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The Institute of Quarrying

Good Practice Guide for Handling Soils in Mineral Workings

GOOD PRACTICE GUIDE FOR HANDLING SOILS

In Mineral Workings

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The information in this publication is general guidance on the best practices and approaches to soils guidance.
Specialist advice should always be sought if you need more details about what action to take in your own circumstances.

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GOOD PRACTICE GUIDE FOR HANDLING SOILS

In Mineral Workings

PART TWO: Model Methodology

- Sheet K -

Hybrid Soil Replacement with Excavators, Bulldozers and Dump Trucks
- Modified Layer by Layer Practice

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Preface

The purpose of Sheet K of the guidance is to provide a model method of best practice where the hybrid combination of excavator and bulldozer with dump trucks are to be used to replace soil using the modified 'layer by layer' practice.

The guidance is intended for use by planning officials, statutory consultees, mineral operators and their supporting teams and specialist consultants, and earth-moving contractors, their site supervisors and machine operators.

Successful soil handling schemes are dependent on the soil resources being clearly identified and the conditions in which they are to be handled. This information should be contained in the Soil Resource & Management Plan (SRMP) and communicated to those involved in its implementation.

Key issues to be addressed are:

i) Avoiding conditions when soils are wet/ plastic during handling
ii) The minimisation of soil compaction caused by trafficking and soil wetness
iii) Using appropriate remedial treatments where these are necessary
iv) Minimising soil loss, and mixing of soil layers or different soil types.

The SRMP should specify the type of earth-moving machinery and soil handling practice, and the soil wetness condition (see Part One of the Guidance) to be deployed to achieve the planned after use, soil functioning, and the environmental and ecosystem services. It is to be communicated in full to all involved and in particular to the supervisors and machine operators by appropriate means; including tool-box talks and site demonstrations. Supervision by trained supervisory staff is essential, as are monitoring and reporting.

The guidance does not specify the size or model of equipment as this is left to the mineral operator and contractor to specify and provide. The machines must be of a kind which are appropriate for the task and the outcomes required, and to be able to carry out the work safely and efficiently.

Should the agreed methodology need to be modified or changed significantly, this should be agreed in advance with the mineral planning authority. The SRMP should include a mechanism whereby unexpected less significant changes can be quickly resolved through consultation between the operator, the planning authority and statutory consultee, and soil specialist.

All persons involved in the handling of soils must comply with all relevant legislation with respect to Health and Safety, in particular the Health and Safety at work Act 1974 and in the case of mineral extraction operations, The Quarries Regulations 1999 and its relevant statutory provisions; in particular those aspects which relate to the construction and removal of tips, mounds and similar structures. These requirements take preference over any suggested practice in this Sheet and the SRMP should have taken these into account.

The users of this guidance are solely responsible for ensuring it complies with all safety legislation and good practice, including the manufacturer's specifications for the safe operation of the specific machines being used, and that all machines are in a good condition and well maintained and are suitable for the task. It is important that those involved in the operation of earth moving machines are competent and have the necessary training and certification.

Introduction

In this soil handling option, back-acting excavators are used to replace the subsoil resources tipped from dump trucks and, specifically low ground pressure bulldozers, are used to spread the topsoil layer. It is referred to as a version of loose soil tipping in DEFRA's Construction Code of Practice for the Sustainable Use of Soils on Construction Sites.

The practice involves the sequential building up of the soil layer(s) identified in the Soil Resource & Management Plan (SRMP) using an excavator to spread the subsoil to final level and a bulldozer to spread the topsoil.

The subsoil is placed first as a series of advancing strips within the safe and efficient operational reach of the excavator boom which defines the width of each successive subsoil strip. On the completion of each subsoil strip before the next is soiled, the topsoil is tipped onto the subsoil for spreading by the bulldozer later.

This method differs from the standard excavator method (Sheet D) in that the topsoil is spread by a bulldozer and over a layer of subsoil.

The procedure for spreading of the topsoil is similar to the practice set out in MAFF 2000, Sheet 15.

It is a preferable practice to the bulldozer windrow/ peninsular method set out in Sheet H as the dump trucks do not traffic the topsoil and risk causing additional severe compaction.

