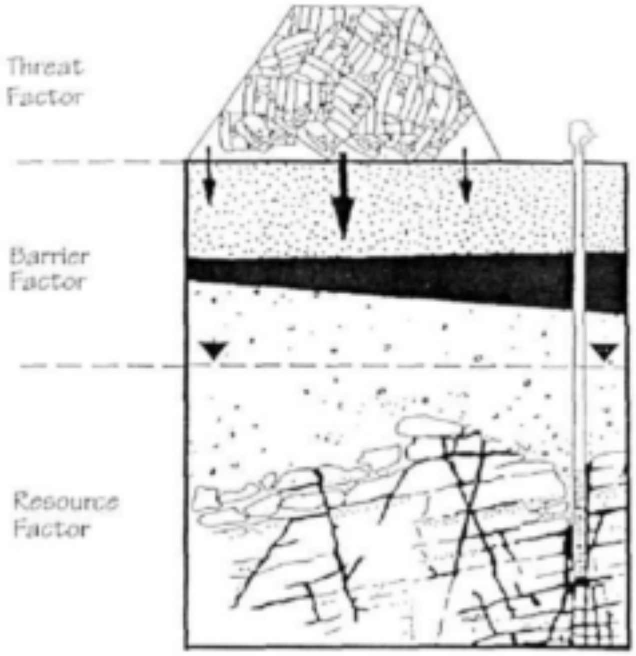

Figure 1: The three factors which impact on site suitability for waste disposal

Barrier Factor

The barrier between a waste pile and an aquifer is represented by the unsaturated zone. It is within this zone that much attenuation of leachate occurs. Important processes in leachate attenuation include chemical precipitation, adsorption, dilution, dispersion and biodegradation. Attenuation is a set of complex and often inter-related processes governed by a number of factors. The modelling of attenuation processes is hence extremely difficult. It was therefore decided that the time that leachate would take to travel from the base of the waste pile to the top of the aquifer would be used to quantify the ability of the barrier zone to separate the waste from an aquifer. Travel time is calculated using Darcy's Law. The data required for the calculation are depth to water and the hydraulic conductivity and porosity of the vadose zone. The Barrier Factor score is obtained by comparing the calculated travel time to a rating curve.

Resource Factor

The quantification of the Resource Factor proved to be most challenging. In attempting to establish the significance of a groundwater body, and then employing a single number to reflect the value of the resource, one is essentially trying to present the science of geohydrology in a short sentence. It was decided at the outset that the **strategic value** of a groundwater body to its user, or potential user, should be considered. This meant that a single user, such as a farmer, was given the same weighting as a large multiple user, for example a town. This required that measurable and definite parameter values be excluded from the assessment process. A questionnaire approach was shown to be the most appropriate means of assessment. Two sets of questions were compiled, the first set dealing with current usage and the second with potential usage. Points are awarded for each answer, thus enabling the quantification of the Resource Factor.

WASP Index

Once scores for all three factors have been determined, the WASP Index is computed using a nomographic solution. The obtained index can be correlated directly against a generalised interpretation, whereby sites are defined as being either highly suitable, suitable, marginal, unsuitable or highly unsuitable. The interpretation was developed and refined using information obtained from the 71 permit applications and the associated reports.

Data Reliability

In order that WASP could have a wide application, a data reliability rating was developed. All input data considered by WASP are rated in terms of their detail and reliability. A simple rating scale of 1 to 3 is used. The three data reliability levels used correspond directly to the types of investigations which may be required by current Integrated Environmental Management principles and procedures. Once all data have been rated, an average is obtained and recorded in brackets after the obtained WASP Index. The data reliability rating allows that the value and reliability of the WASP Index be readily apparent. This aspect will be particularly valuable to DWAF when considering waste site permit applications.

Flexibility

It was found during the development of WASP that not all geohydrological situations could be accommodated in the procedure. At times, one component or factor was so dominant that it over-rode the determined WASP Index. Extremely poor groundwater quality, a very slow travel time through the barrier and an extremely low groundwater potential were three commonly encountered conditions which resulted in over-ride situations. The inclusion and identification of over-ride factors was thus accommodated in WASP to account for such circumstances and hence provide flexibility in the procedure. The employment of an over-ride during site evaluation, however, can only be based on detailed and reliable data and be motivated by a suitably qualified and experience geohydrologist.

DISCUSSION

The validity of WASP was assessed by comparing the WASP Indices obtained for the 10 waste disposal sites studied in detail with observed contamination patterns. All of the obtained indices were found to be accurate assessments of the prevailing conditions. Further validation is nonetheless recommended once more data becomes available.

The integration of WASP, at all levels, into broader waste site suitability assessment procedures and approaches will provide much assistance and impetus to the prevention of contamination of South Africa's aquifers by waste disposal activities. WASP can play a valuable role in initial site screening, identification of additional data requirements and the final assessment of the a suitability for waste disposal. The incorporation of WASP into the current waste site permit application procedure is also seen as being particularly important.

Even though every effort has been made to develop an accurate and reliable tool, WASP does have some limitations. These result largely from the assumptions and simplifications used in WASP. Users of the method must thus be aware of these inherent limitations. WASP does not replace the need for appropriate data and information, nor the need for suitable geohydrological training and experience, in the assessment of site suitability for waste disposal. The procedure is merely a tool to help in the evaluation of proposed and existing sites and promotes sound decision-making. The reliability of the assessment remains a function of the data used and the expertise of the assessor.

A field manual has been prepared so that the procedure can be easily applied under field conditions. Further, software has been written which allows for the easy input of the required data and the automatic calculation of the WASP Index and the interpretation thereof.

