NRA - Thames 294

2

NATIONAL RIVERS AUTHORITY

THAMES REGION

ASSESSMENT OF PESTICIDES IN GROUNDWATER

March 1996

Prepared by:

Joe Gomme
Consultant Hydrogeologist

Project manager:

S.M.Hennings
NRA Thames Region

INDEX OF CONTENTS	Page

Summary

1. Introduction 1

1.1 Project objectives 1
1.2 Definitions of terms used 1
1.3 Report structure 2

2. Description of variables examined, with an explanation of methods used for defining scores 3

2.1 Variables related to hydrogeological context 3
2.2 Variables related to land use 6
2.3 Variables related to pesticide analytical data 7

3. Assessment of data 9

3.1 Source categorisation procedure 9
3.1.1 Procedure 9
3.1.2 Discussion 10

3.2 Relation of chemical data to hydrogeological and land use variables 12

3.2.1 Limitations of the data set 12
3.2.2 Analysis of correlations between variables and pesticide contamination indices 14
3.2.3 Assessment of hydrogeological variables 15
3.2.4 Assessment of land use variables 18
3.2.5 Analysis of data projected onto maps 25

3.3 Definition of risk factor 28

3.3.1 Procedure 28
3.3.2 Discussion 29

4. Prioritisation of sites for further investigation and/or pollution prevention activity 32

4.1 The priority indicator 32
4.2 Discussion 32
4.3 Prioritisation of areas 33

5. Discussion of proposed analytical suites 35

6. Conclusions 38

7. Recommendations 42

Appendix 1: Terms of Reference (Contractor's Brief)
Appendix 2: Table of database variables
Appendix 3: Maps of pesticide contamination for different aquifers
Appendix 4: Pesticides detected in groundwaters in NRA Thames Region
Appendix 5: References and documents consulted
Appendix 6: Table of priority indicators assigned

Joe Gomme
Hydrogeological Advisory Services
55, Copthorne Road,
Shrewsbury, SY 8nw
Tel/fax: 01743 272069

ACKNOWLEDGEMENTS

This report is the result of work by the author in continuous close consultation with members of staff at NRA Thames Region's Reading offices. The project was managed by Sue Hennings. Close cooperation has been provided by the Groundwater Quality (Scientific) and Hydrogeology sections.

Particular thanks are also extended to the water companies in Thames Region which provided data and supporting information.

SUMMARY

This document reports on the collation and assessment of existing data in order to facilitate cost-effective strategies for monitoring and controlling pesticide contamination of groundwater; and to decide on the appropriateness of public water supplies and other currently sampled sources for inclusion in Thames Region's groundwater quality monitoring 'network'. Hydrogeological, land use and pesticide analytical data were collated for these purposes.

A groundwater quality monitoring database was drawn up to store and access this information; it contains data for 625 sources and is linked to the existing Boreholes, Wells and Springs (BWS) database.

Provisional catchment areas have been drawn up for 122 sources using geological maps and simple modelling. These and other more rigorously defined modelled zones have been used to produce land use significance scores for a total of 442 sources, including both public supply and network sources.

Pesticide analytical data are still sparse for many sources, and currently available from water companies in widely differing formats; assessment is thus difficult and the conclusions reached should be regarded as provisional.

The overall picture of groundwater in Thames Region is of almost ubiquitous pesticide presence. More than three quarters of the sources assessed showed high pesticide concentrations and/or persistent contamination.

As expected, atrazine and simazine were the most common pesticides found, with other compounds from the uron and triazine groups also frequently found. A large number of other compounds were found more occasionally.

The gravel and Chalk aquifers appear to be particularly contaminated in some areas, and the Lower Greensand is the least affected aquifer. As was to be anticipated, confined sources generally showed lesser contamination. No further correlations between pesticide contamination and hydrogeological variables could be demonstrated, notwithstanding the consideration of vulnerability classes defined in the published groundwater vulnerability maps.

Sources with significant urban land use in their catchment areas showed notably higher pesticide levels. There were only inconclusive indications of a similar link with railways.

A priority indicator, based on site-specific data and on more general conclusions, has been applied to the sources in the database. This indicator shows which sources are most contaminated with pesticides and which are most at risk. It can thus be used in deciding where investigative and pollution-

preventative actions are most urgently required. Five areas have been identified as having local aquifer contamination problems and 39 sites are classed as requiring urgent attention.

Analytical suites proposed for the national monitoring programme have been reviewed and some questions raised concerning individual compounds. Some additional pesticides, including propazine and cyanazine, should be included.

Finally, a number of recommendations were made with regard to future work to carry this assessment forward. It is important to improve the compatibility of water quality information from NRA's archive and from different water companies, and to analyse this information for individual compounds of importance. It is also considered that further work is necessary to help identify factors which influence pesticide contamination of the different aquifers.

1. INTRODUCTION

This document presents a report of work carried out by the contractor at the request of NRA Thames Region during the period October 1995 to March 1996.

1.1 Project objectives

The project addressed two overall objectives. Firstly it aimed to assess NRA Thames Region's pesticide data in terms of hydrogeological conditions. Secondly it was to gather information on current Network[1] sites in relation to the selection criteria for sites in the proposed national groundwater quality monitoring programme[2]. The project would thereby improve the directing of Regional resources towards cost-effective monitoring and remediation/prevention strategy.

The following specific objectives were also set.

(i) To gather information on public supplies and groundwater quality monitoring sites, assessing each site in terms of vulnerability and suitability as a sample point within the Network.

(ii) To relate pesticide data to site circumstances, drawing conclusions on pesticide occurrence in terms of hydrogeological conditions and catchment land uses.

(iii) To prioritise sources or areas of aquifer for investigation and/or pollution prevention activity with reference to pesticides.

(iv) To recommend analytical suites of pesticides for Network sites, in line with national recommendations for groundwater monitoring.

The full terms of reference for the contract can be found in Appendix 1, which also includes information regarding the background to the project.

Extensive use was made of facilities at the NRA's offices in Reading and of the information and expertise available there. Data for individual sources regarding the hydrogeological situation, land use and pesticide analyses were collated. As part of this process a database was drawn up which permitted the subsequent interpretation of these data for the purposes set out above.

1.2 Definitions of terms used

---

[1] Groundwater Quality Monitoring Network (currently in set-up phase)

[2] Selection criteria were proposed by BGS (reference A).

The term "source" in this report has been reserved exclusively for a groundwater source (i.e. borehole, well or spring). In this context it differs from the term "site", because a single site may include several sources (e.g. a pumping station with several boreholes).

The term "catchment area" refers to zone III (source catchment) as defined in NRA's groundwater protection policy. It is "an area needed to support an abstraction from long-term annual groundwater recharge (effective rainfall)"[3].

A further definition required is that of the term "contamination". This report starts from the assumption that pesticide compounds are not naturally occurring in groundwaters. Therefore any positive detection can be defined as contamination - an alteration of the natural state. These terms do not therefore relate .to the permissible concentration value of 0.1 $\mu g/l$ for pesticides in drinking water.

1.3 Report structure

Section 2 of this report describes the variables used in the interpretation of data and explains the methods used for defining the values for each variable.

In order to facilitate a simple empirical analysis of the very complex data, an empirical categorisation process was derived in consultation with NRA. The latter process is described in Section 3.1, and Section 3.2 proceeds to discuss the interpretation of the pesticide data currently available to NRA.

Section 3.3 sets out the methodology used for the prioritisation of sites for investigative and pollution prevention activities, and Section 4 describes the prioritisation of sites that has been carried out. Section 5 discusses implications of the collected data for proposed analytical suites. Sections 6 and 7 present, respectively, the preliminary conclusions drawn from the data, and some recommendations for future work on the basis of what is reported here.

[3] Reference B.

2. DESCRIPTION OF VARIABLES EXAMINED. WITH AN EXPLANATION OF METHODS USED FOR DEFINING SCORES

The Groundwater Quality Monitoring (GQM) database set up under the contract provides information for each of the 625 catalogued sources[4] regarding their hydrogeological and land-use characteristics, the data so far collected on pesticide presence in their waters, and their suitability for use as monitoring sites. The sources included are all those currently on the Network as well as all public water supply sites within the Region. The database is produced in dBASE and has been linked to the existing Boreholes, Wells and Springs (BWS) database of NRA Thames Region in order to facilitate the cross-referencing of data.

Varying amounts and qualities of information are available for the different sources, and there are many which lack data for one or other of the variables examined. As a result only 506 of the 625 had catchment land uses defined, and only 298 could be given a pesticide contamination category. This restricted the number of sources which could be analysed for any given set of variables.

The variables used in analysing information are described in the remainder of Section 2. Where subsequent sections refer to these variables their names are in italics (e.g. "*no. of samples taken*"). A full listing of all the variables included can be found in Appendix 2.

2.1 Variables related to hydrogeological context

Aquifer

The aquifer tapped by the source is probably the most important hydrogeological variable. Generally, sources taking water from two distinct aquifer units were omitted from the asessment, unless the units could be shown to be in hydraulic continuity (for example the Chalk and Upper Greensand in some cases). The distinct units of some aquifers (e.g. the Marlstone Rock and the silts of the Lias) were not differentiated because of the limited borehole log data available.

[4] The figure of 625 includes a number of sites with multiple boreholes, wells or springs.

Vulnerability

Vulnerability, as defined for the purposes of the database, includes two sub-variables: depth to water (the rest water level measured at the source) and the vulnerability map categories present in the catchment area.

Water level: It is often difficult to give a single figure for water level because data are often sparse and/or outdated. Some levels were taken from records on the well index cards and others derived from water level and topographical maps. Often two or more conflicting levels were available, and in these cases an average figure was generally used.

Vulnerability map category: This variable (derived from the NRA's 1:100,000 scale groundwater vulnerability maps) takes into account any vulnerability map categories covering more than about 20% of the catchment area. All such categories were given equal weight in assigning scores.

Vulnerability scores for non-confined (i.e. outcrop) sources were assigned according to the Table 1 below. Theory suggests that sources with a higher score are more vulnerable.

Table 1: Vulnerability scores for non-confined sources

DEPTH TO WATER (m)	VULNERABILITY MAP CATEGORY[5]			
	H1, H2	H/I[6], H3	I1, I2	L
< 5, or karstic[7]	1.0	0.9	0.8	0.6
5 - 10	0.9	0.8	0.7	0.5
10 - 15	0.8	0.7	0.6	0.4
15 - 20	0.7	0.6	0.5	0.3
> 20	0.6	0.5	0.4	0.2

[5] See vulnerability maps for an explanation of the categories.

[6] "H/I" indicates any combination of High (H) with Intermediate (I) categories.

[7] Karstic aquifers, which are more liable to pollution by rapid fissure flow, are given high vulnerability scores.

In the case of confined sources, the above table was replaced by an index related to distance from nearest aquifer outcrop.

Table 2: Vulnerability scores for confined sources

DISTANCE TO OUTCROP (km)	SCORE (non-karst)	SCORE (karst)
< 1	0.8	0.9
1 - 2	0.6	0.8
2.1 - 5	0.4	0.7
> 5	0.2	0.5

Hydrogeological setting
This variable takes account of two further sub-variables related to vulnerability: percentage of low-permeability cover over the source catchment and the geomorphological situation of the source.

<u>Cover:</u> the percentage of cover was derived using the defined catchment area of the source overlaid on a geological map; drift deposits such as boulder clay and clay with flints, as well as older strata such as the London and Gault Clays, were taken into account.

<u>Setting:</u> topographical maps and water levels were used to decide whether the position of the source placed it in a recharge or discharge area, or somewhere intermediate between these.

Table 3 shows how scores were assigned. All confined sources score 0.3. Once again, theory suggests that a high score relates to a more vulnerable source.

Table 3: Assignation of scores for setting

GEOMORPHOLOGICAL SETTING	AMOUNT OF LOW-k COVER (%)		
	< 40	40 - 70	> 70
Discharge area/valley	0.5	0.4	0.3
Intermediate area/slope	0.7	0.6	0.4
Dry valley	0.8	0.7	0.4
Recharge area/interfluve	1.0	0.8	0.5

Casing depth
The casing depth for each borehole was recorded from the well index card. In many cases, however, it is unknown. The depth of brick linings in large diameter wells was not accepted as casing depth, because of doubts as to the integrity of this type

of structure and its consequent ability to exclude shallow drainage waters.

2.2 Variables related to land use

Land use is clearly of great importance in looking at pesticide contamination, since the pesticides applied in any given area will vary according to what is done with the land. However, before deciding on which land uses may be significant to a source, it is necessary to define a catchment area (see Section 1.2). The catchment areas used for the purposes of this contract were defined by various methods, which are recorded in the database and which included the following:

* the latest source protection zone models completed by NRA;
* source protection zone models produced by Geraghty & Miller under contract to NRA;
* some protection zone models produced by Aspinwall & Co. under contract and subsequently approved by NRA;
* the use of geological maps to identify likely aquifer outcrops which feed a source;
* simple computer modelling (using the WHPA package[8]).

The last two of these were carried out by the author of this report: they are less reliable than the first-mentioned method, and will need to be re-assessed by NRA in the future as resources permit.

Land use significance
Those parts of catchment areas which have impermeable cover were excluded for the purposes of land use definition because of their protective properties with respect to groundwater contamination. The significance of a number of land uses within a source's catchment area was then noted as "H" (highly significant), "M" (moderately significant) or "X" (insignificant). The land uses chosen were based on the those proposed for the national monitoring network strategy (Reference A). Significance indicators were determined as follows:

a) for land uses of large areal extent (i.e. **rural** and **urban**): any use covering >50% of the zone <u>or</u> >75% of the area close to the source (i.e. within 1km of it) was scored "H"; any land use covering only marginal areas, or <10% of the catchment was scored "X"; anything in between was scored "M";

---

[8] The WHPA option used was generally MWCAP with the hybrid zone for t = 1000 days. Occasionally, where there was a need to include more than one source, the GPTRAC option was used. The data sets and plot files produced have been copied to NRA on disk. The names of the copied files reflect the URN numbers of the source modelled: e.g. files 0765 and 0765pl are the data and plot files respectively for the site with URN PGWU.0765. Use of WHPA is recommended in Reference C.

b) for linear features (i.e. **A-roads, rivers** and **railways**) and for point features (i.e. **orchard** and **airfield**), two of these features within the catchment or one <1km from the source gave a score of "H"; one in the catchment >1km from the source scored "M", unless it was on the extreme margin of the catchment, in which case it scored "X".

Information to date is lacking regarding the presence or absence of **sheep, industry** and **landfill** in catchment areas: these data need to be added as they become available.

Land use homogeneity in catchment area
The homogeneity of land use within a source's defined catchment area should in theory give an indication of the range of pesticides which may be in use. A less homogeneous land use may therefore be thought to be likely to result in a wider range of compounds in a source's water. Land use homogeneity was scored in the following manner.

Any site which had only one highly significant land use, and none which were moderately significant, scored 1.0. Each additional highly significant land use reduced this score by 0.2, and each additional moderately significant land use reduced it by 0.1[9].

2.3 Variables related to pesticide analytical data

The following fields in the database were filled by assessing the analytical data available for pesticides for each source. The values currently assigned are derived from the data acquired by NRA until January 1996 and should be revised periodically as more data become available.

Pesticide detections
This figure gives the total number of positive results for pesticides (i.e. those above detection limit) recorded in the data analysed for each source. The precise period of the data varies from source to source according to its availability, but is generally between 1992 and 1995.

Pesticide samples
This is the number of samples taken for pesticide analysis which were considered for each source.

Pesticide found at highest concentration
This variable records a code for the pesticide found at the highest concentration in any sample from the source. These pesticides codes include: ATR (atrazine), SIM (simazine), ISO (isoproturon), CHL (chlorotoluron), DIU (diuron), LIN (linuron), MCA (MCPA), MCB (MCPB), PRN (propazine), CYA (cyanazine), 24D (2,4-D) and DIC (dicamba).

---

[9] Scores were subject to a minimum of 0.2. In the case of a lack of data, the site was scored an arbitrary 0.7 (a "typical" score). This includes all sources for which the defined catchment was entirely confined.

Highest concentration (C_{max})
This is the highest recorded concentration (in μg/l) of any pesticide in samples from the source. $C_{max} > 0.1$ indicates exceedance of the drinking water standard.

Persistence of individual pesticides
Seven separate fields (for atrazine, simazine, chlorotoluron, isoproturon, diuron, linuron and others) were used to denote whether particular pesticides were persistently detected in samples taken from the source. The criteria used to determine relative persistence were twofold:

(i) detection of the compound in at least two samples[10] and;
(ii) detection of the compound in more than 30% of the samples examined.

It will be observed that the perceived persistence depends on detection limits. A compound with lower detection limit may be detected more frequently and thus appear more persistent. Comparisons of persistence between pesticides must therefore be made with caution.

Treated water data tag
Because there is little or no reliable analytical information for the raw water of many sources, data for treated water were examined. Water companies are required to notify NRA of any exceedances of the maximum allowable concentration of 0.1 μg/l for individual pesticides. It is rarely possible to determine the provenance of treated waters, as water from several sources is generally treated at a single treatment plant before sampling takes place, but in a few cases useful data were obtained.

These sources were given a value "e" if they had at any time shown exceedance of the limit.

Quality notes
These notes refer to those pesticide data which were examined by the author for each source. Where some unusual point requires mention it is included (e.g. at some sources very limited suites have been used for pesticide analysis).

Other variables included in the database are summarised in Appendix 2. Details are given in the report accompanying the database.

---

[10] The criterion for number of detections is set low due to the scarcity of sites with more comprehensive data sets.

3. ASSESSMENT OF DATA

3.1 Source categorisation procedure

The categorisation procedure described in Section 3.1.1 allows a simplified assessment of the contamination of each source to be made. The data score and category derived are used in the subsequent Section as pesticide contamination indices to indicate the relative frequency and severity of pesticide contamination of a source.

A brief discussion of the categorisation procedure can be found in Section 3.1.2. The names of variables described in Section 2 appear here in italics.

3.1.1 Procedure

Step 1. Decide whether reliable raw water data are available[11]: if they are, go to step 2; if not, go to step 3.

Step 2. Examine available raw water analyses for pesticides and calculate a data score on the basis:

$$\text{data score} = \frac{\textit{total no. of pesticide detections}}{\textit{no. of samples taken} \times 10}$$ [see footnote[12]]

Note also the *highest concentration* (C_{max}) of any pesticide that has been recorded for the site.

It should be noted if any sources have been analysed for very limited suites of pesticides (i.e. analyses have excluded an important group such as triazine or uron pesticides).

Step 3. Examine the treated water data for exceedances of pesticide limits. Allocate a *treated data tag* to each source on the following basis:

if at least one exceedance has been recorded, the tag is "e";

---

[11] It is considered that a single sample cannot give reliable data: confirmation from at least one further sample would be necessary. As more substantial amounts of data become available, this criterion should be tightened to exclude, say, all sources with less than three or four samples. Data may also be considered unreliable in the event of possible analytical error or highly inconsistent results.

[12] The factor 10 makes the score an approximate indication of the proportion of samples having positive detections of the ten most commonly occurring pesticides (atrazine, simazine, isoproturon, linuron, diuron, chlorotoluron, MCPA, MCPB, mecoprop and 2,4-D); e.g. a score of 0.15 indicates that about 15% of analyses for these individual compounds are positive.

if no exceedance has been recorded for the source, the tag is "u".

Step 4. Place each source in one of the following categories.

CATEGORY A indicates problems with the source which require urgent attention. Normally a source is placed in this category:

* if it has a data score >= 0.3 and C_{max} >= 0.1;
* or if it has an indication of problems and a gap in the data available (e.g. a data score approaching 0.3, C_{max} of 0.30, tag "u", and no analysis of triazines).

CATEGORY B indicates moderate problems with the source that require less urgent consideration. Normally a source is placed in this category if it does not fall into category A and:

* it has a data score > 0.15;
* or if C_{max} > 0.06;
* or if it has a tag "e";
* or if it has an indication of moderate problems and a gap in the available data (e.g. a data score approaching 0.15, C_{max} of 0.06, and no analysis of urons).