Unlike the stripping and storage practices, the replacement of soils is usually in concert with other work to remediate soil conditions such as compaction (**Sheets N & O**) and removal of stones/ non-soil debris (**Sheets L & M**). These actions have their own practices which need to be integrated into this model methodology of soil handling. The need for these will have been specified in the SRMP and/or in the soil replacement conditions attached to the planning consent, or as determined by the soil specialist during the soil stripping/storage/ replacement operations.

The following guidance is only relevant to multiple layered soils.

Advantages & Disadvantages

The advantages of this machinery combination and handling practice are several:

i) Provided the soils are not put into storage mounds, it may result in soil profiles with the less compacted (upper) subsoils which may not require remedial treatment or only minimal of action
ii) It can be easy to create localised changes in subsoil types and variation in horizon depth
iii) It is likely to result in less soil loss and mixing than the excavator only practice
iv) The layer by layer system may be quicker to complete than the bed/strip only practice, provided that remedial treatments are not required of the subsoil
v) It can be moderately flexible in responding to stoppages and restarts due to wet weather
vi) There is some certainty that a transpiring vegetation cover can be established during the soil replacement programme.

The disadvantages are several:

i) The deployment of two different handling methods requires a high level of supervision, skill and discipline in its deployment, and is best suited to experienced operators
ii) There is risk of compaction of the top- and upper subsoil layers by the repeated trafficking of the bulldozer, even if a low ground pressure machine is used. Hence, subsequent remedial treatments are likely to be relied upon
iii) It is slower than both the excavator combination with the bed/strip and windrow practices because of the dual handling practices
iv) Without good control and regular monitoring of soil layer depths, use of profile boards or machine fitted GPS it can be harder to gauge the rate of use of subsoil resource
v) It is not suited both to the replacement of low bearing strength soils (eg peat & organic topsoil), and thin and 'patterned' topsoil layers
vi) Where remedial work is relied upon, the

sequential tipping of topsoil and the laying of the next subsoil strip will have to be delayed until the strip in question is treated

vii) Steep gradient/complex topographies may limit the safe and practical deployment of this handling practice.

Suitability

The hybrid excavator-bulldozer and dump truck combination with the modified layer by layer handling practice methodology is considered by DEFRA as an acceptable alternative practice to loose tipping. However, there is a risk of compaction in the topsoil layer and in the underlying (upper) subsoil, and the implementation of remedial treatments may be restrictive. As it is more reliant on remedial treatment than the standard excavator method (**Sheet D**), it is also more dependent on the soils being in a dry condition. Because of this it is considered only suitable for medium and highly resilient soils (see **Table 7 in Part One and Supplementary Notes 3 & 4**), and should not be considered an alternative to the excavator only practice (**Sheet D**) without justifiable reasons.

Whilst the hybrid method is not considered to be the 'best practice', it may be acceptable in circumstances where

i) The subsoil(s) are of medium to high resilience to compaction (see **Table 7 in Part One, and Supplementary Notes 3 & 4**) and when decompaction treatments can be more relied upon to be effective because of i) a lower risk of soil wetness (low rainfall areas/prolonged dry conditions) and/or ii) the availability of effective decompaction tools

ii) The limitations of compaction and stones/debris is restricted to the topsoil layer

iii) The intended after use, and environmental and ecosystem services are less dependent on maintaining functional characteristics such as soil porosity and hence drainage and aeration, plant available water capacity, and low resistance to plant root growth. This may include the less productivity agricultural and forestry land, some types of natural habitats, and where water storage/infiltration is of less importance for the risk of flooding. Where the soils are stored prior to replacement, effective remedial treatment may have to be relied upon

iv) The soils have been placed into storage stockpiles

v) It is more suited to southern and eastern, and lowland locations, and particularly when there are the more certain weather patterns.

MODEL METHODOLOGY

Basic Soil Replacement Operation

K.1 The following is the basic model methodology using the hybrid method of excavators, bulldozers and dump trucks with a modified layer by layer practice. It is presented here, firstly without any remedial interventions to give clarity of the methodology. Later the methodology is repeated to demonstrate how the interventions can be integrated into the soil replacement process.