CONCLUSIONS

Based on all the reliable waste disposal site data currently available in South Africa and the work performed during the research programme, WASP was found to be capable of providing an accurate and quantified assessment of a site's suitability for waste disposal, based on geohydrological criteria. WASP now needs to be applied to a wide range of waste and geohydrological conditions. Once applied, the performance of the procedure can then be re-assessed.

The objectives of the research project have been achieved by the development, verification and validation of the Waste-Aquifer Separation Principle, abbreviated as WASP. The method was based on 29 methods used throughout the world, but was developed to suit South African conditions. All reliable waste disposal site data currently available were used in the verification of the method while the validation of WASP was based on information from 10 well-studied facilities spread throughout the country. A data reliability rating is coupled to the WASP Index and this allows the value and reliability of the obtained Index to be readily apparent. A degree of flexibility is allowed for in the procedure in order to accommodate special or unique considerations and circumstances. WASP does not, however, replace the need for appropriate data nor the need for the assessor to be suitably qualified and experienced in geohydrology.

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Van Tonder, G. and Muller, J., 1991: The use of a numerical rating system for the evaluation of waste disposal sites in SA; Int. Conf. Proc. Ground Water Quality and Pollution, Midrand, August 1991.

GENERAL PRECAUTIONARY STATEMENT

The quality of an assessment and the accuracy of the results are directly related to the technical capability of the user and the amount and quality of available hydrogeological information. The degree of reliability achieved by anyone using WASP depends on their level of training and on the amount of information available to determine hydrogeological conditions. The application of WASP requires experience in interpreting subsurface geological and groundwater information to produce satisfactory results. It is thus required that only persons of suitable training and experience in the field of geohydrology perform the WASP assessment which will be used to make decisions regarding the suitability of a particular site for waste disposal activities.

Further, it is recognised that this method cannot be suitable for all situations. Even though every effort has been made to develop a systematic and objective methodology, which accurately defines the physical environment, the onus remains with the investigator to ensure site suitability.

WASP METHODOLOGY

THREAT FACTOR

The threat posed by the waste pile is essentially a product of the volume and quality of leachate produced by the waste pile. WASP quantifies this threat by means of the designed final area of the site and type of waste being disposed of.

STEP 1: Quantify input parameters

designed final area of site: The designed final area of the site needs to be measured in hectares.

type of waste: The type of waste being disposed of must be determined and classified according to the following groupings:

garden and building rubble
domestic waste including commercial waste
dry industrial waste and domestic waste
liquid effluent and sludge and domestic waste
hazardous waste (including medical waste)

Note that the most appropriate group must be used as well as the higher level of classification i.e. if both dry industrial waste and sewage sludge is disposed of, the waste must be classified as liquid effluent and sludge and domestic waste.

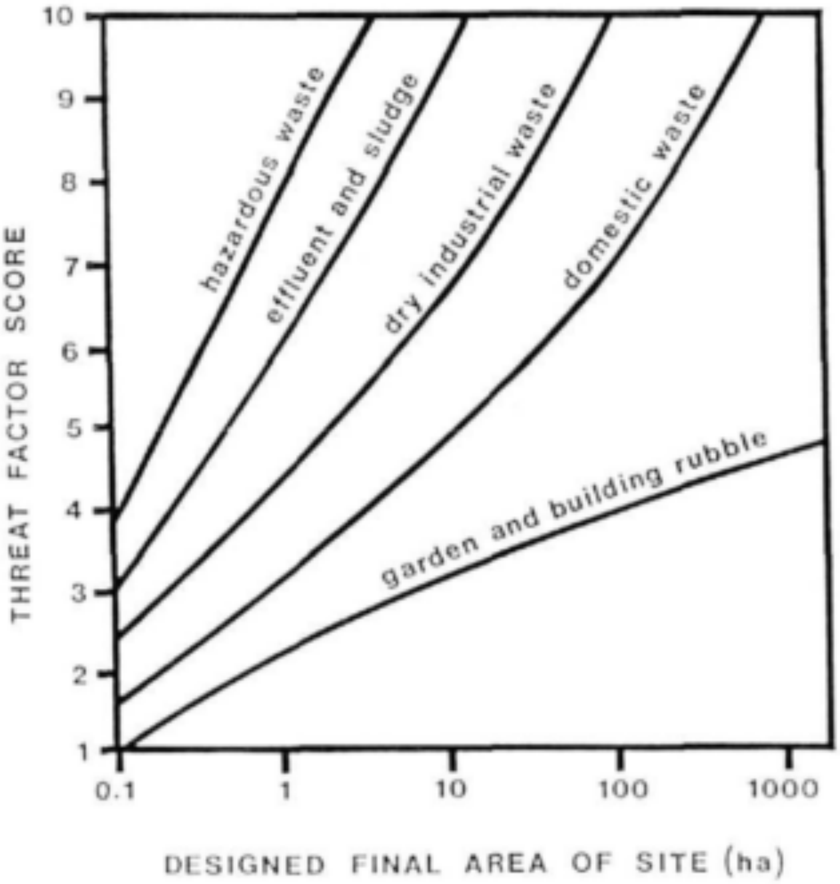
STEP 2: Determine Threat Factor score

Using the Threat Factor score nomogram, read off the Threat Factor score and record.

STEP 3: Determine data reliability rating

Using the Threat Factor score data reliability rating table, assign a point equivalent to the most appropriate level of data reliability for each component, obtain an average for the two and record ie. Level 1 data is assigned 1 point.

THREAT FACTOR SCORE NOMOGRAM



DATA RELIABILITY RATING TABLE FOR THE THREAT FACTOR

DATA RELIABILITY LEVEL	LEVEL 1	LEVEL 2	LEVEL 3
Size of site	Certain - based on site field measurement or approved final site plan.	Based on aerial photograph or map measurements and estimations.	Uncertain - based on estimations.
Waste type	Certain - based on observed and monitored waste deposition.	Based on extrapolated information from similar situations.	Uncertain - based on estimations.

