

CONTAMINATED SITES

Guidelines for the Vertical Mixing of Soil on Former Broad-Acre Agricultural Land



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PREFACE

Former broad-acre agricultural sites have generally been considered unsuitable for residential development. Previous agricultural practices, particularly the regular application of persistent chemicals, may have caused some of these sites to have elevated levels of metals and pesticides. The soil contamination at these sites is characteristically widespread, with relatively low concentrations of contaminants confined to the surface soils. But the soil contamination needs to be reduced to even lower levels so that these sites do not pose a threat to residents who live on or near them in future.

There is at present no readily available or economically feasible method for remediating large quantities of soil with low levels of contamination. Remedies that are commonly used for other contaminated sites, e.g. off-site disposal or on-site containment, are not feasible on such a large scale because of the lack of available landfills and/or because the relatively low levels of contamination do not justify the high costs involved.

At the request of local government, the NSW Environment Protection Authority (EPA) consulted with NSW Health, NSW Agriculture, the Department of Conservation and Land Management, local government councils from across NSW and with members of the Contaminated Agricultural Land Management Advisory Committee to develop these guidelines for the vertical mixing of soil. The guidelines are aimed at environmental professionals or council staff who want to investigate the feasibility of using vertical mixing, whether for large development projects or single building allotments. Vertical mixing of soil is essentially the process of remediating contaminated surface soils by mixing them with cleaner soils found at greater depths.

To ensure that vertical mixing is a practical and effective means of reducing the levels of contaminants in the soil, the EPA (together with the Coffs Harbour City Council and the Department of Conservation and Land Management) conducted a series of vertical mixing trials in the Coffs Harbour area. The trials successfully demonstrated that vertical mixing of soil results in an homogeneous distribution of the chemicals of concern to concentrations below the human health threshold levels.

The guidelines also contain a number of prerequisites for using vertical mixing. The relevant planning consent authority should ensure that all these prerequisites are satisfied before approving the use of vertical mixing at a site.

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1 INTRODUCTION

The growing demand for residential development in New South Wales is increasing the pressure for the release of former broad-acre agricultural land.

However, previous farming practices on broad-acre agricultural land, particularly the use of various pesticides, may have resulted in elevated levels of arsenic, lead, organochlorine and some other residual pesticides and heavy metals in soil. Some imported fertilisers may also contain elevated levels of heavy metals such as cadmium, and regular use of these fertilisers on the former agricultural sites may also have caused some soil contamination.

These chemicals are of particular concern because of their toxicity and their persistence in the environment.

Soil contamination at these former broad-acre agricultural sites is characteristically widespread but at relatively low concentrations, with the contaminants confined to the surface soils. If these sites are allowed to be developed for residential purposes without any remediation, the contaminants may pose a health risk to future residents living on or near them. As a result, these sites are generally considered unsuitable for residential development unless the levels of contamination are lowered.

There are at present no readily available, practical or economically feasible remedies for such large quantities of soil with low levels of contamination. Remedies that are commonly used for other contaminated sites, including off-site disposal and on-site containment, may not be feasible because of the lack of available landfill space and/or because the relatively low levels of contamination do not justify the high costs involved.

An alternative solution is vertical mixing of soil, the process of remediating contaminated surface soils by mixing them with cleaner soils found at greater depths. At the request of local government, the EPA has prepared these guidelines for the vertical mixing of soil. They replace the previous draft version, *Vertical Mixing Guidance Document for Former Broad-Acre Agricultural Sites* (dated May 1994).

2 THE AIM OF THESE GUIDELINES

These guidelines should help council staff and environmental professionals to investigate the feasibility of using vertical mixing of soil to remediate former broad-acre agricultural lands for large development projects or single building allotments. Vertical mixing may be a practical way of reducing the risks of residential development on former agricultural land that contains chemicals at concentrations above the Australian and New Zealand Environment and Conservation Council (ANZECC)/National Health and Medical Research Council (NHMRC) human health investigation threshold levels.

It is important that developers and planning consent authorities consider and assess the costs, benefits and the human health/ environmental risks of various remedial options. There may be some cases where it is more practical and environmentally favourable to rezone land for a less sensitive land use, e.g. commercial, industrial or open parkland.