CATEGORY C indicates no significant problem with the source, although pesticides have been detected. Normally a source is placed in this category if:

* it has a data score <= 0.15 but > 0, and
* C_{max} <= 0.06 but > DL[13], and
* it has a tag "u".

CATEGORY D indicates that no contamination has been detected at a source. A source will only be placed in this category when:

* it has a score of 0, and
* C_{max} = DL, and
* it has a tag "u".

CATEGORY U indicates that the status of the source is unknown due to lack of data. Normally a source is placed in this category if:

* it does not have reliable raw water data, and
* it has a tag "u".

3.1.2 Discussion

To recapitulate, the procedure results in two derived variables which are of great importance for the subsequent analysis. These derived variables are data score and category.

The significant scores and concentrations used in the procedure described above (i.e. the cut-offs between different categories) are to some extent arbitrary: the values of C_{max} are related to the 0.1 μg/l maximum, whilst those of the data score are currently set at equal differences from each other (0.00, 0.15, 0.30). Any of these values could be re-set if particular

[13] ">DL" indicates above detection limit.

operational or other considerations suggested it were appropriate.

The procedure follows simple semi-empirical concepts which are felt to be justified on the basis that pesticide data are still scarce for raw groundwaters, data are held in a variety of incompatible formats which makes analysis difficult, and the project is limited in the extent to which all factors can be considered and incorporated. It is clear that the consideration of all pesticides together as a single group will not produce accurate results when their occurrence depends greatly on the differing characteristics of individual compounds (see also Section 3.2.1). The data leading to categorisations therefore require individual review in all important cases. It is suggested that in the future, given a wider availability of data for pesticide presence in groundwater, important compounds be examined independently of one another.

Nevertheless the categorisation procedure clearly does reflect the presence of contamination by pesticides in a logical fashion, and probably gives a reasonably good measure of reality, in particular for the more persistent and more frequently detected compounds.

Note that this procedure could be used for public supplies and Network sites with respect to other groundwater contaminants, with the substitution of variables and significant concentrations which relate to appropriate water quality standards.

3.2 Relation of chemical data to hydrogeological and land use variables

The available data have been analysed in an attempt to gain a provisional perspective of the important factors in determining the vulnerability of sources and aquifer units to pesticide contamination.

The overall picture is of widespread, almost ubiquitous, contamination of aquifers. Only twelve sources out of the 298 categorised[14] have the D category (uncontaminated), and almost all of these have had no more than three analyses done. This is a very small data set on which to base any firm conclusion even as to the existence of absolutely uncontaminated sources. Fifty-nine sources fall into category A (highly and persistently contaminated), fifty-one into category C (intermittent low-level contamination), and the remaining 176 into category B. This breakdown is further illustrated in Table 5 in Section 3.2.3. (The remaining 327 sources catalogued have the U category.)

3.2.1 Limitations of the data set

As has been noted above, a combination of limited time and limited data sets for pesticide contamination and other variables prevented an in-depth consideration of how different factors affect different compounds. The most important restrictions on available data include the following.

(i) Many Network sites have had only one sample analysed for pesticides to date, so they have a U (unknown) categorisation for pesticide contamination. Pesticide data are also sparse for many sites owned by Thames Water Utilities Ltd (TWUL). A large number of other sites have only two or three sample results available.

(ii) A significant number of TWUL sites have not had well index numbers defined, so that their precise locations and construction details are not known.

(iii) Some public water supplies had no defined catchment zone as of February 1996, and therefore could not be given land use significance or cover scores. These zones are currently being modelled by the Hydrogeology group.

Hence the present analysis is based on a limited number of sources and also to a considerable extent on an overall picture of pesticides as a group. The author is aware that this approach is open to criticism on the grounds that different types of pesticide behave very differently in the environment. For this reason many of the results and conclusions presented here must be taken as provisional, and will need to be verified by future data collection and further analysis.

---

[14] Of the 625 sources, 327 have the category U and 298 have categories A to D.

Appendix 4 contains a brief assessment of the individual pesticides which have been detected in a small number of 3VWC sources.

For the same reason of limitations in the data sets, the reader will quickly appreciate that the analysis has been largely (though not exclusively) confined to Chalk sources, which form by far the largest group of sources possessing reasonably comprehensive information.

Furthermore it is important to stress that there exist some inconsistencies in the pesticide data. A clear example of this is provided by differences between data held on the NRA's Water Quality Archive (WQA) and that provided by Three Valleys Water Company (3VWC). Table 4 shows the number of instances of different compounds as *pesticide found at highest concentration* (see Section 2.3) for 40 3VWC sources. The data set is for all those 3VWC sources which are sampled by both NRA and the water company, each of which use a standard analytical suite. The comparison, although simple, is sufficient to highlight discrepancies. Some of these may simply be due to different sampling dates and the fact that in all cases there is a much more comprehensive data set from Three Valleys than is currently on WQA. Nevertheless it seems likely that there are also discrepancies caused by analytical result variation, particularly in the cases of linuron and, possibly, simazine.

Table 4: *Pesticides found at highest concentration* in 3VWC sources: a comparison between 3VWC and WQA data.

Pesticide	No. of ocurrences	
	WQA	3VWC
Atrazine	14	23
Simazine	0	7
Cyanazine	N/A[15]	1
Mecoprop	2	0
MCPA	1	0
Isoproturon	3	5
Linuron	16	0
Chlorotoluron	4	2
Diuron	6	2
Total	46	40[16]

The case of linuron is particularly striking, given that the data collected by NRA Thames Region have suggested that it may be the most commonly occurring of all compounds in groundwater (even exceeding atrazine in the number of positive detections). The 3VWC data suggest a very different picture.

Despite any such discrepancies, no data have been excluded from the analysis here described.

3.2.2 Analysis of correlations between variables and pesticide contamination indices

The data were analysed to assess the influence of different source characteristics (the variables described in Sections 2.1 and 2.2) on the level of pesticide contamination of the source. Contamination was represented in the assessment by two pesticide contamination indices. These two derived variables are:

(i) the data score (defined in Section 3.1.1, step 2);

(ii) the category assigned to the source (defined in Section 3.1.1, step 4).

---

[15] Cyanazine is not currently on NRA's G4 suite.

[16] The discrepancy in total number of sources between 3VWC and WQA results from several sources which have equally high results on WQA for two pesticides, both of which have been included in the table.

These pesticide contamination indices were examined in conjunction with a variety of hydrogeological and land-use variables which might be expected to influence them, in order to see whether a relationship could be established. Data were produced in tabular, graphical and map formats.

The variables examined which relate to hydrogeological context (and which are defined in Section 2.1) include:

* *aquifer;*
* *vulnerability*, and also its sub-variables, *water level* and *vulnerability map category;*
* *hydrogeological setting*, with its sub-variables, *cover* and *setting*.

The variables considered which relate to land use (which are defined in Section 2.2) were the *land use significance* values. In particular, the assessment concentrated on urban, rural and railway uses.

3.2.3 Assessment of hydrogeological variables

The data show interesting differences between the aquifers, as may be seen from Table 5.

Table 5: Distribution of sources between different categories for each aquifer

AQUIFER	Total no. for aquifer	number (and %) in category			
		A	B	C	D
Chalk	228	46 (20)	137 (60)	39 (17)	7 (3)
U.Greensand	2	1 (50)	0 (0)	1 (50)	0 (0)
L.Greensand	21	0 (0)	14 (67)	4 (19)	3 (14)
Gt.Oolite	18	4 (22)	10 (56)	4 (22)	0 (0)
Inf.Oolite	8	0 (0)	5 (63)	3 (38)	0 (0)
Gravels	12	9 (75)	3 (25)	0 (0)	0 (0)
Lias	4	0 (0)	2 (50)	0 (0)	2 (50)
Corallian	5	0 (0)	5 (80)	1 (20)	0 (0)
TOTALS	298	59 (20)	176 (59)	51 (17)	12 (4)

The table indicates that certain aquifers are generally more contaminated than others. The most regularly contaminated (as evidenced by the percentage of sources falling into categories A and B) are the gravels[17], followed by Chalk and Great Oolite,

[17] Eleven of the twelve gravel sites are in the middle Thames valley.

then Inferior Oolite and finally Lower Greensand. The Upper Greensand, Lias and Corallian have too little data at present to include in the above list. Note that only 21% of all sources have a C or D category, and only 4% have category D (no pesticides detected in any sample).

Figure 1 supports these results while drawing on data for individual compounds. It illustrates the persistence of various pesticides in different aquifers[18]. The results reflect the known widespread groundwater contamination with triazine and, to a lesser extent, uron pesticides. They show that 92% of gravel and 75% of Chalk sites persistently show atrazine present, and simazine is also extremely common (persistent in 61% of Chalk sources). Because of its high levels in gravel and Chalk, diuron too is a commonly persistent compound. Isoproturon is the most commonly persistent pesticide in the Great Oolite (28% of sources). This may reflect the predominance of agricultural land uses in the outcrop area. Chlorotoluron may be somewhat less frequent, and it is notable that propazine and linuron are also persistent in a number of Chalk sources. The other pesticides which have been persistently detected are mecoprop (in five sources), cyanazine (two), MCPB (one) and lindane (two)[19].

There is an indication of a qualitative difference between confined and unconfined sources. This is shown in Figure 2, which plots category against the amount of impermeable *cover* of the catchment zone[20]. Sources in the D category are almost exclusively confined or more than 40% covered, whilst sources with less than 40% cover predominate most heavily in category A. Thus drift and confining conditions are confirmed to help protect groundwater from pesticide contamination.

Nevertheless, some confined sources are contaminated: in cases such as Rectory Farm, Langford (PGWU.0595) and Manor Farm, Garford (PGWU.0566) this may be accounted for by the fact that they are in karstic aquifers with high water levels and are relatively close to outcrop (<1 km); but for other sources such as the Europa Trading Estate borehole 3 (PGWU.0723), a well-confined Chalk site in Erith, and the Slough Trading Estate's borehole 10 (PGWU.0691), a Lower Greensand Site approximately 35 km from outcrop, there seems no obvious explanation for their contamination.

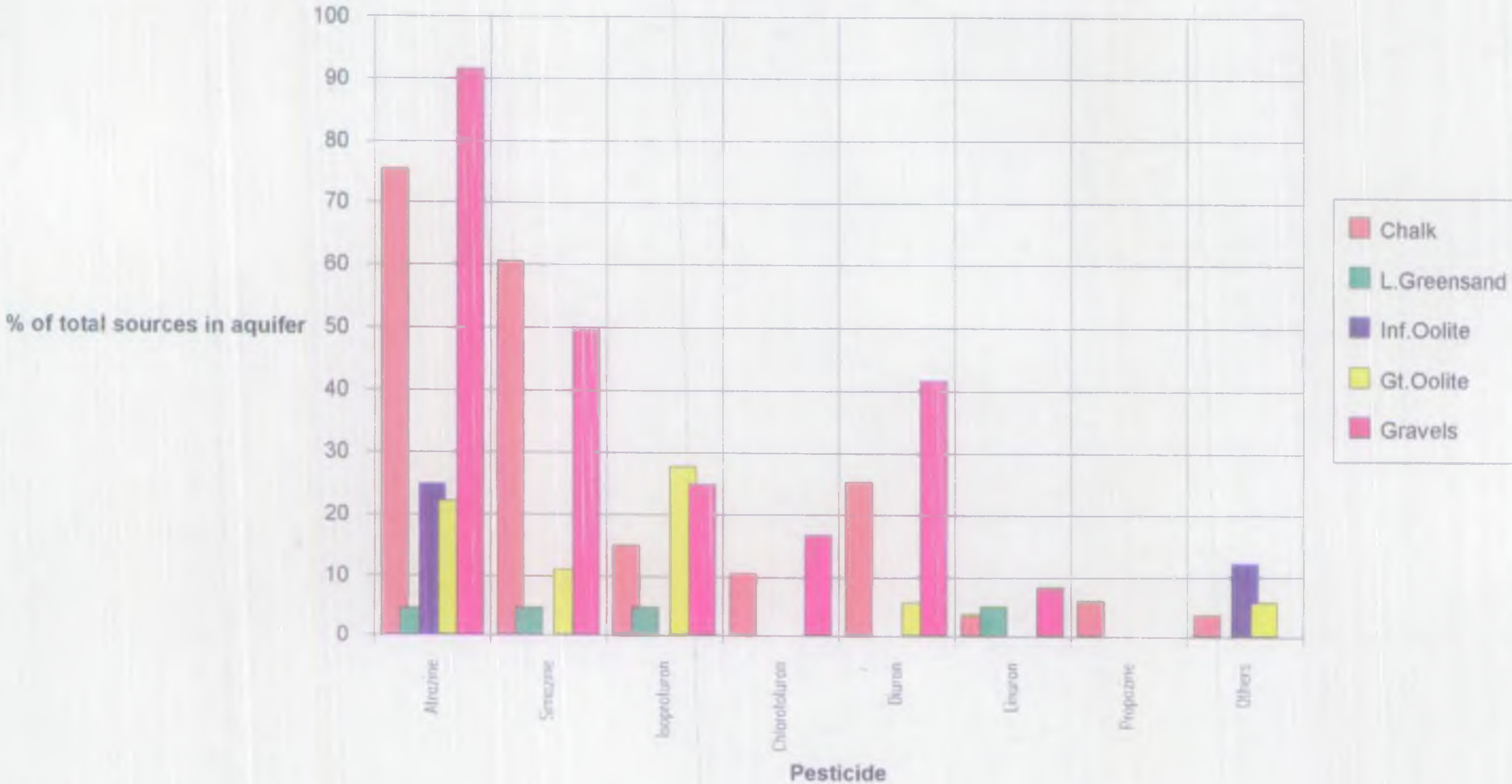
---

[18] See Section 2.3 for a definition of *persistence of individual compounds*. Due to scarcity of data, "persistent" can mean detection in as few as two samples, and means detection in at least 30% of samples examined.

[19] Thames Water have remarked on the persistence of dicamba in one source, but NRA does not yet have the data.

[20] Note: in this and all following bar charts, data are presented as percentages. The numbers printed on the bars themselves indicate the actual number of sources in each data subset.

Figure 1: % of sources in different aquifers with persistent presence of various pesticides



No correlation could be noted between pesticide contamination indices and the remaining hydrogeological variables mentioned above, although the scope of the project did not allow time for the possible use of multiple regression analysis to look for interrelations between different factors.

No simple correlation could be demonstrated for pesticide contamination indices with *vulnerability* or *hydrogeological setting* (the database variables defined in Section 2.1), nor with the sub-components of these variables (*water level*, *vulnerability map category* and *setting*). A typical result is presented in Figure 3, which shows a plot of category against *vulnerability*. In theory one might expect to see a link between high vulnerability and high category, but the figure does not give any clear indication of this. Although the plot suggests that most category D sources have low or medium vulnerability, the small number in the data set (seven sites in all) makes even this evidence inconclusive.

3.2.4 Assessment of land use variables

There are clearer indications of a link between some land use variables and pesticide contamination indices. These links, however, are indications rather than rules.

Figure 4 shows the relationship urban *land use significance*[21] scores and category for Chalk sites. It suggests a link between high urban significance and categories A and B, with a corresponding link between low urban significance and categories C and D. It seems evident that sources with highly significant urban land use in their catchment areas tend to be more contaminated.

Figures 5a and b have been included to demonstrate the danger that a superficial analysis may pass over any interrelationships between variables. Figure 5a illustrates the distribution of rural land use significances between categories, and seems to suggest a good correlation between lesser contamination and predominantly rural catchments. Remembering, however, that high urban significance generally equates with low rural significance, and vice versa, an examination of Figure 5b shows that this would be a false conclusion. The data set for Figure 5b includes only Chalk sources with high urban significance (i.e. urban "H" only), and is therefore a subset of the data shown in Figures 4 and 5a. The figure shows no clear relationship between category and rural land use. The trend shown in Figure 5a is in fact at least largely due to urban land use significance, and has little to do with the presence of rural areas.

Figures 6a and 6b are a similar pair of graphs for railway significance using data sets with the urban significance constant

[21] See Section 2.2: in general "H" means "highly significant", "M" means "moderately significant" and "X" means "insignificant".

Figure 2: All sources, relation between category and cover

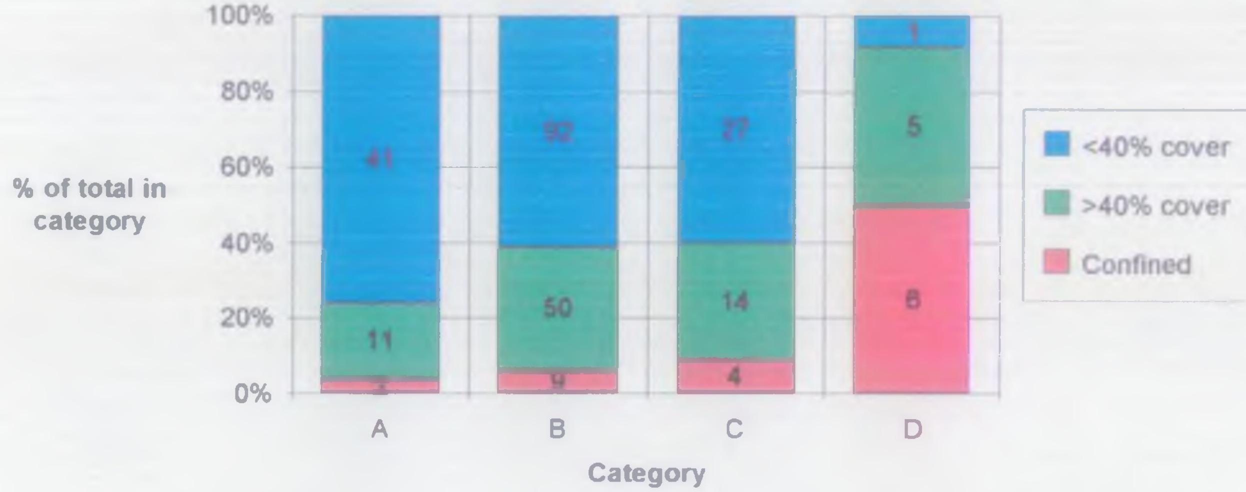


Figure 3: Chalk sites, relation between category and vulnerability score

Figure 4: Chalk sources: relation between urban land use significance and category