BARRIER FACTOR

The time that leachate would take to travel from the base of the waste pile to the top of the aquifer is regarded as a measure of the ability of the unsaturated zone to attenuate the leachate and hence separate the waste from any groundwater resources. Travel time is calculated using Darcy's Law and the required input parameters are the thickness of the unsaturated zone, the hydraulic conductivity of the zone and the porosity of the barrier material. The hydraulic gradient is assumed to approximate unity and can be ignored.

STEP 1:	Quantify input parameters
thickness of barrier zone:	The top of an aquifer is defined by the static water table (or piezometric surface); the thickness of the barrier zone is hence measured in metres from the base of the waste pile to the water table. See conditions where the thickness may be measured otherwise (next page).
hydraulic conductivity:	The hydraulic conductivity, recorded in m/day, must be provided. For the purpose of guidance, some typical ranges of values for different lithologies are presented in a table on the next page. *The highest measured hydraulic conductivity must be used.*
porosity:	The porosity of the vadose zone must be assigned. Some typical ranges of porosity for different lithologies are presented in a table on the next page. It must be borne in mind that the porosity of fractured rocks may range between 1 % and 0.1 %. Unless more detailed information are available, a porosity of 20 % is usually assumed.
	Note that if more than one distinct horizon is present in the barrier zone, the required input parameters must be used to determine the individual travel time through each horizon. A total travel time is calculated by adding the travel times for each horizon.

BARRIER FACTOR

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STEP 1: Quantify input parameters

thickness of barrier zone: The top of an aquifer is defined by the static water table (or piezometric surface); the thickness of the barrier zone is hence measured in metres from the base of the waste pile to the water table. See conditions where the thickness may be measured otherwise (next page).

hydraulic conductivity: The hydraulic conductivity, recorded in m/day, must be provided. For the purpose of guidance, some typical ranges of values for different lithologies are presented in a table on the next page. *The highest measured hydraulic conductivity must be used.*

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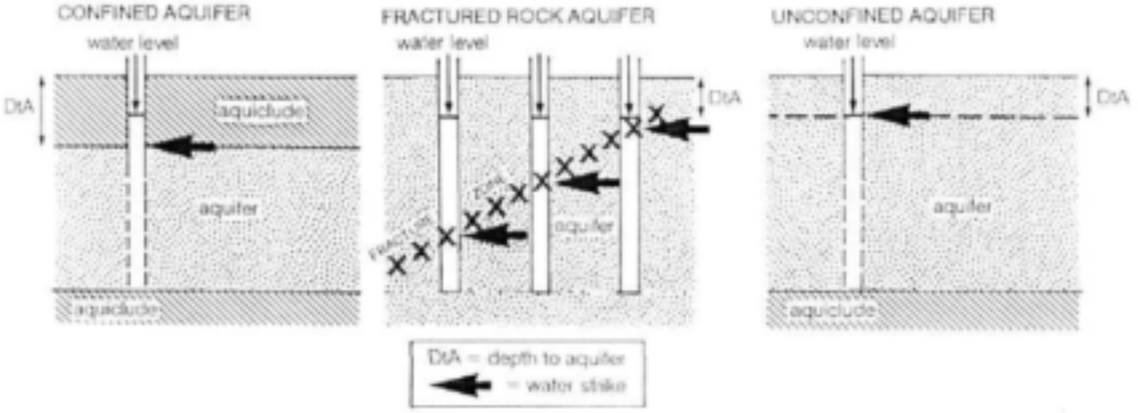
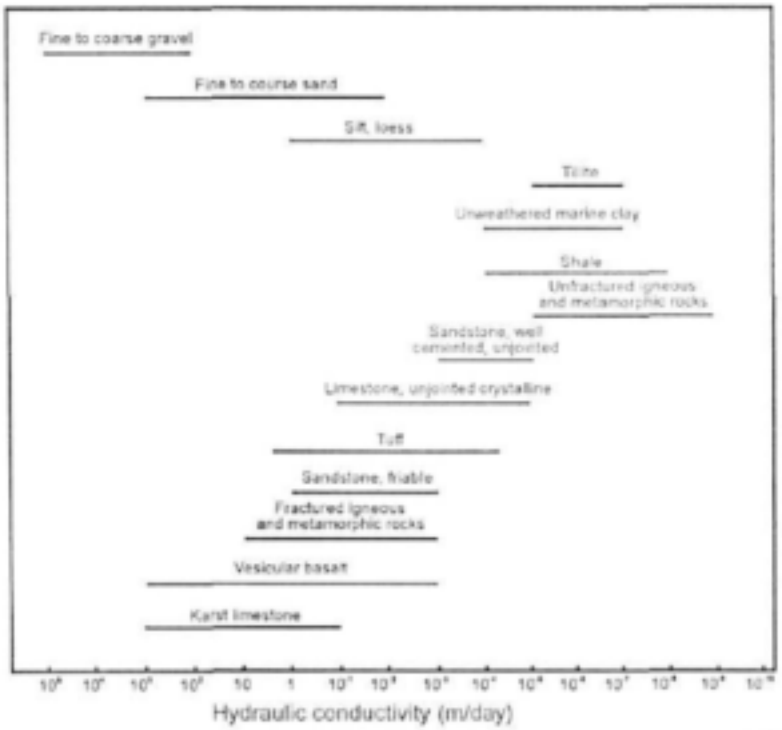
Note that if more than one distinct horizon is present in the barrier zone, the required input parameters must be used to determine the individual travel time through each horizon. A total travel time is calculated by adding the travel times for each horizon.