2.1 Other references

These guidelines should be used in conjunction with the following documents (see Bibliography for full citations):

- *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites* (ANZECC/NHMRC 1992)
- *Draft Sampling Guidelines for Former Banana Plantation Sites* (EPA 1992)
- *The Health Risk Assessment and Management of Contaminated Sites and Protocol for the Health Risk Assessment and Management of Contaminated Sites* (SA Health Commission 1991, 1993)
- *Methods for Evaluating the Attainment of Cleanup Standards* (EPA 230/02-89-042) (USEPA 1989)
- *Planning Guidelines for Contaminated Land, Circular No. C20* (NSW Department of Planning 1991)
- *Schedule 3 of the Environmental Planning and Assessment Regulation 1980, Circular No. E5* (NSW Department of Planning 1994)
- *Contaminated Agricultural Land Management Advisory Committee Report* (NSW Agriculture 1994).

3 LAND REZONING AND THE DEVELOPMENT APPROVAL PROCESS

ANZECC recently published a position paper, *Financial Liability for Contaminated Site Remediation* (ANZECC 1994), which sets out agreed national principles for attaching financial liability for the remediation of contaminated sites. One of the recommendations of the paper is:

Governments should put in place appropriate mechanisms within the planning process to ensure that potentially contaminated land is not rezoned to allow a more sensitive use without adequate assessment of environmental and human health risks and appropriate remediation where necessary.

In NSW, the primary mechanism for controlling the future use of contaminated sites or potentially contaminated sites is the Environmental Planning and Assessment Act 1979, which is administered by local councils and the Department of Planning. The Department of Planning has also provided some planning and development guidance in its revised advisory circular on contaminated land and *Schedule 3 of the Environmental Planning and Assessment Regulation, Circular E5* (NSW Department of Planning 1994).

It is appropriate that the responsibility for approving the use of vertical mixing should be part of local councils' rezoning and development procedures. As the planning consent authority, the council should ensure that all the prerequisites contained in these guidelines are satisfied before approving an application to use vertical mixing. If the council is in any doubt about a specific application of vertical mixing, or needs help in assessing the level of contamination at a site, the council can seek technical advice from the EPA.