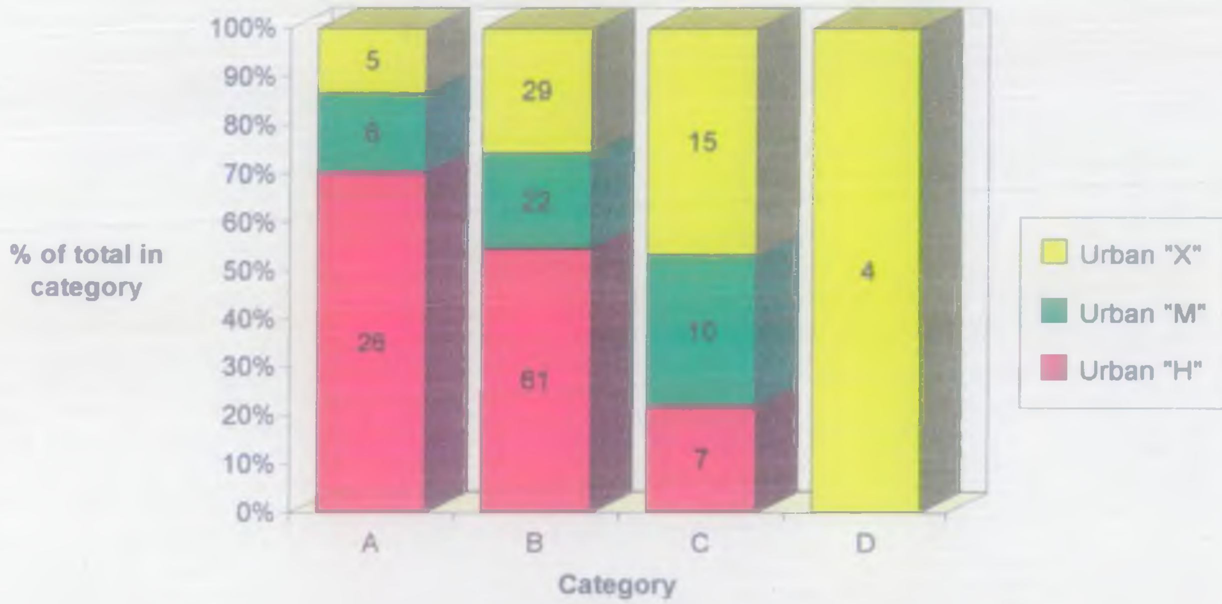


Fig 5a: All Chalk sources, relation of rural land use significance and category

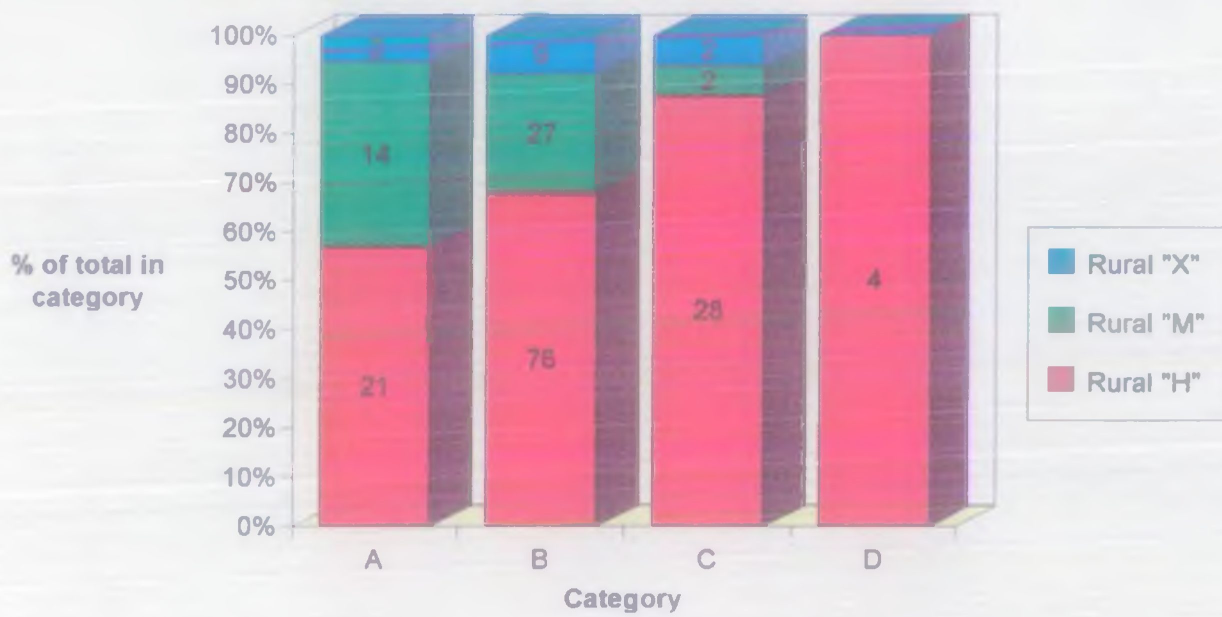


Figure 5b: Chalk sources with high urban significance, relation of rural land use and category

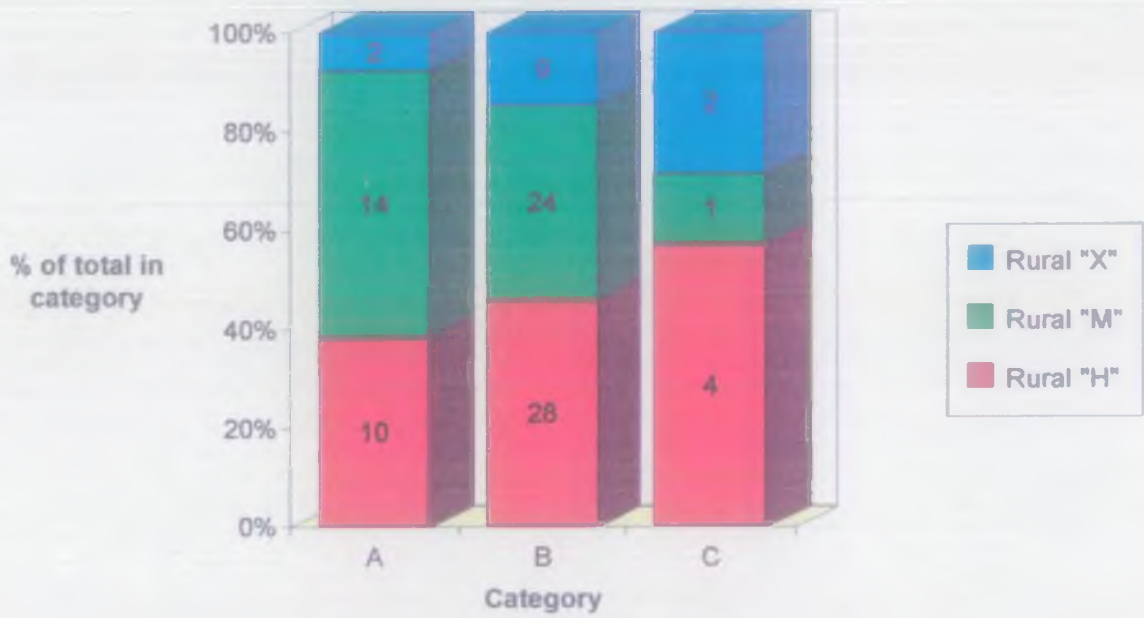


Figure 6a: Chalk sources with moderate urban significance, relation of railway significance to category

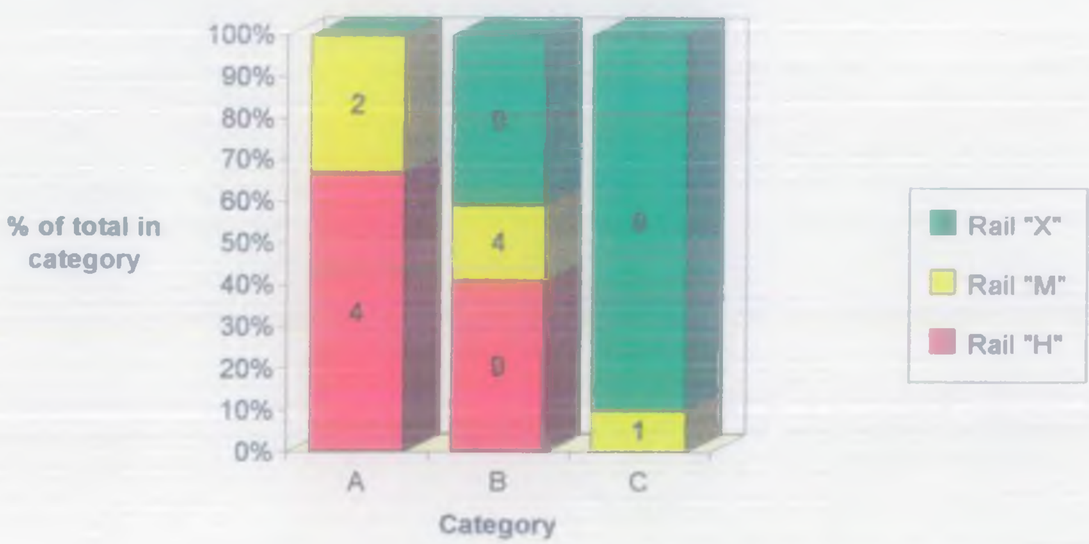


Figure 6b: Chalk sources with no urban significance, relation of railway significance and category

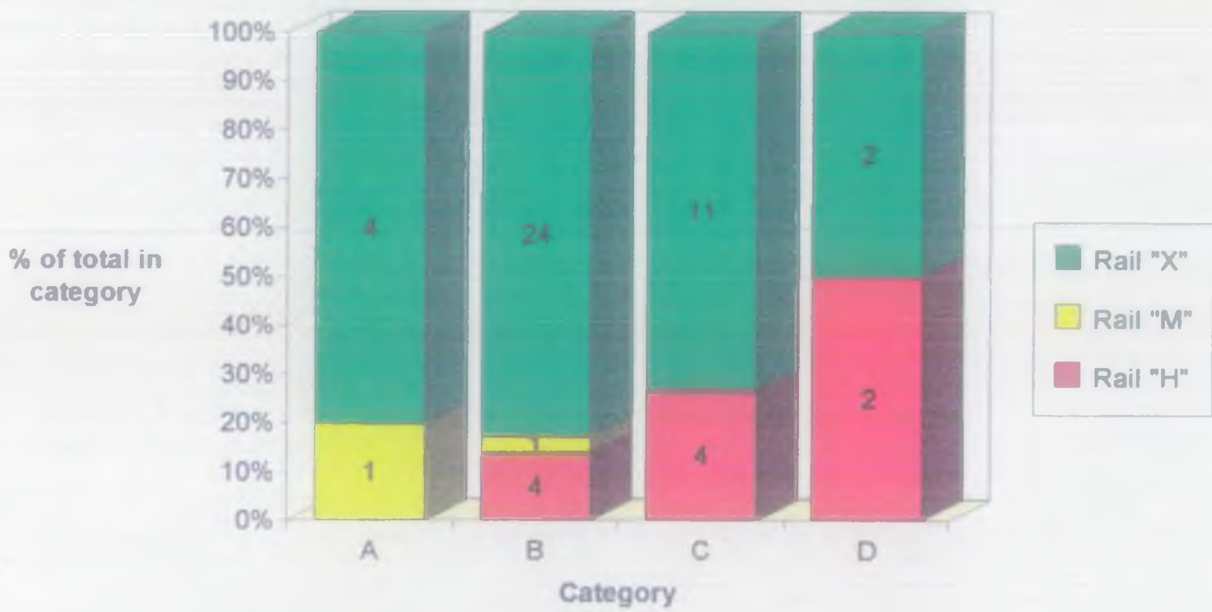
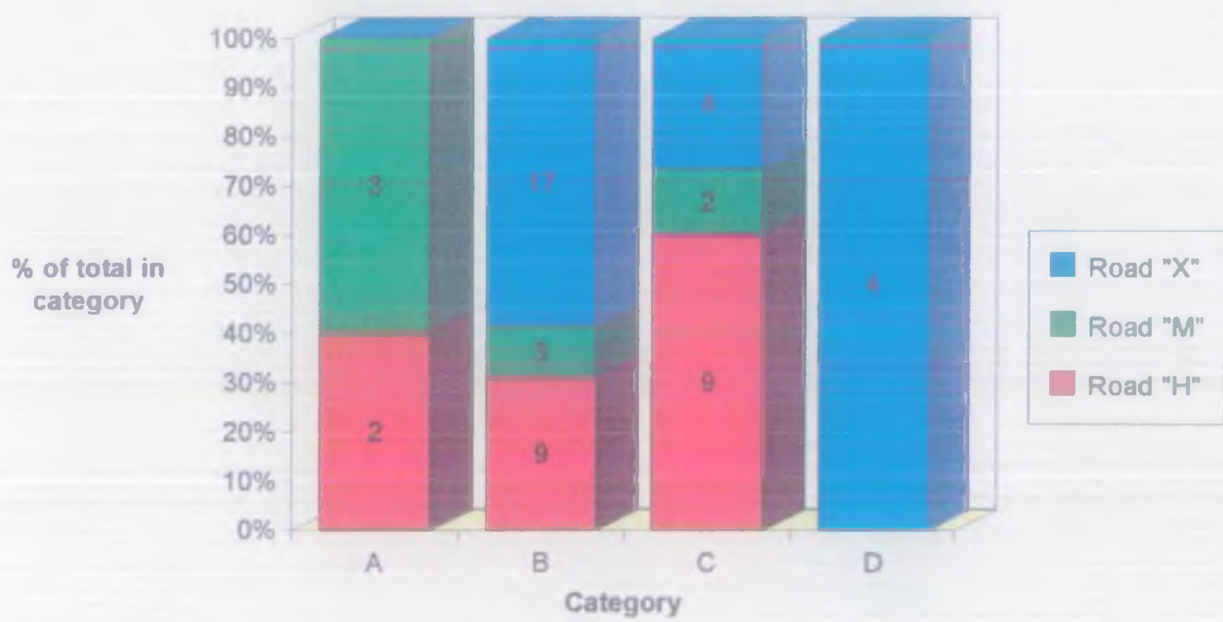


Figure 7: Chalk sources with no significant urban land use, relation between road significance and category



for each graph. The first figure seems to suggest that catchments with railways may correlate with higher contamination (categories A and B); the second, if anything, suggests the opposite - though it is based on rather small data sets. In this manner, therefore, no conclusive evidence that railways are a contaminating factor can be derived[22].

A plot of land use homogeneity score against category was drawn up to examine the possible effect of a variety of different land uses on the contamination indicators. It is not illustrated here since no correlation was apparent.

Figure 7 shows a similar comparison for road (A-road and motorway) significance in catchments with no significant urban land use. This also fails to show any clear links. An analysis of the data for river significance (not shown here) is equally unproductive.
It is known[23] that pesticides carried in river systems can sometimes be the cause of a deterioration of groundwater quality; however this appears not to be capable of generalisation. A more sophisticated approach is required including, perhaps, the examination of which river systems are particularly contaminated and which have established mechanisms of recharge to groundwater. The same can probably be said for roads and railways. An internal NRA report shows very high concentrations of pesticides in soakaways as a result of motorway spraying[24]. There is an assumption that a similar relationship between spraying and contamination exists for rail track, but evidence so far presented is weak[25]. Further work is clearly required to test the assumption more rigorously.

It is also possible that the approach of using contamination indices which include data from all pesticides is obscuring the trends in individual compounds which may be more closely related to particular land uses.

As has been indicated previously, an examination of the data for individual pesticides has largely been ruled out of the work reported here due to the difficulty of collating data from several incompatible archives in a short space of time. Nevertheless some preliminary indications have been arrived at, and show results that were broadly expected. Figure 8 shows the percentage of Chalk sources with persistent detections of four different pesticides as it varies with urban land use

---

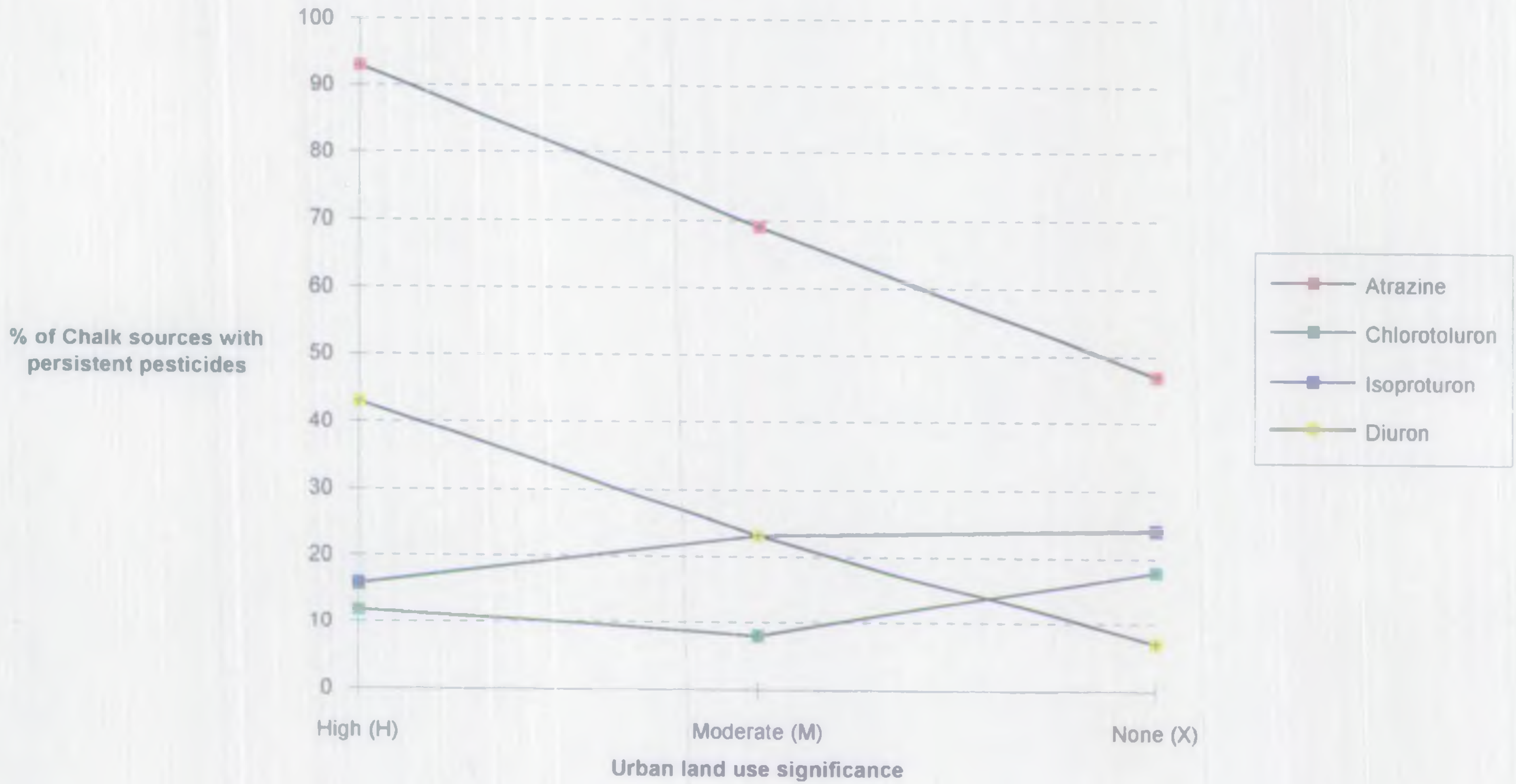
[22] It is emphasised once more that these findings are based on the use of contamination indicators which are derived from all detected pesticides: a different picture may emerge if individual compounds are examined.

[23] References D and E.

[24] Reference F.

[25] Reference G.

Figure 8: Chalk sources, relation of pesticide persistence to urban land use significance



significance. Atrazine and diuron are common in areas with highly significant urban land usage, and notably less so in mixed or predominantly rural areas. Diuron in particular is scarcely to be found where there is no significant urban land use. Chlorotoluron and isoproturon, on the other hand, show an increase from urban-dominated to rural-dominated areas, although these trends are less strongly marked.

3.2.5 Analysis of data projected onto maps

Using graphical information package (SpansMap), the sources were plotted onto base maps of the Region, its river system and its geology, in order to obtain a picture of the spatial distribution of different pesticide data scores and categories. Only the Chalk aquifer appears to present any patterns in this distribution, and the mapped data scores are displayed in Figure 9. (Maps for the other aquifers are included, for completeness' sake, in Appendix 4.) The data score (defined in Section 3.1.1, step 2) reflects the relative frequency of pesticide contamination of a source.

Figure 9 shows that there are noticeable areas with many low data score sources (green and yellow circles), and groups of high data score sources (red squares). Five high score groups can be discerned.

* Group 1 is in the River Lea valley, from Ware to Turnford.
* Group 2, nearby, lies in the Colne valley between Hatfield and Watford, and includes St.Albans.
* Group 3, rather less well defined, is in the higher reaches of the northern valleys in a band from Anstey to Knebworth.
* Group 4 lies between Maidenhead and Goring, along the Thames valley.
* Finally, there is a notable concentration in south London, in the Sutton area (group 5).

Less contaminated areas lie in a band north of the groups 1 and 2 mentioned above, and in the south-west of the Region, particularly in the upper Kennet valley.

Maps of the categories assigned to Chalk sources show similar patterns, but are somewhat less clear because of the lack of differentiation within the large B category.

The projection of the same points onto a geological base map (Figure 10) shows that the sources in groups 1, 2 and 5 are concentrated along the edges of the unconfined Chalk, both north and south of the London basin. Sources in groups 3 and 4 often lie in or near valleys with outcrop Middle Chalk.