CONDITIONS UNDER WHICH THE TOP OF AN AQUIFER IS NOT DEFINED BY STATIC WATER OR PIEZOMETRIC LEVEL



TYPICAL K VALUES FOR DIFFERENT LITHOLGGIES



(After Driscoll, 1986)

TYPICAL RANGES OF POROSITY FOR DIFFERENT LITHOLOGIES

Unconsolidated Sediments	η (%)	Consolidated Rocks	η (%)
Clay	45–55	Sandstone	5–30
Silt	35–50	Limestone/dolomite (original & secondary porosity	1–20
Sand	25–40	Shale	0–10
Gravel	25–40	Fractured crystalline rock	0–10
Sand & gravel mixes	10–35	Vesicular basalt	10–50
Glacial till	10–25	Dense, solid rock	< 1

(Driscoll, 1986)

STEP 2: Calculate the travel time

Using the travel time formula based on Darcy's Law, calculate the individual travel time for each horizon and add to obtain a total travel time in days.

TRAVEL TIME FORMULA

$$Tt = \frac{d}{[K / (n/100)]}$$

Tt	travel time (days)
d	thickness of barrier zone (m)
K	hydraulic conductivity (m/day)
n	porosity (%)

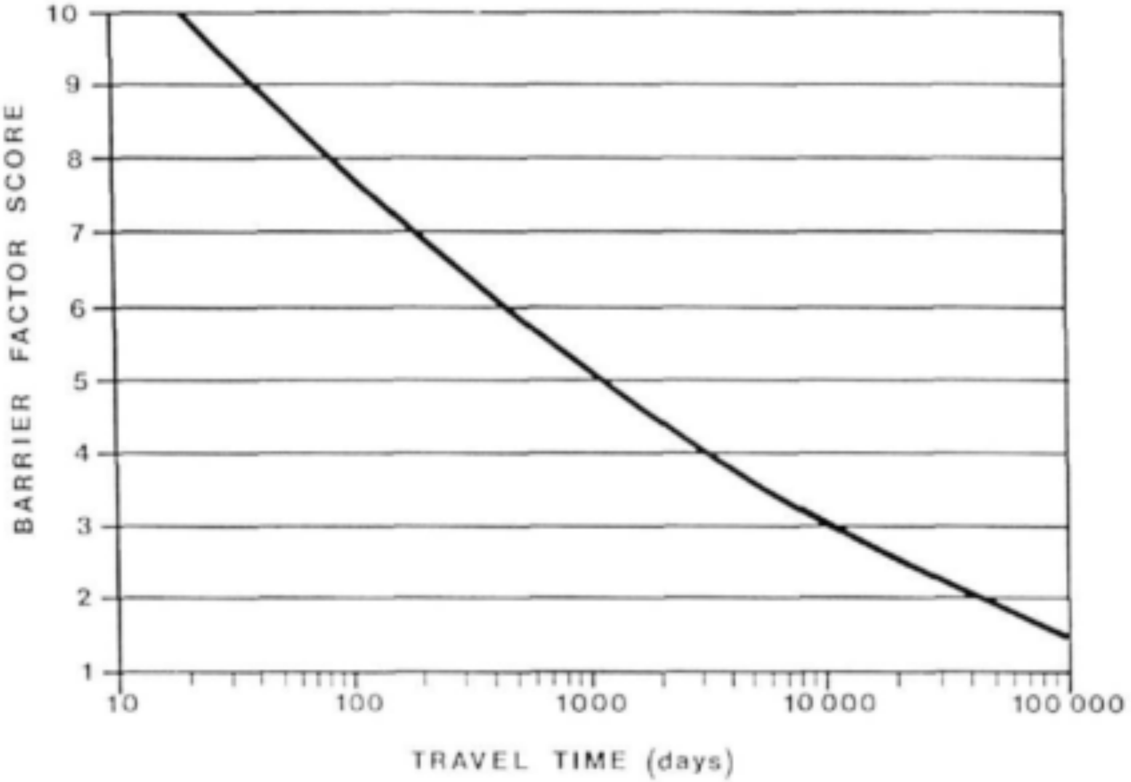
STEP 3: Determine Barrier Factor score

Using the Barrier Factor score nomogram, read off the Barrier Factor Score and record.

STEP 4: Determine data reliability rating

Using the Barrier Factor score data reliability rating table, assign a point for each component equivalent to the most appropriate level of data reliability, obtain an average for the Factor and record i.e. Level 1 data is assigned 1 point.

BARRIER FACTOR SCORE NOMOGRAM



DATA RELIABILITY RATING TABLE FOR THE BARRIER FACTOR

DATA RELIABILITY LEVEL	LEVEL 1	LEVEL 2	LEVEL 3
Thickness	Certain - based on site specific measured depth to water, drilling data and geohydrological borehole log.	Based on measured depth to water, extrapolated information from similar areas.	Uncertain - based on estimation from national or regional maps, guesstimation.
K	Certain - based on site specific *in situ* tests - aquifer tests, borehole percolation tests, double ring infiltrometer tests etc.	Based on laboratory analyses, surface infiltrometer tests, extrapolated information from similar lithologies, standard tables.	Uncertain - based on standard tables, guesstimation.
Porosity	Certain - based on field analyses and laboratory analyses.	Based on extrapolation from similar lithologies, standard tables.	Uncertain - based on standard tables, guesstimation.

RESOURCE FACTOR

The strategic value of a groundwater resource to a ***user***, or ***potential users*** must be based on fitness-for-use in terms of quantity and quality, forming the basis for the quantification of the Resource Factor. The resource is considered in terms of groundwater usage and groundwater potential. A user can range from a single farmer using an aquifer for domestic and agricultural purposes, to a town or city, which does or could use an aquifer as a sole water source or in conjunction with other water sources. All users are treated as having equal weight.