K.2 Key operational points to minimise the risk of severe soil compaction and soil wetness are summarised in Boxes K.1 and K.2.

Box K.1 - To minimize compaction:

- The bulldozer is to only operate on the topsoil
- The dump trucks should only operate on the 'basal'/non-soil layer and not run on the replaced soil layer(s)
- The excavator must only operate on the basal layer
- The machines are to only work when ground conditions enable their efficient operation
- The bulldozer should make the minimal number of passes over the soil as possible
- If compaction has been caused, then measures are required to treat it (see **Sheets N & O**)

Box K.2 - To minimise soil wetness and re-wetting:

- The modified layer by layer system provides a basis to regulate the exposure of lower soil layers to periods of rain and a means of maintaining soil moisture contents. The soil profile within the active strip should be completed including the topsoil layer before rainfall occurs and before replacement is

suspended
- measures are required to protect the face of the soil layer from ponding of water and maintain the basal layer in a condition capable of supporting dump trucks
- The area to be restored is to be protected from in-flow of water, ponding etc. Wet sites must be drained in advance. Before the operation starts the basal layer should be to level and clean.

K.3 The timing of soil handling operations in England and Wales is set out in **Part One, Supplementary Note 4**. For directly placed soils this will use the in situ soil wetness protocol for soil stripping operations to determine the timing for soil replacement (Box K.3). For soil that has been stored, the relaying operation should be governed by the weather (rainfall) criteria set out in Box K.4. Here, the operation will generally need to be completed no later than the end of September unless the establishment of a satisfactory vegetation cover can be assured.

K.4 Soil handling is not to take place during rain, sleet or snow and in these conditions should be prohibited if unsafe for machine operations. Prior to commencing operations, a medium/long term weather forecast should be obtained which gives reasonable confidence of soil handling being completed without significant interruptions from rainfall events. The criteria set out in Box K.4 are to be used to determine whether soil handling should cease or be interrupted with the occurrence of rain.

K.5 All machines must be in a safe and efficient working condition at all times. The machines are to only work when ground conditions enable their efficient operation. The work should only be carried out when the basal layer supports the machinery without ruts or is capable of repair/maintenance. Otherwise the operation is to be suspended until suitable remedial measures can be put in place.

K.6 The operation should follow the detailed SRMP replacement plan showing the soil units to be replaced, haul routes and the phasing of vehicle movements. The soil units should be defined on the site with information to distinguish types and layers, and thickness and conveyed to the operational supervisor/operator. Different soil units to be kept

Box K.3 - Test for Dry and Friable Soils

Soil tests are to be undertaken in the field. Samples shall be taken from at least five locations on the soil handling area and at each soil horizon to the full depth of the profile to be recovered/ replaced. The tests shall include visual examination of the soil and physical assessment of soil consistency.

i) Examination
- If the soil is wet, films of water are visible on the surface of soil particles or aggregates (e.g. clods or peds) and/or when a clod or ped is squeezed in the hand it readily deforms into a cohesive ‘ball’ means **no soil handling to take place**
- If the sample is moist (i.e. there is a slight dampness when squeezed in the hand) but it does not significantly change colour (darken) on further wetting, and clods break up/crumble readily when squeezed in the hand rather than forming into a ball means **soil handling can take place**
- If the sample is dry, it looks dry and changes colour (darkens) if water is added, and it is brittle means **soil handling can take place**

ii) Consistency
First Test
Attempt to mould soil sample into a ball by hand:
- Impossible because soil is too dry and hard or too loose and dry means soil handling can take place
- Impossible because the soil is too loose and wet means no soil handling to take place
- Possible - GO TO SECOND TEST

Second Test
Attempt to roll ball into a 3mm diameter thread by hand:
- Impossibe because soil crumbles or collapses means **soil handling can take place**
- Possible means **no soil handling to take place**

NB: It is impossible to roll most coarse loamy and sandy soils into a thread even when they are wet. For these soils, the Examination Test alone is to be used.