4 THE VERTICAL MIXING PROCESS

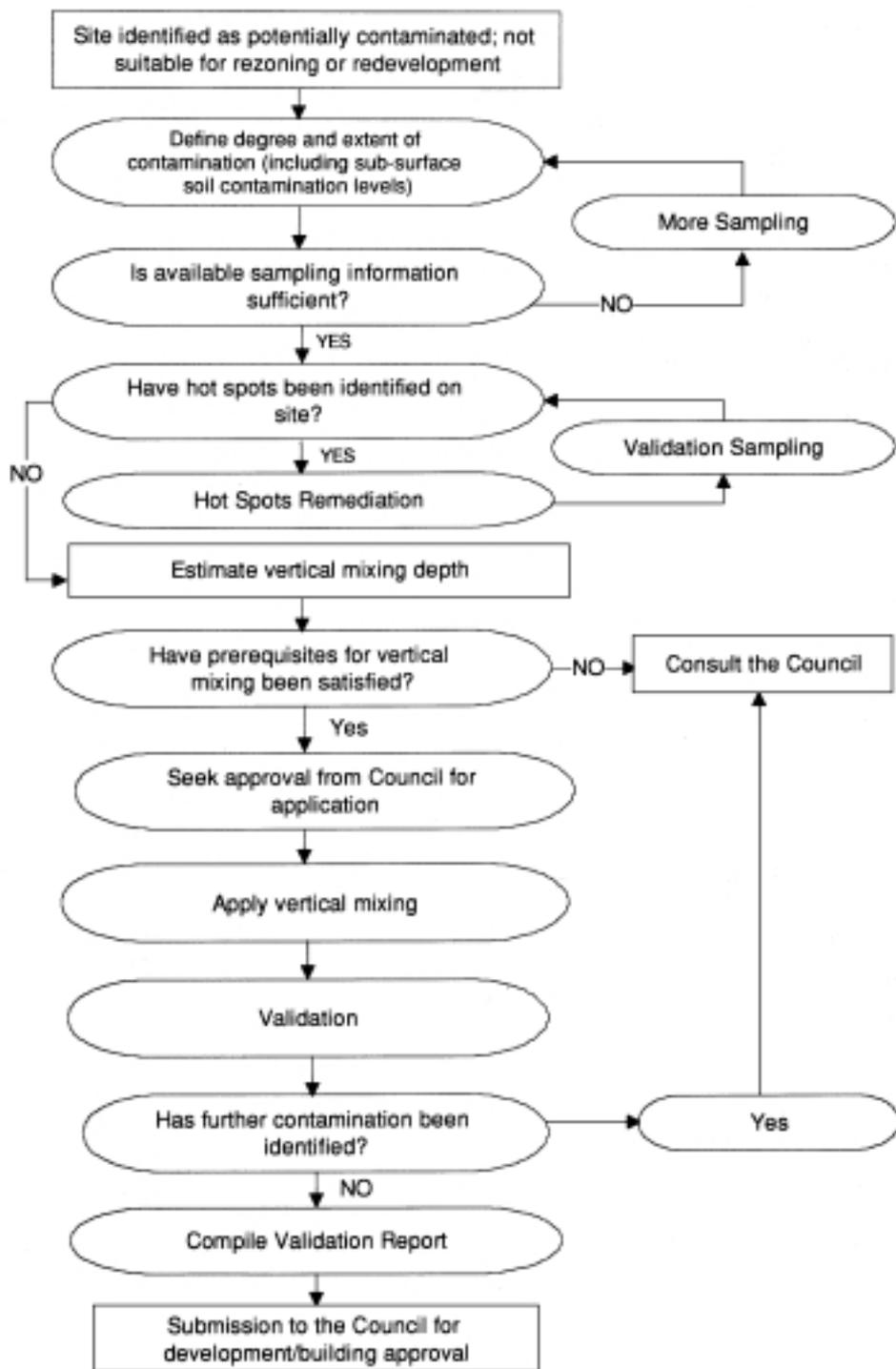
An outline of how to apply the vertical mixing process is shown opposite.

Vertical mixing is basically a process of remediating contaminated surface soils by mechanically mixing them with cleaner soil found at greater depths. This method is based on the theory that the environmental and public health risk from contaminants is a function of the surface soil concentrations of contaminants to which a person is exposed; lowering the concentrations of contaminants lowers the risk to the person exposed to them. Vertical mixing should reduce contaminant concentrations in surface soil to levels that pose an acceptable environmental or public health risk, even in cases where exposure to the soil is continuous and/or over long periods. Vertical mixing should only be applied to areas where the surface soil contains chemicals that are:

- above the ANZECC/NHMRC human health investigation threshold levels, but
- not greater than three times the human health investigation threshold levels.

Precautions should be taken during vertical mixing of soil to minimise lateral mixing.

An outline of the vertical mixing process



5 VERTICAL MIXING TRIALS

In July 1994, to confirm that vertical mixing of soil is a practical and effective method for reducing the levels of contamination at former broad-acre agricultural sites, a series of vertical mixing trials was conducted. These trials were supervised by the EPA, the Coffs Harbour City Council and the Department of Conservation and Land Management.

Three sites in the Coffs Harbour area were selected for the trials. Each of the trial sites satisfied the prerequisites outlined in the draft Vertical Mixing Guidance Document (EPA 1994). Soil management plans, including soil erosion and sediment control plans, were also put in place.

The following equipment was used at different times during the vertical mixing trials:

- dozer ripping, with wing tine only (6 passes)
- dozer ripping with wing tine (2 passes), and mixing with a road stabiliser (3 passes) (homogeneous mixing using the rotary hoeing principle)
- dozer ripping with standard tine (2 passes), followed by blade mixing (1 pass).

The above list is not exhaustive and other machinery may give equivalent or better vertical mixing results. It should also be noted that the vertical mixing process may need to be repeated to ensure that the mixing is effective and that clean-up goals are attained.