STEP 1: Quantify input parameters

groundwater usage: Answer the groundwater usage questions presented in the Resource questionnaire. Remember to answer the questions in terms of the user of the resource.

*For each **yes**, **do not know** or **maybe** answer, award 2 points. Assign points for the percentage of groundwater used, using the groundwater usage bar scale. Add the points and record (minimum of 1 and maximum of 10).*

groundwater potential: Answer the groundwater potential questions presented in the Resource questionnaire. Remember to answer the questions in terms of potential users of the resource.

*For each **yes**, **do not know** or **maybe** answer, award 2 points. Add the points and record (minimum of 0 and maximum of 10).*

STEP 2: Determine Resource Factor score

Add the groundwater usage and groundwater potential points (minimum of 1 and maximum of 20) and, using the Resource Factor bar scale, determine the Resource Factor score and record.

STEP 3: Determine data reliability rating

Using the Resource Factor score data reliability rating table, assign a point, for each set of questions, equivalent to the most appropriate level of data reliability, obtain an average and record i.e. Level 1 data is assigned 1 point.

RESOURCE QUESTIONNAIRE

Groundwater Usage	Groundwater Potential
a. Is groundwater used to meet present water requirements in the area immediately adjacent to the site? b. Is groundwater used within 2 km of the waste pile? c. Is the waste pile located up-gradient of the groundwater users? d. What percentage of water demand is met from groundwater resources?	a. Does the geology of the area portray any features typically associated with usable aquifers? b. Is the long-term safe yield of the aquifer sufficient to fully or partially meet local demand? c. Can the aquifer be used for drought relief purposes or be used locally for reticulation management? d. Is the groundwater quality such that it is fit for use by the potential user? e. Is the waste site the only contamination risk which could threaten aquifer potential?

Note that the 2 km standard set here is merely a guide. In the case of small sites, a smaller radius could be used while at large hazardous facilities, a radius of 5 km may be appropriate. The professional judgement of the geohydrologist performing the assessment must be used.

GROUNDWATER USAGE BAR SCALE

Percentage of water demand met from groundwater resources

0 25 50 75 100

1 2 3 4

Groundwater Usage component score

RESOURCE FACTOR BAR SCALE

Groundwater Usage and Groundwater Potential components combined score

0 5 10 15 20

0 1 2 3 4 5 6 7 8 9 10

Resource Factor score

DATA RELIABILITY RATING TABLE FOR RESOURCE FACTOR SCORE

DATA RELIABILITY LEVEL	LEVEL 1	LEVEL 2	LEVEL 3
Groundwater usage	Certain - based on full hydrocensus, records and reports.	Based on partial hydrocensus and discussions with local residents, driller or geohydrologist.	Uncertain - based on estimations.
Groundwater potential	Certain - based on full geohydrological investigation and detailed study.	Based on extrapolation of information from other areas, discussions with local geohydrologists familiar with the area etc.	Uncertain - based on estimations, interpretation of regional and national geological and geohydrological maps.

SPECIAL PROCEDURES

It is recognised that WASP cannot accommodate all geohydrological situations. A flexible approach is required for unique situations. Two mechanisms are used to facilitate flexibility in WASP:

> *Over-ride factors*: Over-ride factors are defined as those factors of such importance that they can be used singularly to determine the suitability of a site for waste disposal i.e. they over-ride the determined WASP Index. Extremely poor groundwater quality, an extremely slow travel time through the barrier zone and close proximity to water supply boreholes are three common examples of over-ride factors.

> *Detailed specific investigation*: At times, unique geohydrological conditions may be encountered which are not accommodated in WASP. These situations may require more detailed investigation. For example, two different geological units may be located next to one another. The one unit may be very suitable for waste disposal activities while the other has been developed for water supply purposes. A detailed investigation may be required to prove that the two are not in hydraulic continuity and that waste disposal activities may hence take place on the appropriate unit.

It is not possible to provide guidelines as to when a particular consideration becomes an over-ride, or when a unique situation exists which requires more detailed study. The professional judgement of the geohydrologist performing the assessment must be relied on to identify such factors and circumstances and motivate why a special procedure may be adopted. However, such a motivation may only be based on data with a Level 1 data reliability rating i.e. measured and quantified field data which are sufficient to conclusively prove the validity of the motivation.

WASP INDEX DETERMINATION

The suitability of a particular site for waste disposal is determined by obtaining and interpreting a WASP Index. The WASP Index is calculated using the WASP Index nomogram which requires the Three Factor scores as input parameters.

STEP 1: Calculate WASP Index

Using the WASP Index nomogram, determine the Index using the Resource Factor score, the Barrier Factor score and the Threat Factor score. Record the Index.

STEP 2: Calculate the data reliability rating

Using the data reliability rating obtained for each factor, obtain an average and record the final rating in brackets behind the Index.