FIG. 9 PESTICIDE OCCURRENCE IN THE CHALK AQUIFER

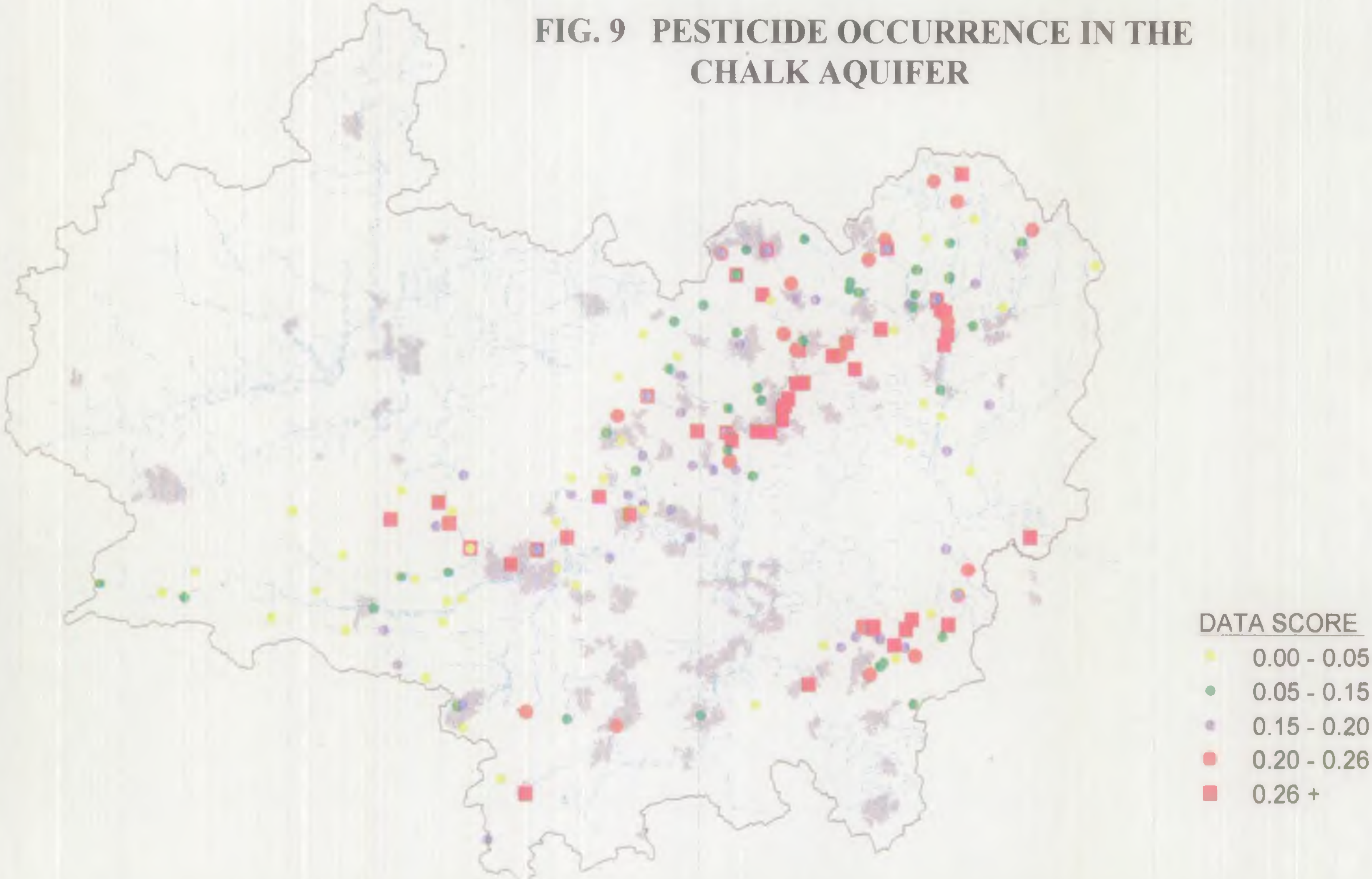
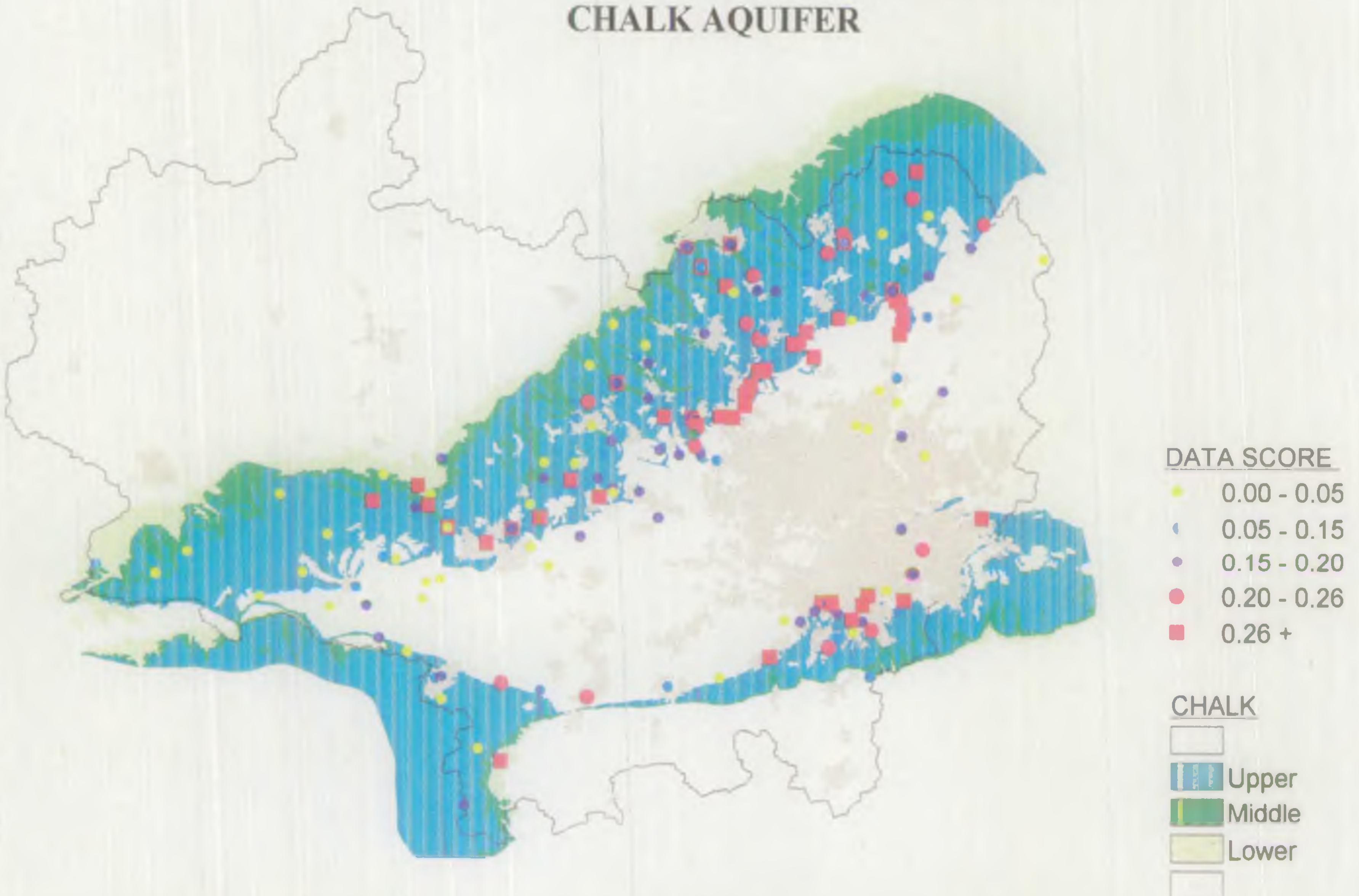


FIG. 10 PESTICIDE OCCURRENCE IN THE CHALK AQUIFER



A preliminary analysis of the data failed to show any clear correlation between the main Chalk unit (Upper, Middle or Lower) tapped and the pesticide contamination indices, or between pumping rate and contamination. A study of a rural Chalk catchment in Cambridgeshire[26] suggested that agricultural pesticides were washed off impermeable drift cover by heavy rainfall and resulted in concentrated slugs of pesticides entering rapid recharge conduits at the edge of the Chalk outcrop. A postulation of any similar mechanism in the London basin would, however, need to demonstrate that a significant quantity of drainage water could flow from clay-covered areas to the affected catchment areas noted above. It has been demonstrated that several of the sources in Group 1 are connected by rapid flow paths to swallow holes in the North and South Mymms areas and that this has resulted in elevated pesticide concentrations in those sources[27]. Other similar mechanisms may operate in other areas.

3.3 Definition of risk factor

The assessment of the data shows that at present we can conclude that three variables generally have an important influence on pesticide occurrence in groundwater. (There may be other such variables but if so the above assessment does not identify them.) The three important variables are:

* *aquifer*,
* *cover* (i.e. confined or unconfined status) and
* urban *land use significance* in the catchment area.

These variables are used to define a contamination risk factor which is based on general observation, and whose value may be "high", "intermediate", "low" or "unknown" (H, I, L or U)[28]. U indicates unknown risk, due to a paucity of pesticide data for a site's characteristics (e.g. some sites do not yet have a defined catchment zone or land use significances).

The procedure used for assigning the risk factor is described in the following Section.

3.3.1 Procedure

The risk factor for a site is defined by following the three steps outlined below.

Step 1: What is the aquifer?

---

[26] Reference D.

[27] Reference E.

[28] It should be pointed out that there are sites with a risk index L which nevertheless do show pesticide contamination.

If aquifer is gravel, score 0 and go to step 3;
if aquifer is Chalk, Great Oolite or Inferior Oolite, score 1 and go to step 2;
if aquifer is Lower Greensand, score 2 and go to step 2;
if aquifer is Upper Greensand, Lias or Corallian, risk factor = U[29].

(NB: scores assigned in step 1 reflect the perceived contamination of each aquifer; this follows the sequence, from highest contamination to lowest: gravel > Chalk = Great Oolite = Inferior Oolite > Lower Greensand. See Section 3.2.3 for details.)

Step 2: Is the catchment completely confined, >40% covered by impermeable deposits, or unconfined (<40% covered)?

If confined, risk factor = L;
if >40% covered, add 1 to score, go to step 3;
if unconfined, add nothing to score and go to step 3;

Step 3: What is the urban land use significance for the catchment (as defined in Section 2.2)?

If highly significant, add nothing to score;
if moderately significant or insignificant, add 1 to score.

If any data are unknown, a best estimate must be used, and should err on the side of caution. If estimates are not available, a risk factor U should be assigned.

The resulting score lies between 0 and 3 (unless it is U). A score of 0 or 1 indicates a high contamination risk factor (factor H); a score of 2 indicates an intermediate risk factor (factor I); a score of 3 indicates a low risk factor (factor L).

Example: Site Z is a Chalk site with a catchment 50% covered by boulder clay, with a highly significant urban land use. Thus in step 1, 1 point is added for the aquifer; in step 2, 1 point is added because the catchment is more than 40% covered; in step 3 nothing is added. The resulting score is 1 + 1 + 0 = 2, giving a risk factor I (intermediate).

3.3.2 Discussion

The question should now be raised: "How good is the risk factor as an indicator of vulnerability to pesticide contamination?" If it is applied to the existing data set, it may be measured against the contamination category in order to obtain an idea of

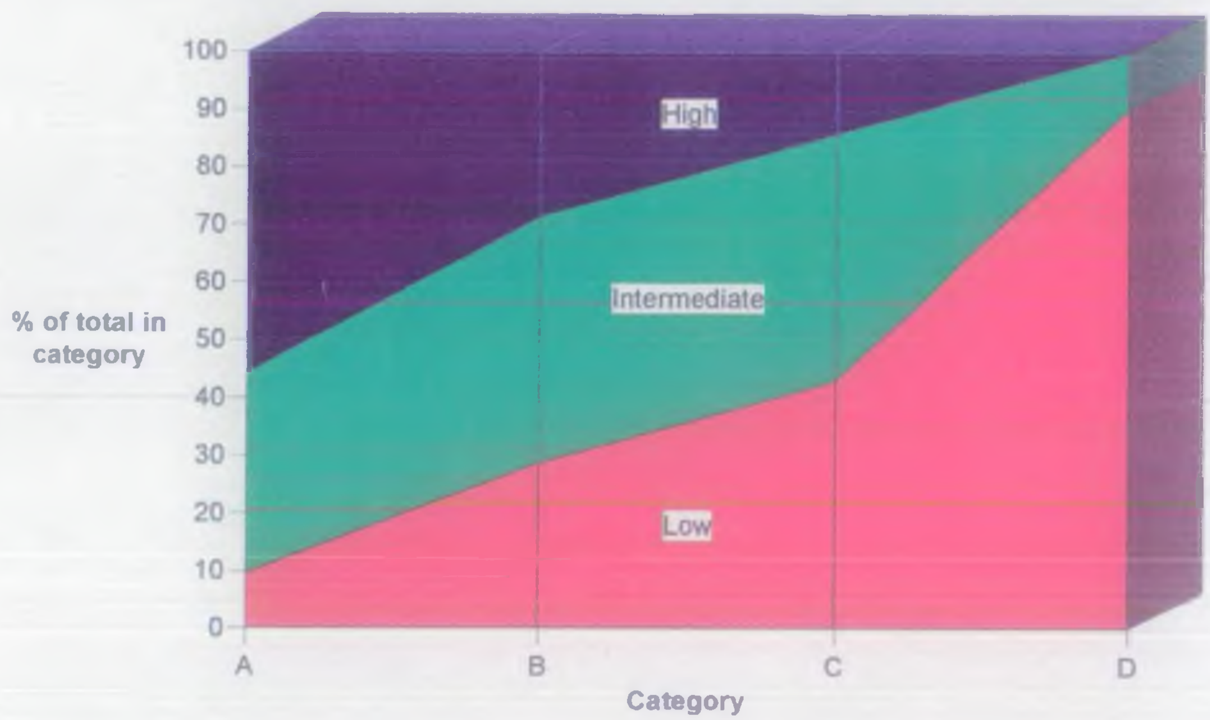
[29] As more data become available for these aquifers, their contamination relative to others will be reassessed and they can then be included in steps 2 and 3.

its usefulness. This has been done in Figure 11, which illustrates the percentages of the sources in each of categories A to D which correspond to the different risk factors. It suggests that the risk factor should be a reasonably good indicator of the probability of contamination, particularly for less contaminated sources. No high risk factor sources have a category D (no pesticides detected), and only a few have a category C, while 56% of sources which fall into category A have a high risk factor. There are, however, a number of low risk factor sites which fall into category A. The overall picture, then, is of an indicator which gives useful pointers without being foolproof.

The risk factor which has been introduced applies a scoring system to rank the risk of contamination at different sites. Because the scoring system is derived from qualitative information, the risk factor may be said to be semi-quantitative. Further work could be undertaken to help define more rigorously the probabilities of contamination that are involved and move towards a more quantitative approach, as described by Pollard et al.[30]

[30] Reference H.

Figure 11: All sources, proportion of categories accounted for by different risk factors



4. PRIORITISATION OF SITES FOR FURTHER INVESTIGATION AND/OR POLLUTION PREVENTION ACTIVITY

The prioritisation scheme presented here draws on the analysis previously described and aims to facilitate decisions on the relative importance of investigative and pollution prevention activities at different sites and in different areas, with respect to pesticides in groundwater.

4.1 The priority indicator

The scheme introduces a priority indicator which consists of two components: the first component is the category (A, B, C, D or U) which derives from the pesticide analytical data available for the site, and which has been defined in Section 3.1. The first component is hence site-related. (For a multi-source site (e.g. a pumping station with several pumping boreholes) a single category has been derived, taking into account the possibly different categories given to individual sources[31].)

The second component relates to the perceived risk of contamination, as deduced from analysis of the data available across the Region. This is the risk factor (H, I, L or U), which is defined in Section 3.3 and is based on general observation.

The priority indicator unites these two components and therefore consists of two letters: e.g. AH or DU.

Thus sites with a priority indicator AH have severe pesticide contamination problems and are in highly vulnerable positions; sites with a priority indicator CL have low-level pesticide occurrence with an indication that they are at little risk; and a priority indicator UU strongly suggests that further investigative work is required for a site.

The methodology for defining the first component of the priority indicator (the category of a source), is set out in Section 3.1.1. That for the second component (the risk factor) is described in Section 3.3.

4.2 Discussion

The sites included in the database have been classed as above with priority indicators. The indicator is a useful tool in delineating priorities for action, which it is suggested follow the outline below. Appendix 6 contains a table of all the sites included in the project, grouped by their priority indicator.

Once the priorities for sites in the Region have been determined they can be sub-divided by factors such as strategic importance, availability of water treatment, etc. A list of proposed actions for sites with different priority indicators follows.

---

[31] Generally a multi-source site is given the highest category belonging to any of its sources.

Indicator AH, AU or UH
These sites show the highest contamination and/or risk and should therefore be given the highest priority and treated as a matter of urgency. Sites which have had few analyses carried out to date (less than, say, four) should be allocated additional sampling visits as soon as practicable in order to confirm the indicated priority. Their data should be reviewed and conclusions should be drawn as to what pesticide pollution prevention measures may be viable for each case. For AU and UH sites, there is an urgent need for further investigative work in order to permit a proper definition of the priority indicator.

Indicator AI or BH
Once the sites previously listed have been considered, sites with these indicators should be assessed as the next priority for preventative action. They are also relatively highly contaminated.

Indicator UU
Very little is known about these sites and they should hence be prioritised for further investigative effort if they are to be included in the Regional groundwater quality monitoring Network.

Indicator AL, or CH
AL and CH sites show conflicting information: high pesticide contamination with low risk factor, or low contamination with high risk factor. They may prove to have been inadequately sampled or assessed, or they may prove to have interesting site-specific factors which protect them or make them vulnerable. These sites, should be placed on a secondary priority list for investigation.

Other indicators
Sites with other indicators do not show either high risk factors or high pesticide contamination levels, and can therefore be listed for continuing routine analysis, data collection and assessment. This should be directed towards assigning priority where there are still unknowns, to improve the quantity and quality of pesticide information available, and to monitor any change in the situation. Once higher priority sites have been satisfactorily investigated and/or pollution preventative measures put in place, these sites should also be considered.

It is emphasised, despite the remarks made above, that the results need to be reviewed on a site-by-site basis in all important cases. Individual pesticide results and the significance of different land uses within the catchment can then be considered in detail and an attempt made to deduce likely sources of contamination for that site, before deciding on necessary investigative or pollution prevention activity.

4.3 Prioritisation of areas

Priorities may be assigned for the consideration of the different areas of aquifer in Thames Region according to their relative contamination and other strategically important factors such as their importance in resource terms (locally and regionally) and any potential changes that may be foreseen due to altering land and pesticide use practices. These other factors are not further considered here.

The maps presented in Section 3.2.5 show that certain parts of the Chalk aquifer are more contaminated with pesticides than others. The five groups of sources defined are in fairly well-delineated geographical areas. Specific reasons for this are not speculated on in this report: nevertheless it would seem to be appropriate for actions in relation to those particular areas of the aquifer to be considered as a priority. Further work is needed on the definition of the areas and the mechanisms by which they are becoming particularly contaminated.

5. DISCUSSION OF PROPOSED ANALYTICAL SUITES

The framework agreement for NRA's National Groundwater Monitoring Programme[32] has proposed the use of an extensive analytical suite which includes eight land use-related analytical suites, each of which contains a list of pesticides. Thames Region is at present working with an independently-derived "G4" suite, since the national programme has not yet been approved.

The definition of the significance of different land uses in the GQM database set up under this project is a significant step towards the application of appropriate criteria for deciding relevant suites for each particular source. It is suggested that the land use significance scores be examined on a source by source basis, and that each source be assessed for the suites of pesticides relevant to all those land uses which are of either high or moderate significance in its defined catchment area.

Table 6 shows a list of compounds appearing either in the suites mentioned above or having been detected in groundwaters (by NRA or by water companies). It shows that some comment is needed with regard to individual compounds.

Some compounds which are not currently included in the proposed land use related suites have been shown to be present in groundwaters in the Region by data from NRA archives and water companies (notably Three Valleys Water Company). The most important of these are propazine, which has been found persistently in thirteen sources by 3VWC and by Sutton & District Water Company (SDWC), and cyanazine, found by the same two companies less persistently but in nearly as wide a range of sources. Propazine is used on intensive vegetable crops such as carrots and parsley, but has only been persistently found in largely urban areas. Cyanazine is in widespread use as a herbicide.