The results of the vertical mixing trials have been positive — the mixing resulted in an homogeneous distribution through the soil of chemicals at concentrations below the ANZECC/NHMRC human health investigation threshold levels. However vertical mixing of soil may be less effective where there are rocks and near the boundaries of a site. Special precautions and validation testing may be required to ensure these limitations are addressed.

6 PREREQUISITES FOR USING VERTICAL MIXING

The following conditions must be satisfied to ensure that the vertical mixing process is applied appropriately.

A The degree of contamination and the lateral and vertical extent of contamination have been established

Before the vertical mixing process is applied, the site should be thoroughly investigated. The site investigators should determine the type of contaminants and the extent and vertical profile of soil contamination. Detailed reports should be submitted to the planning consent authorities.

The site investigation and associated reports should comply with the principles outlined in *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites* (ANZECC/ NHMRC 1992).

The EPA recommends that a suitably qualified independent professional be engaged to design the sampling plan and conduct the field sampling.

B The background concentration of the principal contaminant has been assessed

Within the scope of these guidelines, background concentrations are considered to be the concentrations of contaminants in the subsurface soil at the locations where elevated levels of chemicals are found and vertical mixing is proposed.

An assessment of the background concentration of the principal contaminant is essential to ensure that the mass balance of the equation (see C below) is satisfied. The assessment will also confirm whether the ANZECC/NHMRC human health investigation threshold level for the principal contaminant is achievable.

The site assessment should also determine whether there is sufficient depth of clean subsurface soil for vertical mixing. Sites where subsurface soils are acidic or highly saline when brought to the surface are unsuitable for vertical mixing.

C The soil that needs to be vertically mixed is not more than 0.5 metre deep

Vertical mixing of soil is not recommended if the estimated depth of mixing required to achieve a safe contaminant concentration is greater than 0.5 metre. Homogenisation of soil to a depth greater than 0.5 metre may be difficult to achieve.

To estimate the necessary vertical mixing depth, the following equation should be applied:

$$y = \frac{x (a - b)}{0.9 H - b}$$

where:

- y = estimated vertical mixing depth in mm
- x = depth of soil profile in mm in which concentration is 'a' mg/kg
- a = maximum concentration for the principal contaminant in mg/kg
- b = background concentration of the principal contaminant in mg/kg
- H = ANZECC/NHMRC Human Health Investigation Level for the principal contaminant in mg/kg.

The value of 0.9 is a safety factor which takes into account inefficiencies in the mixing process.

Example

Consider a site in which the following results have been established by a statistically defensible assessment program:

Maximum concentration of contaminants on site:

Surface to 100 mm: arsenic 280 mg/kg, dieldrin 20 mg/kg

100–200 mm: arsenic 10 mg/kg, dieldrin 0.1 mg/kg

By applying the above equation:

$$y = \frac{x (a - b)}{0.9 H - b}$$

Mixing depth required for arsenic:

- a = 280 mg/kg
- x = 100 mm
- b = 10 mg/kg (10 mg/kg is the concentration of arsenic in the subsurface soils)
- H = 100 mg/kg of arsenic in soil

Therefore:

$$y = 337.5 \text{ mm.}$$

Mixing depth required for dieldrin:

a = 20 mg/kg

x = 100 mm

b = 0.1 mg/kg (0.1 mg/kg is the concentration of dieldrin in the subsurface soils)

H = 10 mg/kg of dieldrin in soil

Therefore:

y = 224 mm.

In this case, arsenic is the principal contaminant — i.e. arsenic is the chemical that requires a greater depth of mixing.

In this example, vertical mixing of soil to a depth of at least 337.5 mm is required to achieve a level of contamination below the ANZECC/ NHMRC human health investigation threshold level.

D The land does not have any 'hot spots'

For the purposes of these guidelines, a 'hot spot' is defined as an area of land with a contaminant concentration more than three times the ANZECC/NHMRC human health investigation threshold level. For example, an arsenic or dieldrin hot spot will have levels in excess of 300 mg/kg and 30 mg/kg respectively. Vertical mixing should not be used on lands with such excessively high levels of contaminants.