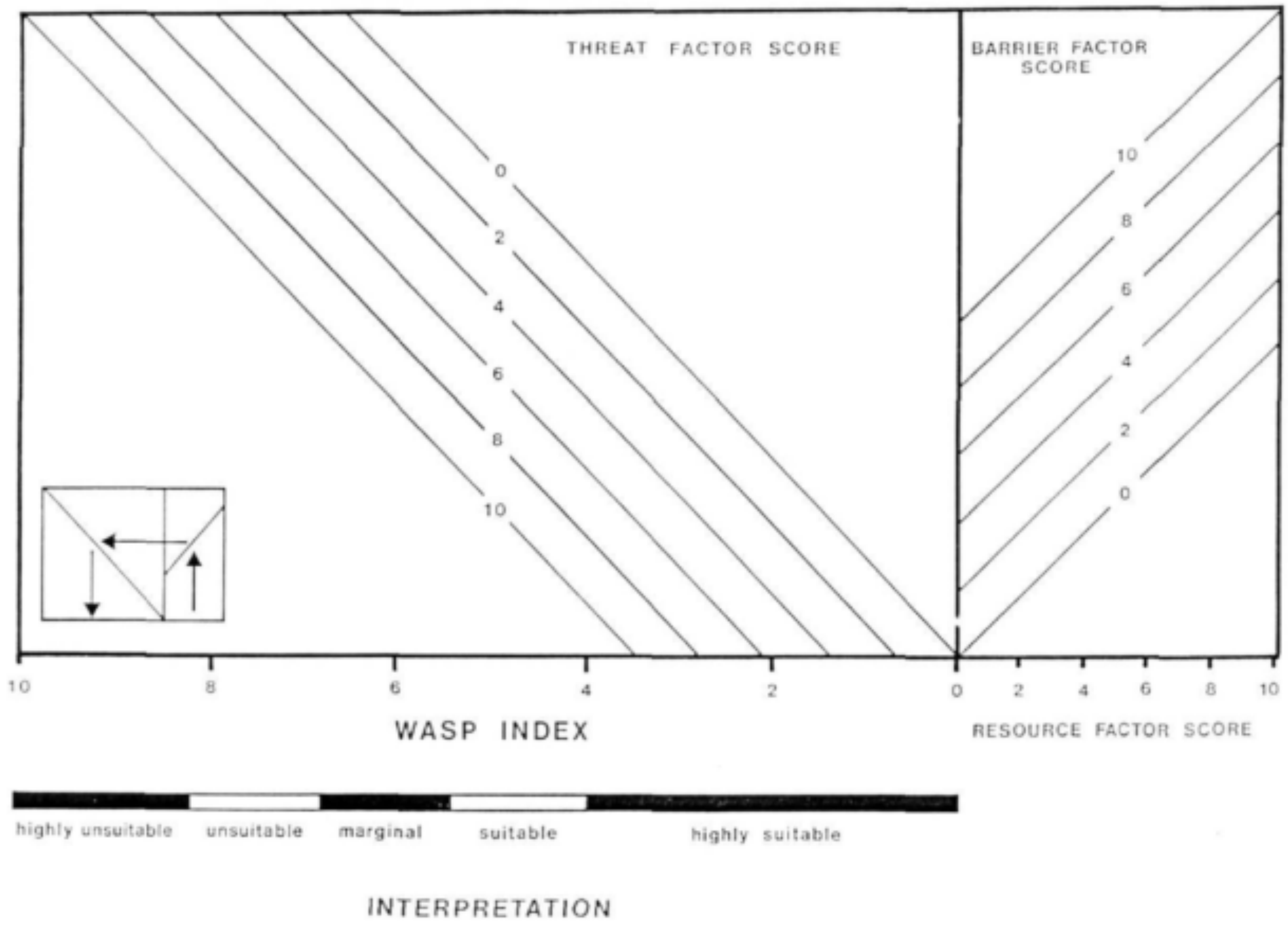
STEP 3: Assess site suitability

Compare the obtained Index to the generalised interpretation bar scale in the WASP Index nomogram. Note that this interpretation can only be considered as a guide to the interpretation.

A data reliability rating of less than 2 indicates that reasonably detailed and quantified data were used in the WASP assessment. A rating of greater than 2 demonstrates that much of the assessment was based on limited data and estimations. Such a rating would typically only be acceptable for planning applications, or ranking of possible sites in order to identify the most feasible site(s) which warrant further investigation.

An example of an assessment is presented in Appendix A, together with spare data sheets.

WASP INDEX NOMOGRAM



WASP SOFTWARE

Software has been developed to facilitate the easy and rapid application of the procedure. The software operating manual is presented as Appendix B of this field manual.

APPENDIX A

Example of a WASP Assessment

WASP Data Sheets

WASP DATA SHEET

NAME OF SITE: Reading Site OWNER: Municipality

TOWN: Barrassville LOCATION: 5km north of town

SPECIAL FEATURES: Runoff drains, leachate collection trenches

COMMENTS: Only waste facility in town

NAME OF ASSESSOR: John Smith DATE: 2 May 1994

THREAT FACTOR

designed final area (ha) 15 ha data reliability rating: 1

type of waste: domestic data reliability rating: 1

Threat Factor score: 5,4 **data reliability rating:** 1,0

BARRIER FACTOR

Layer	d (m)	K (m/day)	n (%)	Tt (days)
Layer 1	2,3	1,3	20	0,35
Layer 2	1,6	0,0006	30	800
Layer 3	1,7	0,03	20	11,3
Layer 4				
Layer 5				
			Total Tt	812

Barrier Factor score: 5,3 **data reliability rating:** 1,7

RESOURCE FACTOR

groundwater usage component score: 8 data reliability rating: 1

groundwater potential component score: 10 data reliability rating: 2

combined groundwater score: 18

Resource Factor score: 9,3 **data reliability rating:** 1,5

WASP INDEX

WASP Index: 6,6 ***data reliability rating:*** 1,4

Site suitability interpretation: marginal

WASP DATA SHEET

NAME OF SITE: OWNER:

TOWN: LOCATION:

SPECIAL FEATURES:

COMMENTS:

NAME OF ASSESSOR: DATE:

THREAT FACTOR

designed final area (ha) data reliability rating:

type of waste: data reliability rating:

Threat Factor score: **data reliability rating:**

BARRIER FACTOR

Layer	d (m)	K (m/day)	n (%)	Tt (days)
Layer 1 Layer 2 Layer 3 Layer 4 Layer 5			Total Tt	