It is suggested that existing data sets be subjected to a detailed desk study of the occurrence of these two compounds: a significant amount of data is already available. If this proved inconclusive, a programme of analysis of a variety of different sources (with a variety of significant land uses) could be drawn up to determine their presence in groundwaters; this could be carried out in cooperation with Three Valleys and Sutton & District Water Companies, whose data (if it is not confirmed by results from other Regions) should be corroborated by split analysis of single samples.

There are six other compounds which have been detected on a number of occasions, but which also do not appear in any of the land use-related suites. These are:

* carbetamide,
* clopyralid,

---

[32] Reference I.

* MCPB*,
* methabenzthiazuron,
* prometryn and
* terbutryn*.

These compounds should therefore be analysed for, and should be added to the appropriate land use suites. (The asterisked pesticides <u>are</u> included in the G4 suite.)

Nine more compounds not included in the proposed suites have been detected very infrequently in groundwaters in Thames Region: these are carbendazim, dicamba, dichlorprop*, dieldrin*, fluroxipyr, flutriafol, cis-permethrin*, trans-permethrin* and lindane*. (Again, the asterisked pesticides <u>are</u> included in the G4 suite.) It is suggested that data for these compounds also be reviewed and consideration given to the desirability of including them in analytical suites, perhaps on an occasional basis. Further discussion of individual pesticide results is given in Appendix 4.

Table 6 also shows that there are eleven pesticides which appear in the land use suites and which have not been detected in the data examined in Thames Region. These pesticides are: asulam, chlorfenvinphos, chlorothalonil, diazinon, fenpropimorph, glyphosate, imazapyr, iprodione, mancozeb, propetamphos and trifluralin. Several of these compounds are not being analysed for at present (or at any rate not on a regular basis) and this may be the sole reason that they have not been detected. It is important that compounds such as glyphosate, which has to date been very little analysed in groundwaters and is being recommended as a "non-polluting" pesticide, should be analysed together with its degradation products in order to ensure that good advice is being given. A general review should, however, be undertaken to decide whether these compounds should remain in the suites.

It may be suggested that the appropriateness of dividing pesticide analysis into land use-related suites should be questioned. This can only be done on the basis of an examination of the frequency of occurrence of individual compounds in sources whose catchments include different land uses, something which has not been possible under the current project.

TABLE 6: COMPOUNDS DETECTED AND COMPOUNDS ANALYSED

Compound	Detected	LU Suite	G4 Suite	Compound	Detected	LU Suite	G4 Suite
2,4-D	O	y	y	Flutriafol	I	n	n
Aldrin	X	n	y	Glyphosate	X	y	n
Asulam	X	y	n	Imazapyr	X	y	n
Atrazine	F	y	y	Iprodione	X	y	n
Bentazone	I	y	n	Isoproturon	F	y	y
Carbendazim	I	n	n	Lindane	I	n	y
Carbetamide	O	n	n	Linuron	O	y	y
Carbophenothion	X	n	y	Mancozeb	X	y	n
Chlorfenvinphos	X	y	y	MCPA	I	y	y
Chlorothalonil	X	y	n	MCPB	O	n	y
Chlorotoluron	F	y	y	Mecoprop	O	y	y
Cis-permethrin	I	n	y	Methabenz'uron	O	n	n
Clopyralid	O	n	n	Prometryn	O	n	n
Cyanazine	F	n	n	Propazine	F	n	n
Diazinon	X	y	y	Propetamphos	X	y	n
Dicamba	I	n	n	Simazine	F	y	y
Dichlobenil	X	n	y	Tecnazene	X	n	y
Dichlorprop	I	n	y	Terbutryn	O	n	y
Dieldrin	I	n	y	Trans-permethrin	I	n	y
Diuron	F	y	y	Trietazine	O	y	n
Fenpropimorph	X	y	n	Trifluralin	X	y	n
Fluroxipyr	I	n	n				

NOTES:

1. In "detected" column, "F" indicates frequent detection, "O" occasional, "I" infrequent and "X" not detected.
2. The second column indicates (yes/no) whether the compound is included in the proposed extended land use suites.
3. The third column indicates (yes/no) whether the compound is included in the existing G4 suite.

6. CONCLUSIONS

1. An extensive database has been set up which includes information regarding source characteristics, hydrogeological situation, pesticide contamination and suitability as a monitoring point for a total of 625 sources. The database will provide a useful resource for the collation and assessment of further data in the future, including those for determinands other than pesticides.

2. The variables used in the assessment are summarised in Section 2 of this report. A full description of all variables in the database and its relationship with the pre-existing BWS database are reported separately (Reference K).

3. A pesticide data score (reflecting contamination) and a categorisation procedure have been introduced: these give a provisional idea of the undifferentiated pesticide contamination of a source. The data scores and categories derived are not precise, because they rely on pesticides as a group and take no account of the very different behaviours and detection limits of individual compounds. Nevertheless it is considered that they provide a reasonable indication of pesticide occurrence in groundwater with relatively little effort. 48% of the catalogued sources have sufficient data to have been categorised.

4. Because there are relatively few data for many sources at present, all sources with two or more analyses have been scored and categorised. It is likely that some of the data for sources with very few analyses are unrepresentative of average conditions. This is particularly true for pesticide data as concentrations of some compounds are liable to enormous fluctuations over short periods: varying weather conditions may often make considerable differences in aquifers subject to rapid flow mechanisms. As more data become available these problems can gradually be minimised.

5. There are noticeable differences between data sets from the two major sources of pesticide analyses (NRA's Water Quality Archive and data provided by Three Valleys Water Company).

6. The overall picture provided by the data is one of almost ubiquitous contamination. Only four per cent of categorised sources have shown no contamination to date, and only 17% fall into the C category indicating intermittent, low-level pesticide occurrence; meanwhile 20% are highly and persistently contaminated.

7. There appear to be some notable differences between different aquifers. In broad terms, the Middle Thames Valley Gravel aquifer may be said to be most contaminated, followed by Chalk and Great Oolite, then Inferior Oolite and finally Lower Greensand as the least contaminated aquifer. (The Corallian, Lias and Upper Greensand have too few data at present to determine their position.) These findings can be supposed to relate to the hydrogeological characteristics of the aquifers.

Those at the head of the list are high transmissivity aquifers subject to rapid recharge, and many of the gravel sources are probably heavily influenced by river water quality. The Lower Greensand is the aquifer which comes closest to classical Darcian conditions, where rapid flow is less likely and the gradual removal of contaminants before they reach deeply into the strata is more probable. A further interesting point, in the light of paragraph 14, is that the Oolites outcrop almost exclusively in rural areas, whereas Chalk and gravel sources are often in urban areas.

8. Data for individual pesticides also show significant differences between aquifers. As was expected, atrazine, simazine, diuron, isoproturon and chlorotoluron (in that order) were commonly detected. Perhaps less expected were the results for propazine (persistent in a number of sources) and for linuron (less commonly found than propazine).

9. It is also clear that, as should be expected, confined sources are less contaminated than unconfined; and there is rather limited evidence to suggest that sources with at least 40% of impermeable cover in their catchments are also protected to an extent. There are nevertheless some confined sources which are significantly contaminated, as well as many unconfined sources which are not.

10. No general correlation could be found between pesticide contamination indices (data score and category) and other hydrogeological variables, including *water level*, *vulnerability map category* and *setting*. It was initially expected that the risk to groundwater from pesticides would be related to these variables, but no substantiation of this is provided by the data. Many "A" and "B" categories (sources with significant pesticide contamination) are found with low *vulnerability* and *setting* scores, and "C" and "D" (sources with lesser problems or no problem) categories often have high scores for these variables. It is therefore provisionally concluded that these variables are not good indicators of pesticide occurrence in groundwater.

11. Paragraph 10 mentions three of the four variables proposed by BGS for use in the ranking procedure for determining the suitability of a source for the national Monitoring Network. That there seems to be little evidence to link them to contamination is therefore a cause for concern, and suggests that the procedure needs to be reviewed (although it is recognised that potential for contamination is not the only criterion for inclusion of sites in the Network). The suggestion that vulnerability map classes bear no relation to pesticide occurrence in groundwater is particularly interesting.

12. Those sources with significant urban land use in their catchment areas tend to be more contaminated; those in predominantly rural areas tend to be correspondingly of better quality. This may be due to the different surface drainage systems which operate in urban and rural areas: in urban areas deep-laid drainage systems and soakaways often by-pass the soil

profile to give direct access to the aquifer, thus preventing any attenuating action of the soil during drainage.

13. There is some suggestion that the presence of railways in catchment areas may adversely affect groundwater quality, but this is not conclusive. The presence of major roads and rivers do not seem to be important factors in the overall picture.

14. The pesticides examined in Thames Region can be divided into three groups:

i) pesticides persistently detected: atrazine, simazine, diuron, isoproturon, chlorotoluron, propazine and linuron (although analytical methods for the latter are under examination);

ii) pesticides detected in a small number of sources, or detected with some regularity at several sources: mecoprop, MCPB, cyanazine, terbutryn, trietazine, prometryn and methabenzthiazuron; and

iii) pesticides detected only infrequently: carbetamide, clopyralid, MCPA, lindane, bentazone, dicamba, permethrins, dichlorprop, dieldrin, carbendazim, flutriafol and fluroxypyr.

15. Maps showing the geographical distribution of pesticide contamination indices illustrate some groupings of highly contaminated sources in the Chalk aquifer, particularly in areas close to the edge of the London Clay. The main area of lesser contamination is in the upper Kennet valley region.

16. An important objective of the project was to help with the prioritisation of sources for action to investigate and control pesticide contamination. A prioritisation scheme, based on the assessment carried out, has been introduced for this purpose. The scheme is based on a semi-quantitative priority indicator which has two components: the first, site-specific, reflects the actual occurrence of pesticides recorded at the site; the second is a risk factor based on general observation, and takes into account those characteristics of a source catchment which were found to correlate with contamination. The risk factor is a potentially useful indicator for sources which lack analytical data. It will need to be re-examined as further pesticide data become available.

17. Sources have been prioritised in accordance with the environmental factors described. Seventeen sites fall within the AH priority class, 4 within the AU class and 18 within the UH class; these are regarded as the highest priority sites. The specific concerns of water companies (eg. strategic importance) will be considered in the next stage of work.

18. The prioritisation of aquifers or areas of aquifer for pollution prevention activity is according to their relative contamination. Some distinct areas of the Chalk aquifer have

been highlighted as particularly contaminated, and may warrant early attention.

19. The proposed analytical suites for the National Monitoring Network have been briefly reviewed in the light of analytical data from Thames Region. Two compounds, cyanazine and propazine, which are not included in the former have been frequently detected in groundwaters, whilst a number more are detected occasionally. Several pesticides which are listed in the proposed suites have not been detected, though in several cases this may be for lack of analysis for those compounds.

7. RECOMMENDATIONS

1. The current sparsity of pesticide data for many sources and in several areas of the Region make it essential that further data collection continues as rapidly as possible; it is also important to gather data from water companies.

2. In order to permit an efficient analysis of existing data, a systematic method for the integration of information coming from NRA itself and from water companies is required. This could be based on the DWI-modified format. Packages currently used by Groundwater Quality (Scientific) for assessment[33] need continued support and development. In the medium term it clearly remains extremely desirable that mechanisms be found to link water quality archives with the BWS and GQM databases.

3. Data on the variables described (held in the GQM database) should be regularly updated, particularly with respect to pesticide contamination results, so that a clearer picture can emerge over time.

4. As further data become available, it will be important to review in particular the categorisations and priorities assigned to all those sources which have had very few analyses to date.

5. The procedures for assigning priority indicators should also be revised to give them a more quantitative basis.

6. In the meantime, the prioritisation scheme that has been introduced should be used as the basis to consider important avenues of attack on the problems of pesticide contamination in the Region. After liaison with water companies, priority indicators should be reviewed for any site-specific concerns.

The location of individual sources in relation to the areas of aquifer known to show contamination (see section 3.2.5) should be studied. This will indicate whether the action should be orientated towards source protection or resource protection measures.

The following suggestions are made for sites with particular indicators.

* Indicator AH, AU or UH: site should be most urgently considered. Sites with few analyses should have these verified by further sampling and conclusions should be drawn as to viable pesticide pollution prevention measures. For AU and UH sites, urgent investigation required to permit proper definition of priority indicator. There are 39 sites in the AH/AU/UH group.

---

[33] Packages used for data assessment include Spans Map and Hydrodat.

* Indicator AI or BH: site should be considered the next priority for preventative action.

* Indicator UU: site should be prioritised for further investigative effort if it is to be included in the Network.

* Indicator AL or CH: site should be placed on a secondary priority list for investigation.

* Other indicators: continuing routine analysis, data collection and assessment to assign priority where still necessary and to monitor any change in the situation. Once higher priority sites have been satisfactorily investigated and/or pollution preventative measures put in place, these sites should also be considered.

7. The noted discrepancies between pesticide analytical results from 3VWC and NRA - most particularly, but not solely, in the case of linuron - emphasise the necessity to include in future analytical programmes a cross-laboratory comparison of results. This should be preceded by a general review of the results available in order to identify other possible inter-laboratory differences.

8. Limited time to arrange data in compatible formats has so far inhibited assessment of the occurrence of individual pesticides. If more robust conclusions are to be drawn from the considerable quantities of data already available, further work to review results for individual compounds is necessary. Better substantiated correlations between contamination levels and various environmental factors may then become apparent.

9. Owing to the different detection limits available for pesticide analyses, a range of "standards" between detection limit and the drinking water standard is needed. The categorisation procedure used 0.1ug/l (for C_{max}) and 0.06ug/l; these grouped sources in a reasonable manner and could be used in subsequent reports on pesticides in groundwater. However, the use of detection limit (variable) made comparison between pesticides difficult, so detection limits (or minimum reporting values) for all pesticides being examined should be reviewed and one acceptable value derived for comparison purposes.

10. In order to gain a good overall picture of pesticide occurrence at a source, it is important to ensure that sources which are sampled annually are not always sampled at the same season.

11. The possibility of statistical analysis of data in order to detect any possible interrelationships between different environmental factors relevant to pesticide occurrence should be considered. It may also be useful to examine from a statistical viewpoint the correlations reported here in order to test their significance.

12. Although many factors have been looked at in isolation, a number of combinations of factors which might provide indications of pesticide contamination mechanisms have not been examined. It remains possible that understanding of contamination pathways influenced simultaneously by more than one factor may be advanced by such an examination. Examples include:

* the combination of impermeable cover with stratigraphic variation (i.e. particularly fissured units with little cover may be more contaminated);
* water level and stratigraphic variation;
* large-scale transmissivity variations (on the scale of several site catchments) and gross pumping rate for particular areas of aquifer.

13. If revision of data and/or further analysis reveals hitherto undetected correlations between particular site characteristics and pesticide occurrence, the process of assigniation of the risk factor should be amended to include them.

14. The land use significances derived from defined source catchment areas should be used to determine appropriate analytical suites to be employed regularly for each source.

15. The actual pesticides listed in each land use-related suite can only be finalised after more detailed examination of individual pesticides. Certainly, the land use-related lists of pesticides proposed in the framework agreement for the national Monitoring Network should be reviewed in the light of analytical results available from Thames Region. In particular it is strongly recommended that propazine and cyanazine be included in the appropriate lists.

16. The groundwater vulnerability maps appear to offer only limited guidance with respect to pesticides and risk assessment. Since urban areas appear to show significant contamination compared with other land uses, restriction of all pesticide use (in general terms) should only be recommended in urban areas. In other areas, hydrogeological and other site-specific factors must be considered along with information on the pesticide products proposed for use.

APPENDIX 1: CONTRACTOR'S BRIEF

1. Introduction

Thames Region's current groundwater quality monitoring programme (covered by a "Network" of sites) has identified some high concentrations and wide ranging types of pesticides in samples taken since monitoring started in 1992. In addition, water companies have provided pesticide data for raw water samples associated with public supply abstractions which are not part of the Network and they are obliged to notify the NRA of exceedance in treated water of parameter 55 (pesticides) in the drinking water regulations. These data, particularly for raw water, need to be assessed together to ensure that current sampling points are suitable for monitoring purposes and that available data contribute to policy and strategic activity for which the NRA is responsible.

For any set of analytical results to be meaningful, information needs to be gathered on current sampling points (approximately 330, including all public supplies and Network sites). The Network is under review and currently consists of boreholes and wells in regular or constant use, and springs. The majority are public supply abstractions for which catchment zones have been estimated. Conclusions need to be drawn on pesticide occurrence in terms of hydrogeological conditions and catchment land uses in Thames Region. The relevance of current and proposed analytical suites will then become evident. Once vulnerable sample points or areas of aquifer have been identified, the NRA will be able to prioritise the investigation of sources affected by pesticides and direct pollution prevention activity more effectively.

The project is closely linked with proposals for a national groundwater quality monitoring strategy. Thames Region's current network sites need to comply with site selection criteria recommended by the British Geological Survey (BGS), which involves algorithm and ranking procedures for all sources (boreholes/well/springs) across the Region. Sites which do not comply with the criteria may need to be removed from the Network. Information gathered during an assessment of pesticide results will be relevant to the site selection procedure. Indeed, this aspect of the work will be given considerable emphasis.

The project revisits the desk-study aspects of public supply and current Network sites only, all of which have been visited by NRA and/or water company staff. Close liaison with NRA staff, therefore, will be beneficial to the Contractor. Exceptionally high concentrations and/or unexpected pesticide occurrence will be factors which trigger further NRA visits to individual sites and NRA staff may be able to revisit sites within the contract period. Where public supplies are involved, water companies will need to be consulted on their views regarding priority investigation of sources.

Relevant documentation includes 'Groundwater Quality Assessment: A National Strategy for the NRA' (BGS Technical Report WD/94/40C, 1994) and 'Framework agreement for sampling, analysis and data transfer for the NRA's National Groundwater Quality Monitoring Programme' (NRA/WSA/WCA, 1995), relevant pages of which are enclosed. A preliminary assessment of Network data from (January 1992 to October 1994) is enclosed for information. Groundwater Vulnerability maps have been published for some parts of Thames Region; these, along with the principles of their production, may provide useful information. There may be limited contact with the NRA's Toxic and Persistent Substances (TAPS) Centre at Peterborough, although permission should be sought from the NRA's Nominated Representative beforehand. All relevant data at the NRA's Reading office will be made available once the contract has been let although a portable PC will be needed.

2. Study Area

A map of NRA Thames Region is enclosed. A map showing the distribution of current Network sites is given with the NRA's preliminary report on data (enclosed). The location of public supply abstractions will be made available once the contract has been let.

3. Overall Project Objective

To assess Thames Region's pesticide data in terms of hydrogeological conditions thereby improving the direction of Regional resources towards cost effective monitoring and remediation/prevention strategy, and, while doing so, to gather information on current Network sites in relation to the selection criteria for sites in the proposed national groundwater quality monitoring network.

Specific Objectives

i) To gather information on monitoring sites, reporting on each site in a manner which enables sites to be assessed in terms of vulnerability and suitability as a sample point within the Regional Network.

ii) To relate pesticide data to site circumstances and draw conclusions on pesticide occurrence in terms of hydrogeological conditions and catchment land uses in Thames Region.

iii) To prioritise sources or areas of aquifer for investigation and/or pollution prevention activity with reference to pesticides.

iv) To recommend analytical suites (pesticides) for network sites in line with national recommendations for groundwater monitoring (enclosed).

4. Method of Working

The study will be carried out by the Contractor, supervised by Ms S Hennings and assisted by NRA staff.

The work will consist of a desk study and will involve close liaison with NRA staff in the Groundwater Quality, Monitoring Services and Hydrogeology departments in NRA Thames Region. Whilst much information will be obtainable from OS and geology maps, there will be a large amount of information only available from NRA records, so facilities will be made available for work at the NRA's Reading office.