If isolated hot spots are identified at a site, the EPA recommends further sampling to define the extent of these hot spots. Small volumes of contaminated soil should be remediated/managed by other means, e.g. excavation and treatment or, where permitted, disposal at a controlled landfill. Validation testing should also be conducted to ensure that hot spots have been successfully remediated/removed.

E There is no viable alternative technology for remediating the contaminants at the site

If there is no practical destruction process for a contaminant, vertical mixing of soil may be an alternative to landfill or on-site containment (the only other options).

F The contaminants at the site are not volatile

If there are volatile contaminants at the site, vertical mixing of soil may cause the contaminants to be released into the atmosphere. This is unacceptable, and alternative treatment options would need to be investigated.

G The proposed plan for managing the soil at a site has been accepted by the appropriate planning consent authority

Some broad-acre agricultural land is on steep slopes with high average rainfall. Using vertical mixing at such locations may cause soil erosion and instability problems and may also reduce the fertility and productivity of the soil. Vertical mixing should be avoided during months where there is a strong possibility of storms or heavy rainfall.

It is essential that operational and long-term soil management plans are lodged with and approved by the appropriate planning consent authority before the vertical mixing process is used. The proposed soil management plan should be prepared on a site-specific basis and should provide:

- information on rainfall intensity/susceptibility of soil to erosion
- slope factors
- appropriate soil erosion and sediment control plans
- programs for monitoring and maintaining the erosion and sediment control measures
- site rehabilitation plans, including plans for soil compaction, mulching and/or revegetation
- plans to minimise nuisances, e.g. dust
- expert geotechnical advice on potential soil movement (where necessary).

The Department of Conservation and Land Management is currently preparing guidelines for protecting and managing soil resources for proposed vertical mixing sites. Soil management plans should be prepared in accordance with those guidelines when they are made available.

H The site is not situated in an environmentally sensitive area

For the purposes of these guidelines, an environmentally sensitive area is an area that is located:

- within 40 m of a natural water body or wetlands
- on a flood plain
- within a drinking water catchment area
- in a recharge area for groundwater resources either currently being exploited or which may reasonably be expected to be exploited in the future
- in an area with highly permeable soils.

I An Occupational Health and Safety Plan that satisfies WorkCover requirements has been prepared

The OH&S plan should include the following information:

- identification of the chemical of concern and the potential risks faced by remediation workers and the surrounding community
- a safe system of work (work method procedures), during remediation works, for site workers and the surrounding community that will ensure that their health is protected
- a monitoring program during remediation works
- safe limits for the parameters being monitored and action to be taken when these limits are exceeded
- a contingency plan and emergency procedures to be adopted in situations which might arise and which are not covered by normal OH&S procedures
- a list of site supervisors specifying their responsibilities with regard to OH&S
- any precautions for site users after remediation is completed.

7 VALIDATING VERTICAL MIXING

After the vertical mixing process has been used at a site, the effectiveness of the mixing process needs to be validated.

Because the focus of these guidelines is the remediation of former agricultural land to a standard suitable for residential development, it is appropriate to use the ANZECC/NHMRC human health investigation threshold levels as the validation criteria. These threshold levels are based on human health considerations using a risk assessment approach. The results of validation through the 'disturbed profile' of the soil should demonstrate that the contaminant levels are below the human health investigation threshold levels. The threshold levels for the more common contaminants are shown in the table below.

Contaminant	Human health investigation threshold level
Arsenic ¹	100 mg/kg
Lead ¹	300 mg/kg
DDT ^{2,3}	50 mg/kg
Aldrin/Dieldrin ^{3,4}	10 mg/kg

1 ANZECC/NHMRC (1992), Table 1, p. 38
2 Beard (1993)
3 The level is still being considered by the National Health and Medical Research Council.
4 DiMarco (1993)

For other chemicals, refer to ANZECC/NHMRC (1992) or SA Health Commission (1991 and 1993). If ANZECC/NHMRC human health investigation threshold levels are not available for a particular contaminant, environmental investigation levels should be used.

If a site owner proposes to use former agricultural land for a purpose other than residential development, the above human health investigation threshold levels may not apply.

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APPENDIX A

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