Barrier Factor score: **data reliability rating:**

RESOURCE FACTOR

groundwater usage component score: data reliability rating:

groundwater potential component score: data reliability rating:

combined groundwater score:

Resource Factor score: data reliability rating:

WASP INDEX

WASP Index: *data reliability rating:*

Site suitability interpretation:

WASP DATA SHEET

NAME OF SITE: OWNER:

TOWN: LOCATION:

SPECIAL FEATURES:

COMMENTS:

NAME OF ASSESSOR: DATE:

THREAT FACTOR

designed final area (ha) data reliability rating:

type of waste: data reliability rating:

Threat Factor score: **data reliability rating:**

BARRIER FACTOR

Layer	d (m)	K (m/day)	n (%)	Tt (days)
Layer 1 Layer 2 Layer 3 Layer 4 Layer 5			Total Tt	

Barrier Factor score: **data reliability rating:**

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Layer 1 Layer 2 Layer 3 Layer 4 Layer 5			**Total Tt**	

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RESOURCE FACTOR

groundwater usage component score: data reliability rating:

groundwater potential component score: data reliability rating:

combined groundwater score:

Resource Factor score: **data reliability rating:**

WASP INDEX

WASP Index: *data reliability rating:*

Site suitability interpretation:

APPENDIX B

WASP Software Manual

WASP SOFTWARE MANUAL

The following minimum hardware is required to run the WASP software:

- a 386 computer
- a colour monitor
- VGA graphic capability
- at least DOS 3.1

1. INITIATION

The software can operate either from the A drive or can be copied from the floppy onto the C drive. The programme is initiated by entering the executable command <*WASP*>. This command will initiate the programme and produce the first screen with the WASP logo and title. Keying <*Enter*> will move on from the first screen to the remainder of the programme. The first three screens provide some background to WASP. To move from one screen to the next key <*Enter*>. Should you wish to bypass the background information screens, key <*F5*>.

2. PROGRAMME OPTIONS

After the background information has been presented, the user has the following options:

a. *Open new WASP profile*
b. *Retrieve WASP profile*
c. *Print WASP profile*

To select the option wanted, either move the highlight to the option required and press <*Enter*> or type the letter <*N*>, <*R*>, or <*P*> to initiate the next step.

2.1. Opening a New WASP Profile

Once you have keyed <*N*> or entered the highlight on *Open WASP profile*, you will be asked to input a profile name. This name must be limited to eight characters. Once you have entered the site name, press <*Enter*> to bring up a new screen where the following site information can be entered:

a. site name and site owner
b. town and location
c. date
d. evaluator
e. features and comments.

For each one of the above inputs, the <*F1*> key provides a help screen in which it is explained what information must be entered. For example, if one types <*F1*> under *site name*, you will be informed *Type in the name of the waste site*. To exit from the *F1* mode, merely press the <*Esc*> key.

At any stage in the WASP programme, one can move from one input box to the next using the <*Tab*> key. <*Tab*> moves you one box forward, while <*Shift Tab*> moves you one box backwards. Once you have entered all the required information, follow the instructions as at the base of the screen, i.e. *F5 to go to next stage*.

2.2. Retrieving a WASP Profile

To retrieve an existing WASP profile, enter <*R*> or move the highlight to *Retrieve WASP profile* and key <*Enter*>. A new screen will appear containing a list of all the existing files which have previously been saved. Only nine files can be shown on the screen at any one time, but by using the up and down arrows, one can scroll through the complete list.

To select the file which you would like to retrieve, use the up or down arrows to highlight the file required and key <*Enter*>. The *site information* screen will then appear. Should you wish to edit any of the data presented on this screen, move to the required box and make the necessary changes. When the necessary edits have been made, follow the command at the bottom of the screen, i.e. *F5 to go to the next stage*.

2.3. Printing a WASP Profile

To print a WASP profile, type <*P*> or move the highlight to *Print a WASP profile* and press <*Enter*>. A file list will appear and by using the up and down arrows, one can highlight the file one wishes to have a printout of. Once the file has been selected, key <*Enter*>. The WASP profile will then be sent to the printer and a hardcopy produced. Wait until the option screen is re-displayed.

NOTE: Before printing, make certain that your printer is in graphics mode. To do this, run the DOS programme <GRAPHICS> from the DOS prompt *before* starting the WASP programme.

3. ENTERING DATA

3.1. Stage 1: Threat Factor Score

Four data inputs are required to calculate the Threat Factor score:

a. the size of the site and the reliability of the data, and
b. the type of waste site and the reliability of the data.

The <*F1*> help key can, at any stage, be used to explain what data input is required. To exit from the help screen, key <*Esc*>.

3.1.1. Size of the Site

The size of the site is defined as the designed final site area, measured in hectares. Once this data have been entered, the programme automatically moves on to the data reliability box for that input. Selected the applicable highlighted score of 1, 2 or 3 and key <*Enter*>.

3.1.2. Waste Type

The programme automatically presents a list of the waste categories. Select the applicable type by moving the highlight to the appropriate type using the arrow keys and keying <*Enter*> or by entering the corresponding number from 1 to 5. Once the waste type has been entered, the programme automatically moves on to the data reliability box for that input. Selected the applicable highlighted score of 1, 2 or 3 and key <*Enter*>.

3.1.3. Threat Factor Score Calculation

Once the data have been entered, the software automatically uses the nomogram to calculate the Threat Factor score. The calculated Threat Factor score is shown graphically on the nomogram and is also recorded to the right of the nomogram together with the data reliability rating.

Alterations to the data entered can be made by moving between the different input boxes, using the <*Tab*> and <*Shift Tab*> keys, modifying the data and while still in the box being altered, keying <*F2*>. A re-calculation of the Threat Factor score is then immediately performed and the score updated. If <*F2*> is not keyed, the changes will not be recorded.