The methodology adopted will involve the following:

a) Creation of a database which allows sample points to be represented and ranked in accordance with BGS recommendations for site selection for the national monitoring network; to be accessible and developed by Thames Region staff at a later date, ie. Lotus 123 or DBase. [Project Record].

b) Collection of paper-based information and data pertaining to the hydrogeological context, the site characteristics and the location features of approx 330 sites. Information to be collected for Network sites specifically (approx 290) includes:
- degree of confinement (confined; semi-confined; unconfined)
- hydrogeological setting (valley; slope; interfluve and depth to water table)
- depth control over sample (subjective)
- borehole construction complexity (adits, etc)
- definition/precision of catchment area/capture zone (unknown; poor; moderate; good). Note, estimates may be needed for non-public supply boreholes.
- land use definition and homogeneity in catchment (poorly defined/inhomogeneous; well defined/ homogeneous)
- broad category land uses within catchment and significance to sample point
- indications of risks to groundwater quality from pesticide data.

[Project Record].

c) Assessment of pesticide data in relation to hydrogeological conditions and catchment land uses at each site. Where the above-listed information is insufficient, additional information may be sought. A brief 'report' to be produced for each site, concluding with recommended future analytical suites for each (within the nationally recommended framework). [Project Record].

d) Summary report on the occurrence of pesticides in groundwater in the context of hydrogeology and land uses in Thames Region, building upon and expanding the brief report produced by NRA [Project Report].

e) Prioritisation scheme for the selection of sources for further investigation and pollution prevention work, taking account of i) pesticide data, ii) hydrogeological information and groundwater vulnerability and iii) priorities of water companies. [Project Report].

f) Recommend sources or areas of aquifer for i) investigation of pesticide occurrence and/or ii) pollution prevention activity to prevent further deterioration in groundwater quality [Project Report].

g) Tutor Thames Region staff on use of databases and prioritisation scheme.

5. Consultants Experience

The consultants appointed will have to demonstrate expertise and experience in the following areas:

Hydrogeological investigation
Groundwater quality monitoring programmes
Pesticide science as it relates to groundwater contamination

Land management as it relates to pesticide use
Computing and database management
Project management
Report writing for technical issues

6. Outputs

The output from this project consists of two parts:

Project Record: consisting of a database and factual summary for each sample point (see section 4 a,b and c above). These outputs are considered to be working documents which are required to be accurate, reproducible and accessible, and will be audited at random by NRA staff.

Project Report: including an interpretative report, detail of and justification for the prioritisation scheme and recommendations (see section 4 d, e and f above). The report is to be precise, accurate and focused on the stated objectives. It should be written in clear and unambiguous terms. Conclusions and recommendations should be technically well-founded, substantiated by the findings of the study and defensible. There should be an Executive Summary.

7. Targets and Timescales

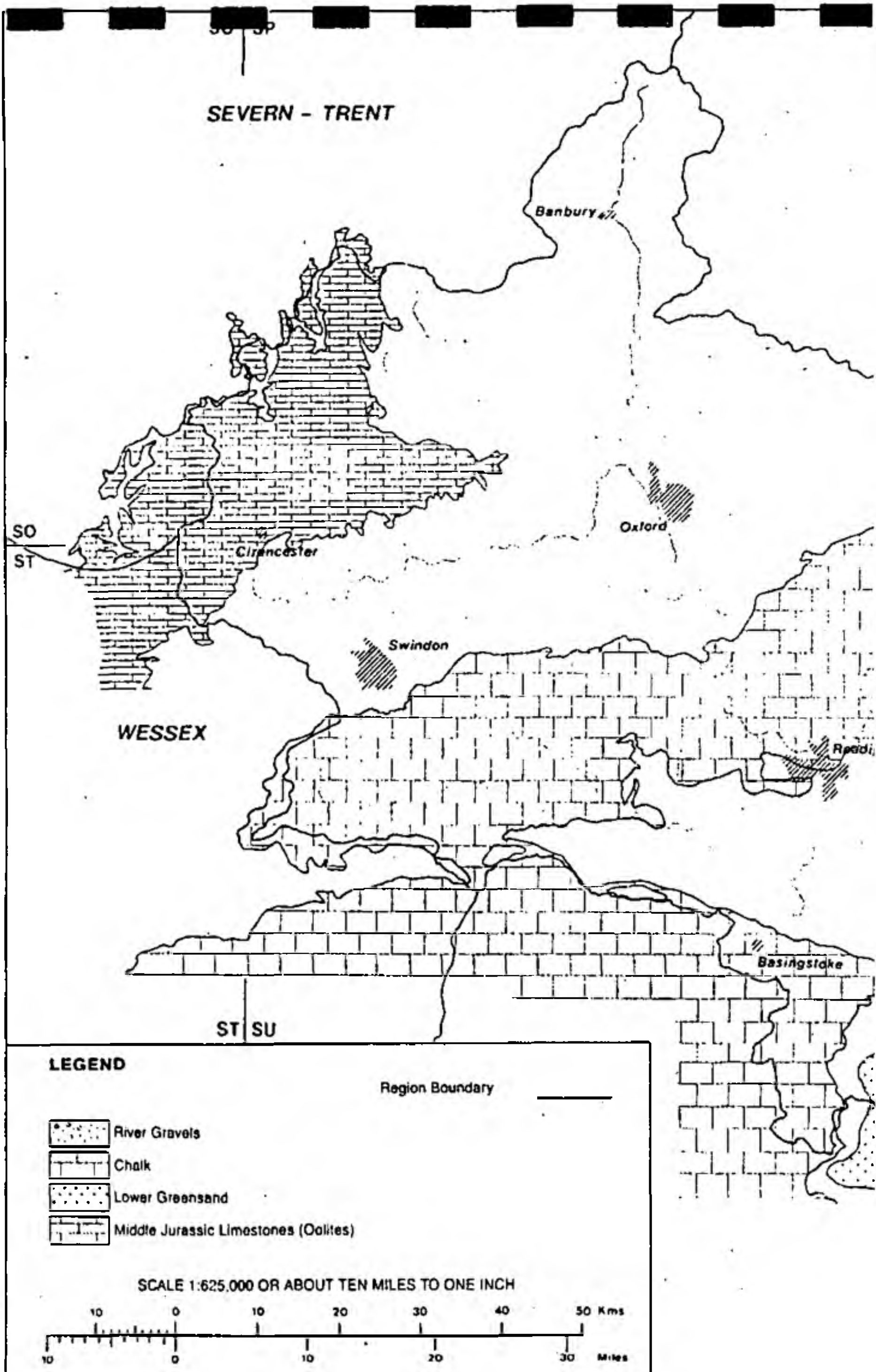
7.1 Key Dates:

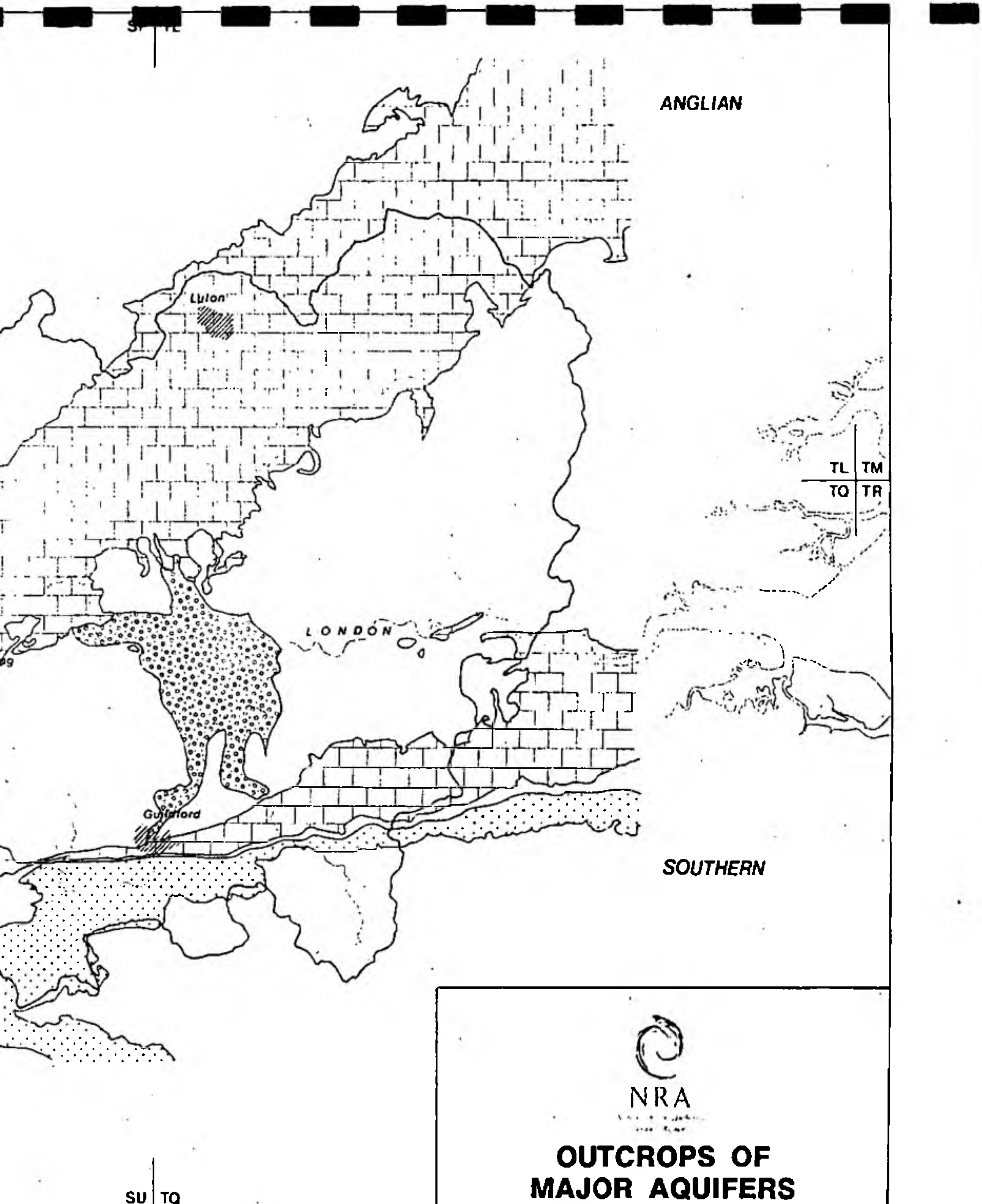
- Formal Initial Meeting
- End month 1 - Framework for database and prioritisation scheme to be demonstrated to and approved, and database entered (incomplete) on NRA system
- End months 2 and 3 - informal account of progress on database, etc
- Middle month 4 - Draft Project Report
- End month 4 - Formal Progress Meeting
- End month 5 - Project Record and database (complete) operational on NRA system
- End month 5 - Final Project Report.

Project to end by 22nd March 1996.

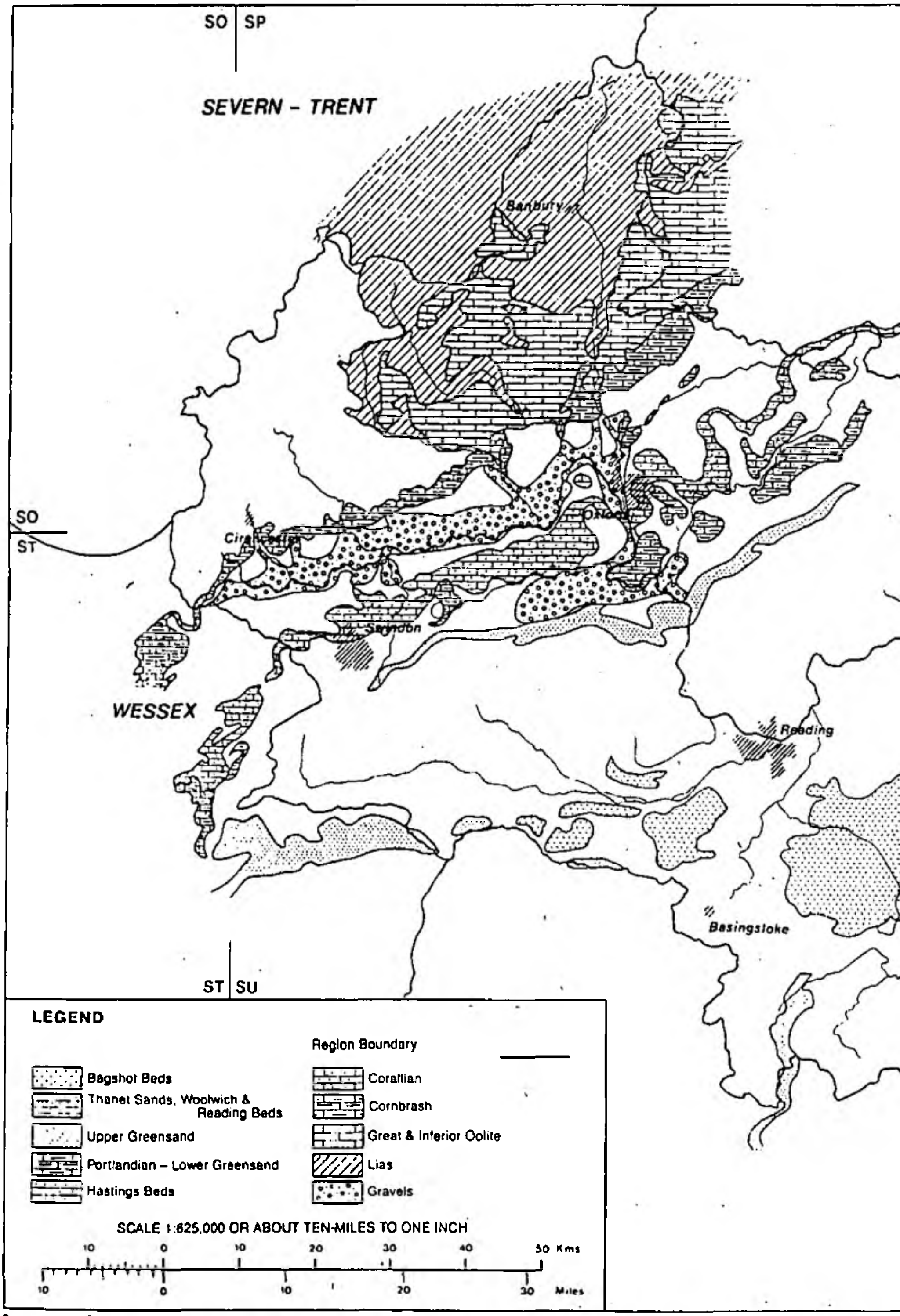
7.2 Deliverables:

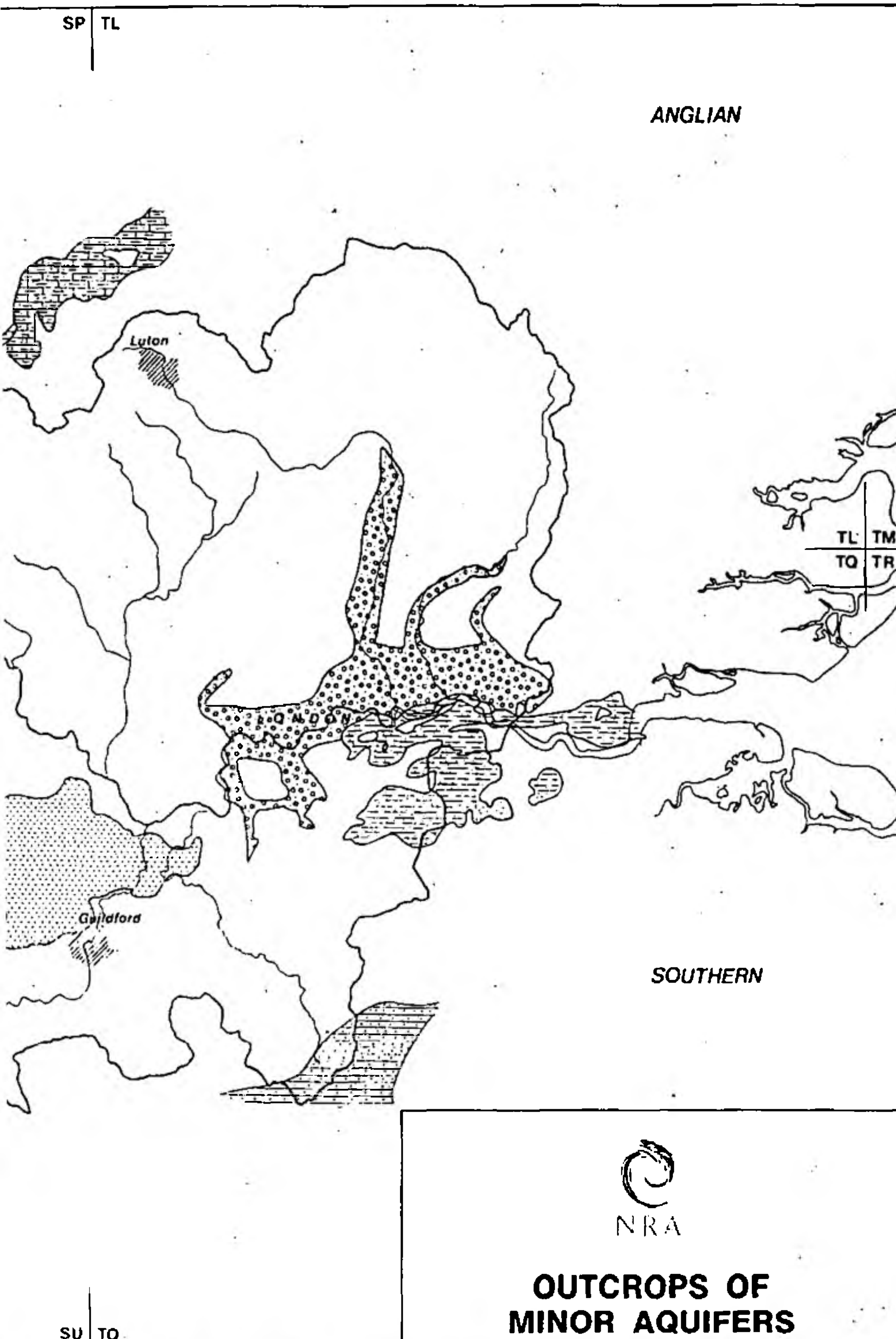
- Database operational on NRA system and NRA staff tutored
- Project Record - 1 copy
- Draft Project Report - 3 copies
- Final Project Report - 8 copies.