Box K.4 - Rainfall Criteria:

- In light drizzle soil handling may continue for up to four hours unless the soils are already at/ near to their moisture limit
- In light rain soil handling must cease after 15 minutes
- In heavy rain and intense showers, handling shall cease immediately.

In all of the above, after rain has ceased, soil tests shall be applied to determine whether handling may re-start, provided that the ground is free from ponding and ground conditions are safe to do so.

Box K.5 - Orientation of the Excavator

Usually, the excavator is orientated and operates with its tracks at 90° to the axis of the strip being replaced as this is the most stable operating position.

Whilst the reach of the boom and hence the width of the bed/strip can be significantly increased by orientating it with the tracks parallel to edge of the soil being spread, this may affect the stability of the excavator, particularly on a gradient or where the basal layer has a low baring capacity. Hence, its safe deployment needs to be checked before its adoption.

Box K.6 - Choice of Bucket Type

For hard /stony soils toothed buckets are needed. Where the mixing of soil layers at their interface is to be minimized, a bucket with a 'blade' is preferable where the soil is 'soft' and free of large stones or particularly stony stone free. Where there is a watching archaeological brief, the use of bladed buckets will normally be required.

Similarly, the choice of bucket type, whether it is a standard 'digging'/bulking or wide ditching type will depend on the soil strength and stoniness. The preferred type of bucket to place the subsoils is usually a digging/bulking bucket with an attached blade or a wide ditching bucket, but a toothed bucket can be used.

separate are to be marked out and information to distinguish types and layers, and ranges of thickness needs to be conveyed to the operational supervisor/machine operator. Detailed daily records should be kept of operations undertaken and site and soil conditions.

K .7 Profile boards should be used to control soil horizon thickness in each strip and overall levels achieved verified using soil pits. Allowances (i.e. a bulking factor) should be made for any settlement that may take place of the replaced loose soil.

K.8 The excavator and dump trucks are only to stand, work and travel on the basal/formation layer, and the bulldozer is to only operate on the topsoil after it is tipped onto the subsoil.

K.9 The excavator placed strip width and axis is to be demarcated. The strip width is determined by excavator boom length less the stand-off to operate; typically, about 3-4m (Box K.5). Excavators with long booms ('long reach') can be used, but may be more restricted by gradient limitations, and require skilled and experienced operators.

K.10 The type of bucket to be used largely depends on the nature of the soil (Box K.6).

K.11 The number of subsoil strips to be soiled before the sequentially tipped topsoil (**Figure K.3**) is spread to final level over the subsoil layer depends on the soiling capacity for the day's work as no subsoil should be left uncovered.

K.12 The dump truck reverses up to edge of the first strip to be subsoiled and tips the subsoil, without the wheels riding onto the basal layer (**Figures K.1 & K.2**). The dump truck should not drive away until all the subsoil is deposited within the strip without spillage; this may require assistance from the excavator to 'dig away' some of the tipped soil. The excavator is to spread the tipped subsoil to full thickness by digging, and using the pushing and pulling action of bucket.

K.13 Each load of subsoil should be spread following tipping before another is tipped. Should the spread soil comprise of large blocks (>300mm), normally these should be broken down by using the excavator bucket into smaller pieces before the next load is spread. The process is repeated until the strip is completely covered with the required depth of the subsoil layer.

K.14 On completion of the first subsoil strip, the topsoil needed to cover the soiled strip is to be tipped onto the subsoil. The dump truck reverses up to edge of the subsoil strip and tips the topsoil, without the wheels riding onto the subsoil (**Figure K.3**). The dump truck should not drive away until all the soil is deposited within the strip without spillage (see Box K.7); this may require assistance from the excavator to 'dig away' some of the tipped soil. The topsoil is to be spread to final depth after the completion of the further strips of subsoil (**Figure K.3**).

Box K.7 - Soil Profiles Greater Than 1m Thickness

When the replaced soil profiles reach about 1m in height from the basal layer it may not be possible to discharge the load from smaller dump trucks directly onto the previously placed lower layers because of the height of the dump truck body. The preferred solution is to tip the soil against the partially completed profile as heaps without the dump trucks rising onto or reversing into the placed material. The soil material is then lifted by the excavator onto the profile. It is considered preferable to accept some limited soil losses rather than to contaminate the topsoil with overburden. The loss of top-soil is minimised if the basal/ formation layer is kept to level and clean.