Once the Threat Factor score has been calculated, one can proceed to the next stage of the WASP evaluation by keying <*F5*>.

3.2 Stage 2: Barrier Factor Score

The data inputs required to calculate the Barrier Factor score are:

a. the thickness of each geohydrologically distinct unit or layer in the unsaturated zone;
b. the hydraulic conductivity of each unit;
c. the porosity of each unit; and

d. the data reliability for each of the data inputs.

A travel time is calculated for each layer and the total travel time is used to quantify the Barrier Factor score by means of a nomogram. A brief explanation of the basis of this component is given by entering *<F1>* when the Barrier Factor score screen is first displayed.

3.2.1. Thickness

The thickness of the barrier zone is usually defined as the depth to water, measured in m. The thickness of each individual unit or layer needs to be determined from soil profiles or borehole logs. Once the thickness has been entered, the highlight moves directly to the data reliability box for the preceding data input.

3.2.2. Hydraulic Conductivity

The hydraulic conductivity and the associated data reliability of each layer is required. Hydraulic conductivity is expressed as m/day. As a first approximation, a list of some typical values for different lithologies is presented by keying *<F1>*. Should the data from the help screen be used, a data reliability of 3 ***must*** be recorded.

The programme only accepts values ranging between 99 m/day and 0.00000001 m/day.

3.3.3. Porosity

The porosity and the associated data reliability of each layer are required. Porosity is expressed as a percentage. As a first approximation, a list of some typical values for different lithologies is presented by keying *<F1>*. Should the data from the help screen be used, a data reliability of 3 ***must*** be recorded. Attention must be paid to the value used when dealing with fractured environments, as the porosity can be an order of magnitude less than in the case of porous media.

3.3.4. Barrier Factor Score Calculation

As the data are being entered, the programme automatically calculates the travel time through each unit. The total travel time for the various layers is the summation of the travel time for each of the layers and is shown at the bottom of the table. Further, as the data for each horizon are entered, the calculated Barrier Factor score will immediately register on the nomogram. If the total travel time is calculated at less than 10 days, the Barrier Factor score is automatically considered to be 10.

NOTE: Those fields not required in the input table are left with default 0 values i.e. if only one layer is present, the remaining input boxes for layers 2 to 5 stay as default 0 values.

Once the information for all the layers have been entered, the final barrier score will be shown graphically on the nomogram. The Barrier Factor score is also recorded to the right of the nomogram together with the Factor score data reliability rating.

Alterations to the data entered can be made by moving between the different input boxes, using the *<Tab>* and *<Shift Tab>* keys, modifying the data and while still in the box being altered, keying <*F2*>.

Once the Barrier Factor score has been calculated, one can proceed to the next stage of the WASP evaluation by keying <*F5*>.

3.3. Stage 3: Resource Factor Score

The Resource Factor is assessed by answering a set of questions relating to:

a. groundwater usage, and
b. groundwater potential.

To proceed with the determination of the Resource Factor score, type either <*U*> or <*P*>.

3.3.1. Groundwater Usage

The input required in order to answer the questions asked are either <*No*>, <*Yes*>, <*Maybe*>, or <*Don't know*>. Either type the letters <*N*>, <*Y*>, <*M*> or <*D*> or highlight the appropriate answer using the arrow keys and key <*Enter*>. The answer to each question must also be accompanied by the level of data reliability for that answer.

As the data are entered, the score and data reliability for Groundwater Usage is immediately calculated by the programme and shown at the bottom of the screen. Be sure to answer all questions.

Once the data reliability is entered for the final question, the programme will immediately return to the main Resource Factor score screen and allow you to then select the Groundwater Potential questions by entering <*P*>.

3.3.2. Groundwater Potential

The procedure for entry of the answers to the questions for Groundwater Potential is the same as that for Groundwater Usage. Once the final question is answered, the programme returns to the main Resource Factor screen.

3.3.3. Resource Factor Score

Once the final question under Groundwater Potential has been answered and its data reliability rating has been entered, the Resource Factor score is automatically calculated by the programme. The score, together with the data reliability rating, is recorded at the bottom right hand side of the screen. Be sure that each individual question has been properly answered.

All the data required for the WASP Index calculation have now been entered. Proceed to the index calculation by keying <*F5*>.

4. CALCULATION OF WASP INDEX

As the WASP Index nomogram appears on the screen, the programme initiates the WASP

Index calculation. This is indicated by the movement of the red line on the monogram.

The final WASP Index is recorded both graphically and beneath the nomogram. The suitability of the site, based on geohydrological criteria, is also displayed, as is the WASP Index data reliability rating.

A help screen <*F1*> exists to explain special procedures or important over-ride factors which may need to be considered in the final assessment of the site suitability. Key <*Esc*> to exit from the help mode.

Key <*F5*> to return to the start of the data input (Stage 1) for that waste site, should you wish to make some alterations.

Key <*Enter*> to save data and exit.

5. SAVE PROFILE AND EXIT

Data from a site profile can be saved at anytime by keying <*Esc*>. The programme will then ask if one wants to save the current WASP profile. Having entered either <*Y*> and a profile name or <*N*>, the programme returns to the options screen. At this stage one can either print out the WASP profile, retrieve another existing WASP profile, open a new profile or exit from the programme by keying <*Esc*>.

To exit from the programme at anytime, key <*Esc*> until the DOS prompt appears on the screen.

IMPORTANT KEYS

<*F1*>	help	<*Esc*>	exit help screen
<*F2*>	calculate	<*Esc*>	save WASP profile
<*F5*>	go to next stage	<*Esc*>	exit programme
<*Enter*>	select highlight	<*Tab*>	move one box forward
		<*Shift Tab*>	move one box back