SEVERN - TRENT
Banbury
Oxford
SO
ST
Cirencester
Swindon
WESSEX
Basingstoke
ST | SU
LEGEND
Region Boundary
River Gravels
Chalk
Lower Greensand
Middle Jurassic Limestones (Oolites)
SCALE 1:625,000 OR ABOUT TEN MILES TO ONE INCH
10 0 10 20 30 40 50 Kms
10 0 10 20 30 Miles



Prepared by Thames Water, Cartographics, Reading 1990


SO SP
SEVERN - TRENT
Banbury
SO
ST
Cirencester
Oxford
Swindon
WESSEX
Reading
Basingstoke
ST SU
LEGEND
Region Boundary
Bagshot Beds
Thanet Sands, Woolwich & Reading Beds
Upper Greensand
Portlandian – Lower Greensand
Hastings Beds
Corallian
Cornbrash
Great & Inferior Oolite
Lias
Gravels
SCALE 1:625,000 OR ABOUT TEN-MILES TO ONE INCH
10 0 10 20 30 40 50 Kms
10 0 10 20 30 Miles



OUTCROPS OF MINOR AQUIFERS

Prepared by Thames Water Cartographics Reading 1990

APPENDIX 2: TABLE OF VARIABLES USED IN GQM DATABASE

Field name	Description	Type	Width	Section
Abs_reg	Abstraction regime	N	1.1	4C3
Acc_hs_ok	Is access good in health & safety terms?	L	1	3d
Air_sig	Significance of airfields in catchment	C	1	5b
An_note1	Analytical suite note 1	C	55	7c
An_note2	Analytical suite note 2	C	55	7c
Aquifer	Aquifer tapped by source	C	3	7a
Aq_thick	Effective aquifer thickness	N	2	7d
Rural_sig	Significance of rural areas in catchment	C	1	5a
Atr	Atrazine persistently detected?	L	1	6f
Bh_comp_kn	Is borehole completion known?	L	1	3g
Case_dep	Recorded casing depth	N	3	7c
Chl	Chlorotoluron persistently detected?	L	1	6f
Complete	Information complete in database?	L	1	7i
Conf	Confined/unconfined status of source	C	1	7b
Cons_comp	Construction complexity	N	1.1	4C1
Cover	Indicator of impermeable cover	N	1	7h
Ctyd_cond	Condition of source surroundings	N	1.1	4C2
Cz_def	Quality of catchment zone definition	N	1.1	4D3
Data_len	Length of analytical data	N	1.2	4A1
Dep_ctrl	Is depth control of sample available?	L	1	7k
Det_range	Current determinand range	N	1.2	4A3
Diu	Diuron persistently detected?	L	1	6f
Hi_conc	Highest concentration of any pesticide	N	1.2	6e
Hi_pest	Pesticide found at highest concentration	C	3	6d
Hyd_set	Hydrogeological setting	N	1.1	4B2
Indexno	Well index number	C	9	2
Ind_sig	Significance of industry in catchment	C	1	5
In_use	Is source in use?	L	1	3c
Iso	Isoproturon persistently detected?	L	1	6f
Lfill_sig	Significance of landfills in catchment	C	1	5
Lin	Linuron persistently detected?	L	1	6f
L_use_def	Land use homogeneity in catchment	N	1.1	4D1
Mon_status	"Network" or "Unspecified"	C	8	3k
Moor_sig	Significance of moorland in catchment	C	1	5
Notes	General notes and comments	M		9b
Note_czd	Note on catchment zone definition	C	20	4D4
Orch_sig	Significance of orchards in catchment	C	1	5b
Other	Other pesticides persistently detected?	L	1	6f
Penet	Degree of aquifer penetration	N	1.1	4B3
Pest_anal	Total no. of analyses for all pesticides	N	3	6c
Pest_det	No. of pesticide detections	N	3	6a
Pest_sampl	No. of pesticide samples	N	3	6b
Poll_cat	Pollution category of source	C	1	8a
Pt_pol_x	Point-source pollution excluded?	L	1	3b
Pt_s_pol	Pollution point sources in catchment	N	1.1	4D2
Pump_ok	Is pump good for sampling?	L	1	3f
Qual_alg	Result of quality algorithm	C	4	3j
Q_notes	Notes on analytical data	M		9a
Rail_sig	Significance of railways in catchment	C	1	5b
Risk_fac	Pollution risk factor	C	1	8b

Field name	Description	Type	Width	Section
River_sig	Significance of rivers in catchment	C	1	5b
Road_sig	Significance of A- and M-roads in catchment	C	1	5b
Sample_f	Current frequency of sampling	N	1.2	4A2
Setting	Indicator of setting	N	1	7i
Sheep_sig	Significance of sheep farming in catchment	C	1	5
Sh_hor_x	Does casing exclude shallow drainage?	L	1	3h
Sim	Simazine persistently detected?	L	1	6f
Single_aq	Does source tap only one aquifer?	L	1	3i
Site_name	Name of source	C	30	2
Sur_in_x	Surface drainage excluded?	L	1	3a
Treat_data	Treated water data tag	C	1	6g
Urban_sig	Significance of urban areas in catchment	C	1	5a
URN	NRA's User Ref. No.	C	4	2
Valid_spt	Is sampling point otherwise valid?	L	1	3e
Vuln	Vulnerability	N	1.1	4B1
V_map_cat	Indicator of vulnerability map category	N	1	7g
Wat_lvel	Recorded water levels	C	6	7e
W_depth	Indicator of depth to water	N	1	7f

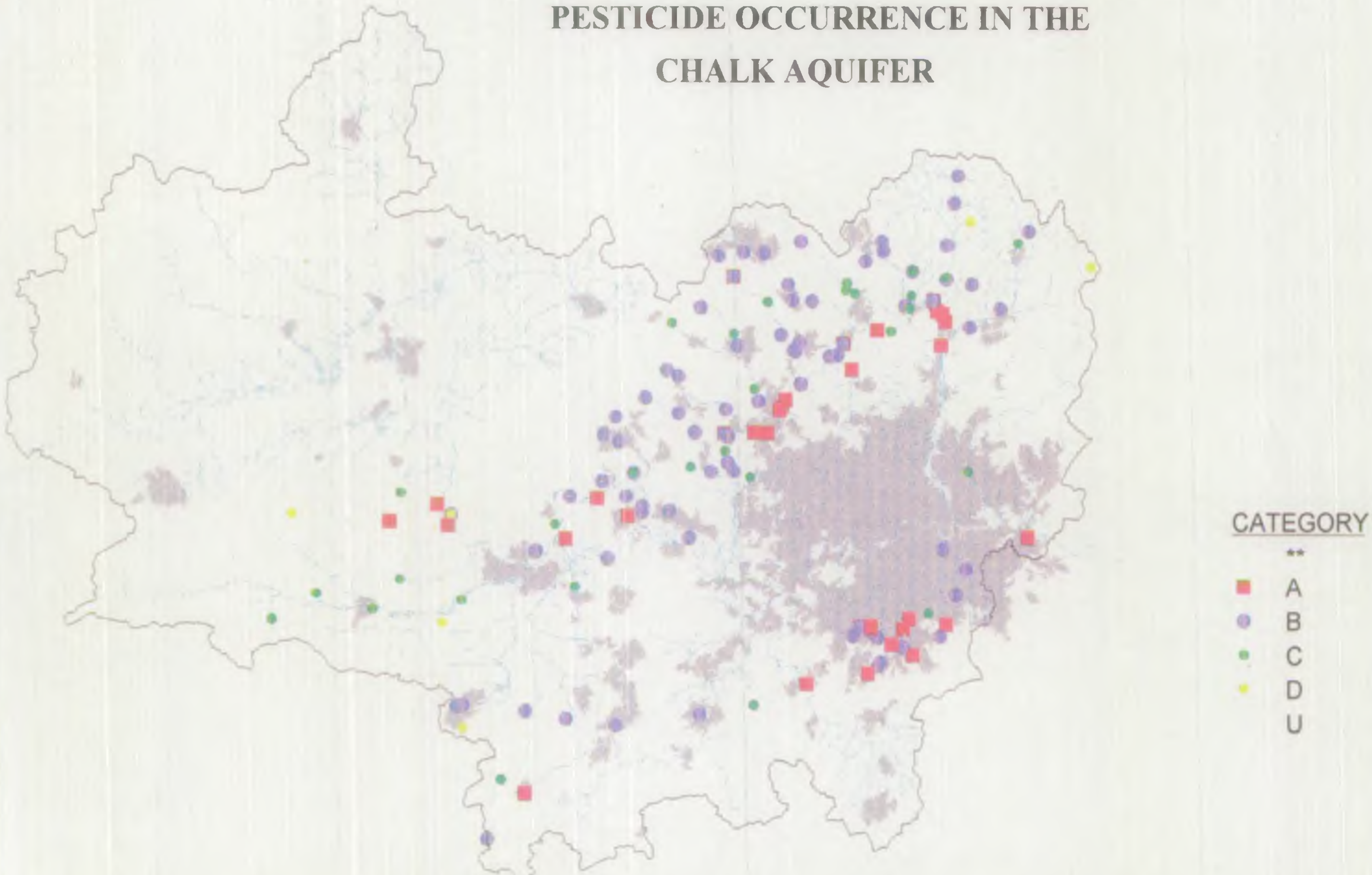
Notes: "Type" column indicates variable type: "C" = character, "L" = logical, "M" = memo, "N" = numeric

In the width column, some numeric variables are designated, e.g., 2.1. This indicates two places before and one after the decimal point.

The "Section" column indicates the appropriate Section of the report which gives details of the variable.

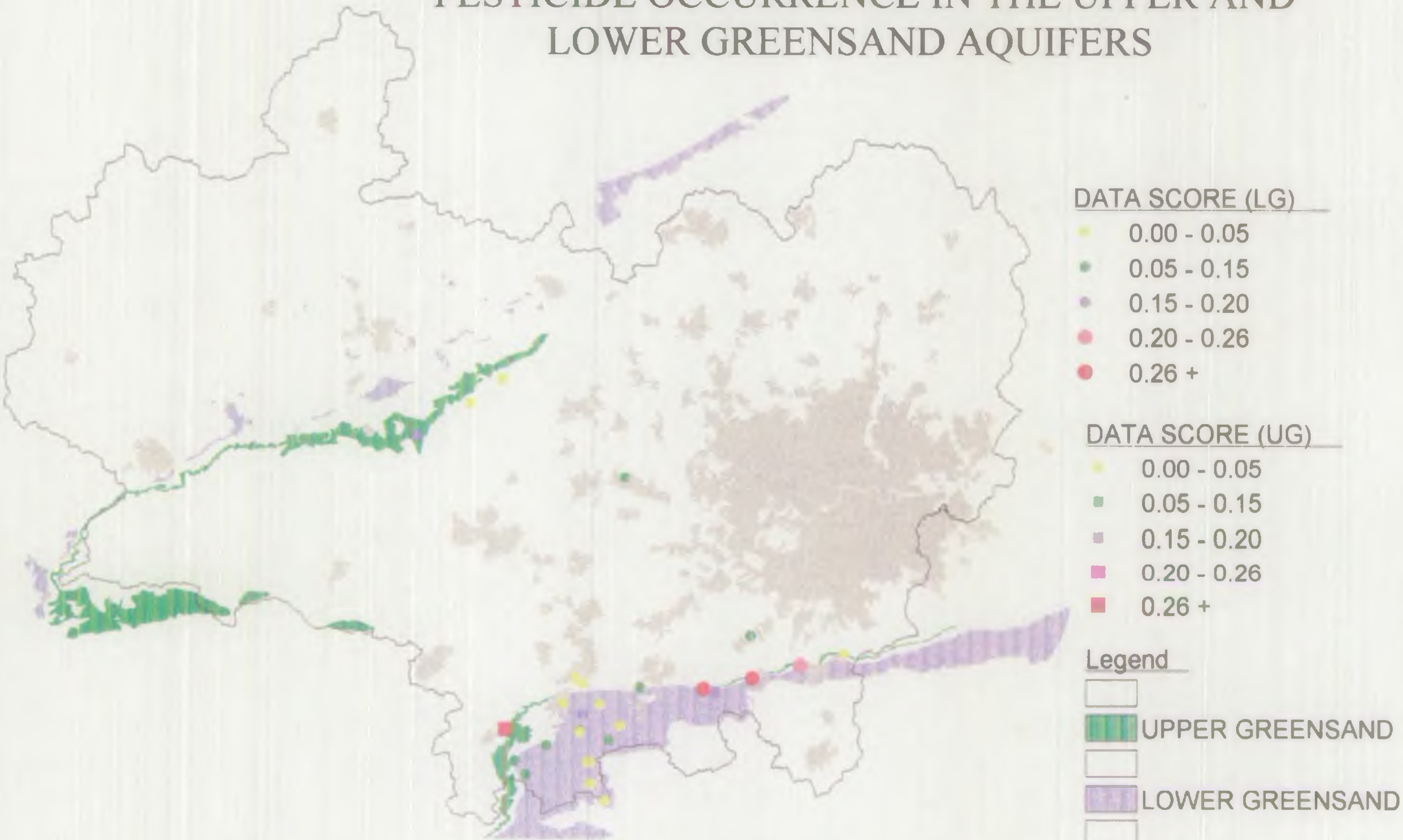
APPENDIX 3: MAPS OF PESTICIDE OCCURRENCE IN THE DIFFERENT AQUIFERS

PESTICIDE OCCURRENCE IN THE CHALK AQUIFER

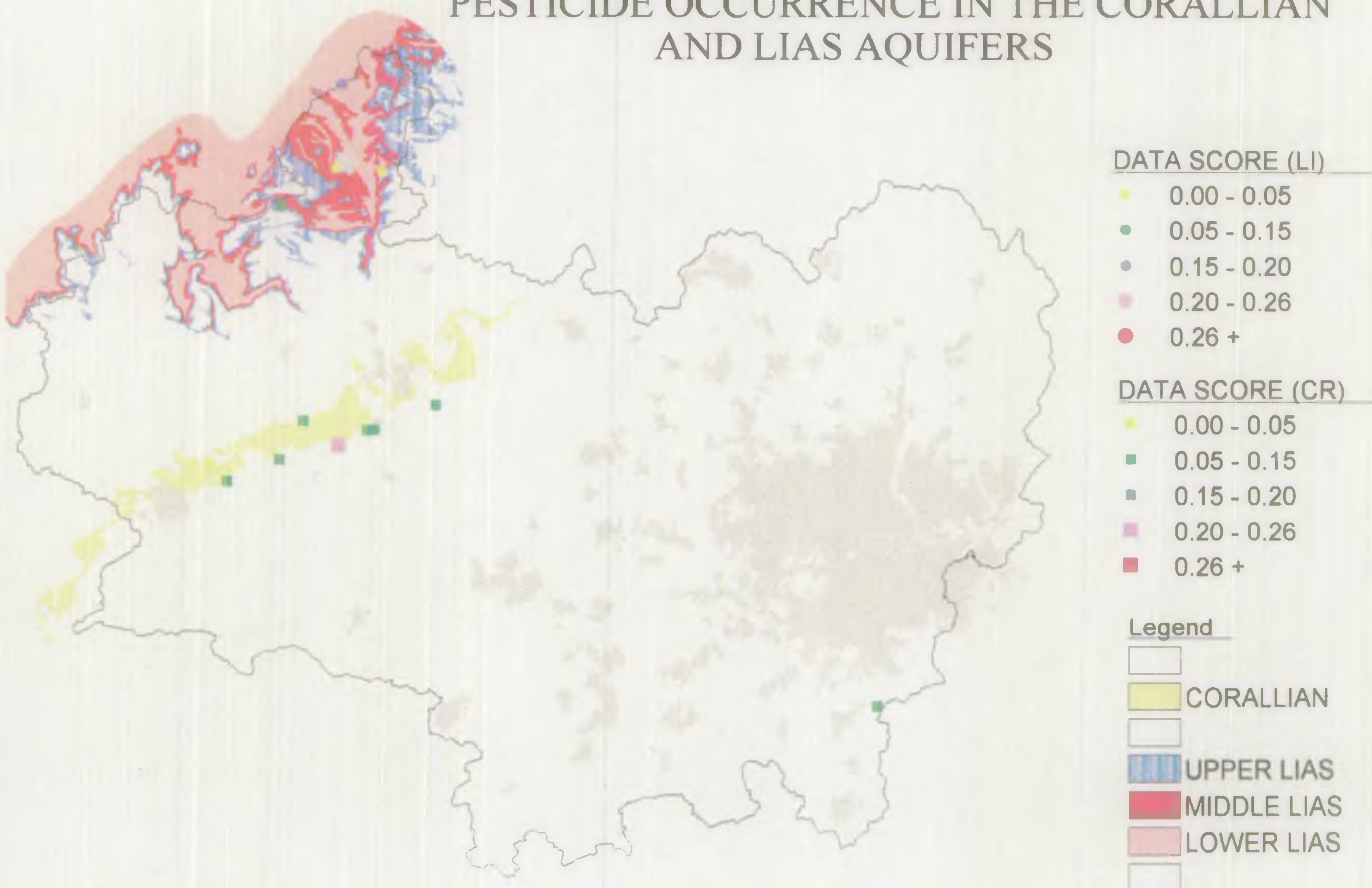


PESTICIDE OCCURENCE IN THE GREAT AND INFERIOR OOLITE AQUIFERS

PESTICIDE OCCURRENCE IN THE UPPER AND LOWER GREENSAND AQUIFERS



PESTICIDE OCCURRENCE IN THE CORALLIAN AND LIAS AQUIFERS



APPENDIX 4: PESTICIDES DETECTED IN GROUNDWATERS IN NRA'S THAMES REGION

As discussed in the main text of the report, a detailed examination of individual pesticides has not been carried out under the present project. It was felt that it would therefore be useful to include a list of the pesticides which have been detected in groundwater samples which were included in the data analysed.

The pesticides can be divided into three groups, as follows.

1. Pesticides persistently detected in at least three percent of the sources examined include atrazine, simazine, diuron, isoproturon, chlorotoluron, propazine and linuron.

2. Pesticides detected persistently in a very small number of sources, or detected with some regularity in several sources, include mecoprop, MCPB, cyanazine, terbutryn, trietazine, prometryn and methabenzthiazuron.

3. Pesticides detected very infrequently include carbetamide, clopyralid, MCPA, lindane, bentazone, dicamba, cis- and trans-permethrin, dichlorprop, dieldrin, carbendazim, flutriafol and fluroxypyr.

One small part of the data were examined for pesticide detection frequency as a sample of the whole data set: these were data from 3VWC (the easiest to assess rapidly) for about half their sources, from 1994 to 1995. The table on the following page shows the frequency of detection of pesticides in this data subset, and the maximum concentrations. Four of the most commonly occurring compounds (atrazine, simazine, chlorotoluron and diuron) have been excluded since better measures of their presence in groundwaters are readily available. One other common pesticide, isoproturon, is included as a reference point with which the frequency and concentrations of the other compounds can be compared.

Other pesticides which were looked for but not detected by 3VWC in this data subset include azinphos-methyl, bromoxynil, chlorothalonil, diazinon, dicamba, dichlorvos, fenoprop, fenpropimorph, ioxynil, iprodione, malathion, propiconazole, propyzamide, tecnazene, triallate, and 2,4,5-T.

Frequency of detection and maximum concentrations for various compounds in some Three Valleys Water Company sources.

COMPOUND	f	C_{max} µg/l	COMPOUND	f	C_{max} µg/l
Bentazone	2	0.02	MCPA	2	0.16
Carbendazim	1	0.03	MCPB	9	0.03
Carbetamide	13	0.02	Mecoprop	12	0.05
Clopyralid	13	0.05	Methabenz'uron	21	0.05
Cyanazine	86	0.05	Prometryn	36	0.03
Fluroxypyr	2	0.03	Propazine	122	0.03
Flutriafol	1	0.03	Terbutryn	49	0.03
Lindane	1	0.006	Trietazine	30	0.05
Linuron	16	0.02	Isoproturon	146	1.35

APPENDIX 5: REFERENCES AND DOCUMENTS CONSULTED

A. "Groundwater quality assessment: a national strategy for the NRA"; BGS Tech. Report WD/94/40C, 1994.

B. "Policy and practice for the protection of groundater", p.19; NRA, 1992.

C. "Groundwater protection for small sources"; Southern Science, 1995.

D. "Pesticides in major aquifers" (various reports); WRc.

E. "Diuron contamination of groundwater between northern New River and North Mimms areas, with special reference to the Mimmshall Brook"; NRA internal progress report; June 1994.

F. "Hertfordshire County Council - weed control programme 1991-1994"; NRA draft internal report; Mar. 1996.

G. "Report on the monitoring of pesticides by NRA in connection with the spraying of railway lines to control weed growth"; NRA draft internal report, Feb. 1996.

H. "Risk assessment for environmental management: approaches and applications"; Pollard, S.J., et al., J.CIWEM, 1995, pp 621-628.

I. "Framework agreement for sampling, analysis and data transfer for NRA's National Groundwater Quality Monitoring Programme"; NRA, Mar. 1995.

J. "Groundwater quality monitoring programme. Pesticides. January 1993 to October 1994"; NRA, 1995.

K. "Groundwater quality monitoring database - GQM"; Gomme, Mar. 1996

APPENDIX 6: TABLE OF PRIORITY INDICATORS ASSIGNED

KEY:

* = sites identified by responding water companies as requiring specific attention

See text for explanation of priority indicator (eg. AH, DU, etc)

SITES WITH PESTICIDE CONTAMINANTION (WORST CASES)

SITE NAME	AQUIFER	CAT	RISK	OWNER	
BATCHWORTH PS	CK	A	H	3V	
BERRY GROVE PS	CK	A	H	3V	
BRAY PS	GR	A	H	MSWC	
BUSHEY HALL PS	CK	A	H	3V	
BUSHEY PS	CK	A	H	3V	
CHERTSEY PS	GR	A	H	NSWC	
DORNEY PS	GR	A	H	TWU	•
EASTBURY PS	CK	A	H	3V	
KENLEY PS	CK	A	H	ESWC	•
SHEEPLANDS PS	CK	A	H	TWU	•
SURREY STREET PS	CK	A	H	TWU	•
SUTTON COURT ROAD PS	CK	A	H	SDWC	
SUTTON PS	CK	A	H	SDWC	
TOLPITS PS	CK	A	H	3V	
WALL HALL PS	CK	A	H	3V	
WINDMILL HILL PS	CK	A	H	MSWC	
WOODCOTE PS	CK	A	H	SDWC	
AMWELL HILL PS	CK	A	I	TWU	
BISHOPS RISE PS	CK	A	I	3V	
BRICKET WOOD PS	CK	A	I	3V	
BROXBOURNE PS	CK	A	I	TWU	
CHEAM PS	CK	A	I	SDWC	
COMPTON PS	CK	A	I	TWU	•
ESSENDON PS	CK	A	I	3V	
GATEHAMPTON PS	CK	A	I	TWU	•
GREENLANDS FARM	CK	A	I	-	
MUSLEY LANE PS	CK	A	I	3V	
NORTH MYMMS PS	CK	A	I	3V	
PERROTS FARM PS	CK	A	I	SDWC	
RYE COMMON PS	CK	A	I	TWU	•
TROWELL COVERT SPRING	GO	A	I	-	
WEST WICKHAM PS	CK	A	I	TWU	
WITNEY, STATION LANE IND. EST.	GO	A	I	-	
AMWELL MARSH PS	CK	A	L	TWU	
EUROPA TRADING ESTATE	CK	A	L	-	
KENSWORTH LYNCH PS	CK	A	L	3V	
RECTORY FARM BH	GO	A	L	-	
SOMERFORD LAKE BH	GO	A	L	-	
COLLEGE AVE PS	CK	A	U	MSWC	•
HAWRIDGE FARM	UG	A	U	-	
HURLEY PS	CK	A	U	MSWC	•
YOUNG STREET PS	CK	A	U	ESWC	

SITES WITH SIGNIFICANT PESTICIDE CONTAMINATION

SITE NAME	AQUIFER	CAT	RISK	OWNER
AMWELL END PS	CK	B	H	TWU
GERRARDS CROSS PS	CK	B	H	3V
HOLYWELL PS	CK	B	H	3V
LANGLEY PS	CK	B	H	SDWC
MILL END PS (RICK.)	CK	B	H	3V
MUD LANE PS (HOLYWELL BH6)	CK	B	H	3V
NETHERWILD PS	CK	B	H	3V
NONSUCH PS	CK	B	H	SDWC
PERIWINKLE LANE PS	CK	B	H	3V
PURLEY PS	CK	B	H	ESWC
SECOMBE CENTRE (PS)	CK	B	H	SDWC
SHORTLANDS PS	CK	B	H	TWU
SLOUGH TRADING ESTATE	CK	B	H	-
SOUTH CERNEY (ECC QUARRIES)	GR	B	H	-
THE GROVE PS	CK	B	H	3V
WATTON ROAD PS	CK	B	H	3V
WEST HAM PARK PS	CK	B	H	MSWC
WEST HAM PS	CK	B	H	MSWC
WHEATHAMPSTEAD PS	CK	B	H	3V
WOODMANSTERNE PS	CK	B	H	SDWC
ADDINGTON PS	CK	B	I	TWU
ALMA ROAD PS	CK	B	I	3V
AMERSHAM PS	CK	B	I	3V
ASTON PS	CK	B	I	3V
BEDWYN PS	CK	B	I	TWU
BEENHAMS HEATH PS	CK	B	I	MSWC
BERKHAMPSTEAD PS	CK	B	I	3V
BLACKFORD PS	CK	B	I	3V
BOW BRIDGE PS	CK	B	I	3V
BULSTRODE PS	CK	B	I	3V
CHALFONT ST GILES PS	CK	B	I	3V
CHALK HILL SPRING	GO	B	I	-
CHORLEYWOOD PS	CK	B	I	3V
CODICOTE PS	CK	B	I	3V
CRESCENT RD PS	CK	B	I	3V
DEAN FARM	GO	B	I	-
DEPTFORD PS	CK	B	I	TWU
GREYWELL PS	CK	B	I	MSWC
GT MISSENDEN PS	CK	B	I	3V
HAMPNETT VILLAGE SPRING	GO	B	I	-
HINDHEAD PS	LGH	B	I	MSWC
ITCHEL PS	CK	B	I	MSWC
KINGS WALDEN PS	CK	B	I	3V
LYEWAY FARM	CK	B	I	-
MARLOWES PS	CK	B	I	3V
MOLEWOOD PS	CK	B	I	3V
NORTHFIELD BARN SPRING	IO	B	I	-
OAKS PS	CK	B	I	SDWC
PINNOCK PS	IO	B	I	STWC
ROESTOCK PS	CK	B	I	3V
SHAKESPEAR RD PS	CK	B	I	3V
STANSTEAD MOUNTFITCHET PS	CK	B	I	3V
STONECROSS PS	CK	B	I	3V
THE MALT HOUSE	GO	B	I	-
TOWER PS	LGH	B	I	MSWC
TUGHILL BARN, SPRING OPP.	GO	B	I	-
UPCOTE FARM SPRING	IO	B	I	-
VILLAGE SPRING, GUITING POWER	IO	B	I	-
WEYSPRING PS	CK	B	I	MSWC
WHITEHALL FARM SPRING	GO	B	I	-
BANDONS FARM BH	CK	B	L	-
BOXALLS LANE PS	LGF	B	L	MSWC
BOXALLS LANE PS	CK	B	L	MSWC
BRIZE NORTON, ASTROP FARM	GO	B	L	-
CHARTRIDGE PS	CK	B	L	3V
CHIPPING PS	CK	B	L	3V
CLEAR CUPBOARD SPRING	IO	B	L	-
CLEEVE PS	CK	B	L	TWU
CLIFTONS LANE PS	LGH	B	L	ESWC
COOLING STN C2, WYNN RD	CK	B	L	-
DORKING PS	LG	B	L	ESWC
DUDGROVE FARM	GO	B	L	-
EAST HYDE PS	CK	B	L	3V
HADHAM MILL PS	CK	B	L	3V
HEADLEY PARK PS	LG	B	L	MSWC
HIGH BUTTON SUPPLY	LG	B	L	-
HOLLY LANE PS	CK	B	L	SDWC
HOMELEAZE FARM	GO	B	L	-
KENSWORTH LYNCH PS	CK	B	L	3V
LITTLE GADDESDEN PS	CK	B	L	3V
LOSELEY PARK	LGH	B	L	-
LOWER FARM	GO	B	L	-
NORTHMOOR PS	CK	B	L	3V
OAK HANGER PS	LGH	B	L	MSWC
REDRICKS LANE PS	CK	B	L	3V
ROYDON PS	CK	B	L	3V
R. COE & SONS	LGH	B	L	-
SACOMBE PS	CK	B	L	3V
STANDON PS	CK	B	L	3V
THE CLEARS PS	LGF	B	L	ESWC
THUNDRIDGE PS	CK	B	L	3V
TILFORD MEADS PS	LGH	B	L	MSWC
TYTTENHANGER PS	CK	B	L	3V
WHITEHALL PS	CK	B	L	3V
WORSTED LANE PS	CK	B	L	3V
ABINGDON, VINEYARD MALTINGS	CR	B	U	-
BOURNE END PS	CK	B	U	TWU * note
CHIPPINGHURST MANOR	CR	B	U	-
COOKHAM PS	CK	B	U	MSWC *
HALL FARM	LI	B	U	-
HOOK NORTON, THE BREWERY	LI	B	U	-
HUGHENDEN PS	CK	B	U	3V
LADYMEAD PS	CK	B	U	TWU *
MEDMENHAM PS	CK	B	U	TWU *
MILL END PS (WYCOMBE)	CK	B	U	TWU *
PANN MILL PS	CK	B	U	TWU *
PAVLOVA LEATHER	CR	B	U	-
PLAYHATCH PS	CK	B	U	TWU *
RUNLEY WOOD PS	CK	B	U	3V
SHEEPCROFT FARM	CR	B	U	-
TAPLOW COURT PS	CK	B	U	TWU
TAPLOW PS	CK	B	U	TWU *

note: category may be higher (further data available)

SITES WITH LESS SIGNIFICANT PESTICIDE CONTAMINATION

SITE NAME	AQUIFER	CAT	RISK	OWNER	
DIGSWELL PS	CK	C	H	3V	
HUNTON BRIDGE PS	CK	C	H	3V	
NEWBURY RACECOURSE BH	CK	C	H	-	
PORTHILL PS	CK	C	H	3V	
STROUD GREEN PS	CK	C	H	TWU	
BATSFORD PARK ARBORETUM	IO	C	I	-	
BOARS HOLE FARM, BHB	CK	C	I	-	
ELCOT PARK HOTEL	CK	C	I	-	
FOSSBRIDGE SPRING	GO	C	I	-	
FULLING PS	CK	C	I	3V	
NEW GROUND PS	CK	C	I	TWU	* note
PICCOTTS END PS	CK	C	I	3V	
PROSPEROUS HOME FARM	CK	C	I	-	
SCHOOL LANE PS, WELWYN	CK	C	I	3V	
SOUTH FARM SPRING	GO	C	I	-	
SPEEN PS	CKG	C	I	TWU	*
THE CAUSEWAY PS	CK	C	I	3V	
WADESMILL ROAD PS	CK	C	I	3V	
WATER HALL PS	CK	C	I	3V	
WEST HYDE PS	CK	C	I	3V	
BLEWBURY PS	CKU	C	L	TWU	
COTCHET FARM, CATCHPIT OUTLET	LG	C	L	-	
ICKENHAM PS	CK	C	L	3V	
LASHAM PS	CK	C	L	MSWC	*
NORTH STORTFORD PS	CK	C	L	3V	
PARK FARM	GO	C	L	-	
RUSHMOOR PS	LGF	C	L	MSWC	
TILFORD PS	LGH	C	L	MSWC	
TOUTLEY PS	CK	C	L	MSWC	
UFTON NERVET PS	CK	C	L	TWU	
WANSTEAD WELL (REDBRIDGE)	CK	C	L	TWU	
WARWICK WOLD PS	LGF	C	L	ESWC	
WENDLEBURY FACC. CHICKEN FAR	GO	C	L	-	
HARPSDEN, BH3	CK	C	U	TWU	
LAGGOTS FARM	CR	C	U	-	
OLD CHALFORD PS	IO	C	U	TWU	*
SEVEN SPRINGS PS	IO	C	U	TWU	
ST MARY'S CONVENT	UG	C	U	-	
WEST HORSLEY PS	CK	C	U	NSWC	

note: category may be higher (further data available)

SITES WITH NO PESTICIDE CONTAMINATION

SITE NAME	AQUIFER	CAT	RISK	OWNER
WARREN FARM BH	CK	D	I	-
ALDERMASTON COURT	CK	D	L	-
BRANDS FARM BH	CK	D	L	-
BRITTY HILL PS	LGH	D	L	MSWC
CLIDDESDEN PS	CK	D	L	MSWC
FAIRFIELD LODGE BH	CK	D	L	-
THE BOURNE PS	LGH	D	L	MSWC
TONGHAM PS (GRANGE ROAD)	LGF	D	L	MSWC
ASTROP HILL FARM	LI	D	U	-
CROUCH HILL FARM	LI	D	U	-

SITES FOR WHICH PESTICIDE DATA ARE UNAVAILABLE FOR CATEGORISATION

SITE NAME	AQUIFER	CAT	RISK	OWNER
BATTLE HOSPITAL BH	CK	U	H	-
CLEAN LINEN SERVICES BH	CK	U	H	-
CLEVELAND FARM (ECC QUARRIES)	GR	U	H	-
EAGLE IRON WORKS	GR	U	H	-
EPSOM IND. ESTATE (NONSUCH)	CK	U	H	TWU
EPSOM PS	CK	U	H	TWU
ETON PS	GR	U	H	TWU
GLORY MILL PAPERS, BH1	CK	U	H	-
HODDESDON PS (ESSEX ROAD)	CK	U	H	TWU
LECHLADE GARDEN CENTRE	GR	U	H	-
MIDDLEFIELD ROAD PS	CK	U	H	TWU
PIM BOARD & CO LTD	GR	U	H	-
QUEENSMEAD PS	GR	U	H	NSWC
RAILKO	CK	U	H	-
SPRINGWELL PS, BH1	CK	U	H	3V
STOCKERS PS	CK	U	H	3V
WADDON PS	CK	U	H	TWU
WALTON BRIDGE PS	GR	U	H	NSWC
ALBERT ROAD PS	CK	U	I	3V
ASHTON KEYNES PS	GO	U	I	TWU
AXFORD PS, BH?	CK	U	I	TWU
BAUNTON PS	IO	U	I	TWU
BISHOPS GREEN PS	CK	U	I	TWU
BRADFIELD VALLEY PS	CK	U	I	TWU
BRADFIELD WINDMILL PS	CK	U	I	TWU
BRADFORDS FARM	CK	U	I	-
BRITWELL PS	CKU	U	I	TWU
BROADMEADS PS	CK	U	I	TWU
CHADWELL SPRING	CK	U	I	TWU
CLATFORD PS	CK	U	I	TWU
COBBLERS HILL SPRING	GO	U	I	-
DARNICLE HILL PS	CK	U	I	TWU
ESSENDON PS	CK	U	I	3V
FAIRFORD PS	GO	U	I	TWU
FIELD BARN COTTAGE, BHB	CK	U	I	
FOGNAM DOWN PS	CKU	U	I	TWU
FRIARS WASH PS	CK	U	I	3V
HUNGERFORD PS	CK	U	I	TWU
KINGSCLERE PS	CK	U	I	SWPLC
LIDDINGTON WARREN FARM	CKU	U	I	-
LYEFIELD SPRING	IO	U	I	-
NEW BARN FARM	CK	U	I	-
OGBOURNE PS	CKU	U	I	TWU
PIT HALL FARM	CK	U	I	-
RAMSBURY PS	CK	U	I	TWU
SHEEPCOTE FARM	CK	U	I	-
SHEPHERDS SHORE PS	CK	U	I	WWPLC
SMITHAM PS	CK	U	I	ESWC
STURT ROAD PS	LGH	U	I	TWU
SYREFORD PS	IO	U	I	TWU
THEALE PS	CK	U	I	TWU
WARREN FARM	CK	U	I	-
WEST HAGBOURNE PS	UG	U	I	3V
WINDRUSH FARM	IO	U	I	-
WOOD HANGER PS	LGH	U	I	MSWC
WRc	CK	U	I	-
YATESBURY PS	CKU	U	I	WWPLC
ADWEST ENGINEERING BH	CK	U	L	-
ALBURY (BLACKHEATH LANE)	LGH	U	L	TWU
ALBURY (BROOK)	LGH	U	L	TWU
ALBURY (COTTERELL'S FM)	LG	U	L	TWU
ALBURY (SHERE HEATH)	LG	U	L	TWU
ARBORFIELD PS	CK	U	L	TWU
BLACKMOOR NURSERIES	LGH	U	L	-
BREWER STREET PS	LGF	U	L	ESWC
BRITANNIA NURSERY BH	CK	U	L	-
BROOMFIELD PARK BH	CK	U	L	-
CHIEVELEY	CK	U	L	TWU
CLOCK HOUSE NURSERY BH	CK	U	L	-
EAST BARNET PS	CK	U	L	3V
EAST HAM PS	CK	U	L	TWU
EAST WOODHAY PS (SWPLC)	CK	U	L	SWPLC
EAST WOODHAY PS (TWU)	CK	U	L	TWU
GLAXO LABS	CK	U	L	-
GRAZELEY PS		U	L	ex-TWU
GREYHOUND STADIUM BH	CK	U	L	-
G.E. THORN BH	CK	U	L	-
HADLEY ROAD PS	CK	U	L	TWU
HAWRIDGE PS	CK	U	L	TWU
HILL BARN FARM	FML	U	L	-
HILLINGDON HOSPITAL	CK	U	L	-
HONOR OAK WELL	CK	U	L	TWU
HUTTONS FARM	CK	U	L	-
JOHNSON MATTHEY BH	CK	U	L	-
KODAK LTD, WELL5	CK	U	L	-
LANGLEY VALE PS	CK	U	L	TWU
LATTON PS	GO	U	L	TWU
LECKHAMPSTEAD PS	CK	U	L	TWU
LILBURY HALL BH	CK	U	L	-
LITCHFIELD FARM SPRING	GO	U	L	-
MARLBOROUGH PS	CK	U	L	TWU
MARLEY TILE BH	CK	U	L	-
MERTON ABBEY PS	CK	U	L	TWU
MEYSEY HAMPTON PS	GO	U	L	TWU
MORTIMER PS	CK	U	L	TWU
MOUSEHILL PS	LGH	U	L	TWU
NETLEY PS	LGH	U	L	TWU
NETTLEBED ESTATE	CK	U	L	-
OAKTHORPE DAIRY, BH1 & BH2	CK	U	L	-
OLD FORD WELL (DACE ROAD)	CK	U	L	TWU
PARKVIEW NURSERY	CK	U	L	-
RAMNEY MARSH PS	CK	U	L	TWU
REDBOURNE PS	CK	U	L	3V
RIPLEY GRANGE BH	CK	U	L	-
RODBOROUGH PS	LGH	U	L	TWU
RODING PS	CK	U	L	EWC
RODMARTON MANOR BH	IO	U	L	-
ROWBURY FARM BH	CK	U	L	-
SELHURST PS	CK	U	L	TWU
SEVEN KINGS PS	CK	U	L	EWC
STREATHAM PS	CK	U	L	TWU
TURNFORD WELL	CK	U	L	TWU
WARLEY HOSPITAL, BHA	CK	U	L	-
WATCHTOWER HOUSE BH	CK	U	L	-
WEST PARK HOSPITAL	CK	U	L	-
WHIPPS CROSS HOSPITAL BH	CK	U	L	-
WOODBRIDGE SPRING	IO	U	L	-
WOODS FARM PS	CK	U	L	TWU
ASHDOWN PARK PS	CKU	U	U	TWU
ASTON TIRROLD PS	CKU	U	U	TWU
BARCOTE FARM	CR	U	U	-
BENNETS END	CK	U	U	TWU
BIBURY PS	IO	U	U	TWU
BROOMIN GREEN PS	CK	U	U	3V
BUCKLAND GREEN PS	LGF	U	U	ESWC
BURNHAM PS	CK	U	U	TWU
CHILDRY WARREN PS	CKU	U	U	TWU
CHINNOR PS	UG	U	U	TWU
CHURCH FARM	CR	U	U	-
CLANDON PS	CK	U	U	NSWC
COLD ASH PS	CK	U	U	TWU
DAGENHAM PS	CK	U	U	EWC
DANCERS END PS	CK	U	U	TWU
DAPDUNE ROAD PS	CK	U	U	TWU
DATCHET PS	CK	U	U	TWU
EYDON HALL FARM	LI	U	U	-
FETCHAM PS AT ELMER	CK	U	U	ESWC
FRESDEN FARM	CR	U	U	-
GREYS ROAD PS	CK	U	U	TWU
HAMPDEN PS	CK	U	U	TWU
HOME FARM	CR	U	U	-
LEATHERHEAD PS	CK	U	U	ESWC
LEWKNOR PS	CKU	U	U	TWU
LOWER SWELL RAW	IO	U	U	TWU
MANOR FARM (COMMON BARN)	CR	U	U	-
MANOR ROAD PS, WANTAGE	UG	U	U	TWU
MARLOW PS	CK	U	U	TWU
MEYSEY HAMPTON PS	IO	U	U	TWU
MILLMEAD PS	CK	U	U	TWU
PANGBOURNE PS	CK	U	U	TWU
RADNAGE PS	CK	U	U	TWU
SAVEE FARM	LI	U	U	-
UPPER SWELL RAW	IO	U	U	TWU
UPTON PS	UG	U	U	TWU
WALLINGFORD MALTINGS	UG	U	U	-
WATLINGTON (SPRING LANE PS)	UG	U	U	TWU
WENDOVER PS	CK	U	U	3V
WEST HENDRED PS	UG	U	U	TWU
WITHERIDGE HILL PS	CK	U	U	TWU
WROUGHTON PS	UG	U	U	TWU