K.15 On completion of the first subsoil strip and tipping the topsoil, repeat the process until sufficient strips have been placed to provide an adequate area for the bulldozer to work efficiently in spreading the topsoil to the final depth (**Figure K.3**).

K.16 At the end of each day the current strips should be completed if rain is forecast. If during a day it is evident that a full strip cannot be completed, then complete the part of a strip that has been started to final topsoil level.

K.17 At the end of each day, or during the day if interrupted by rain, make provisions to protect base of restored strip from ponding/runoff by sumps and grips, and also clean and level the basal layer. At the start of each day ensure there is no ponding in the current strip or operating areas, and the basal layer is to level with no ruts.

Method with Integration of Remedial Actions

K.18 The following is the model methodology using the hybrid excavator, bulldozer and dump truck practice with the remedial interventions to demonstrate how integration is to be achieved. The key operational points to minimize the risk of severe soil compaction and soil wetness are summarised in Boxes K.1 and K.2 above.

K.19 Usually there will be a need for remedial treatment during the replacement operation with this machinery combination and handling practice. The placement of the stripped soils in storage is very likely to result in the need for remedial treatment. Where compaction occurs, treatment will need integrating into the replacement process as will any need for the removal of stones or non-soil debris. Both decompaction and removal of materials are covered in separate **Sheets L to O**. Where required, the early installation of under drainage can either be integrated sequentially during the replacement of the soils or later during the aftercare period.

K.20 Box K.8 sets out some of the remedial options/ combinations to facilitate decompaction, and where necessary, the removal of stones and non-soil debris for a final profile comprising a basal layer, subsoil and topsoil layers. Except for Option 3, these actions need to be undertaken sequentially as each soil strip is placed.

K.21 Prior to commencing operations a weather forecast should be obtained which gives reasonable confidence of soil replacement proceeding without interruptions from rainfall events (Box K.4).

Box K.8 - Integration of Decompaction & Stone/ Debris Removal

Option 1: is where the basal layer needs to be treated but is left until the subsoil is placed when both are decompacted together, followed by the decompaction of the topsoil and subsoil layers together (and basal layer) using tines that are long enough. This option is not suited to digging where the soil horizons would be mixed.

Option 2: is where each layer is treated separately by either tines or digging.

Option 3: is where the basal layer is treated or left untreated, followed by the placement of the subsoil and topsoil layers, which are to be decompacted by the use of tines. In the case of deep horizons this option can be limited by the capability of the machinery, the tines or bucket used. This option is not suited to digging where the soil horizons would be mixed.

K.22 If significant rainfall occurs during operations, the replacement must be suspended, and where the soil profile has been started it should be replaced to top-soil level. Replacement should not restart unless the weather forecast is expected to be dry for at least a full day and the soils are in a dry condition (Box K.3).

K.23 The operation should follow the detailed replacement plan in the SRMP showing the soil units to be replaced, haul routes and the phasing of vehicle movements. The soil units should be defined on the site with information to distinguish types and layers, and thickness and conveyed to the operational supervisor/operator. Different soil units to be kept separate are to be marked out and information to distinguish types and layers, and ranges of thickness needs to be conveyed to the operational supervisor/operator. Detailed daily records should be kept of operations undertaken and site and soil conditions (including the removal of stones and other non-soil debris that needs to be removed), and the results of the effectiveness of the work undertaken, and any need for additional remedial treatments.

K.24 Profile boards should be used to control soil horizon thickness in each strip and overall levels achieved verified using soil pits to verify. Allowances (i.e. a bulking factor) should be made for any settlement that may take place of the replaced loose soil.

K.25 The excavator and dump trucks are only to stand, work and travel on the basal/formation layer. Only where the remedial work involve the use of a bulldozer does machinery have to traffic the basal layer and subsoil(s) being treated, as the excavators work from the basal layer.

K.26 The initial strip width and axis is to be demarcated. Strip width is determined by excavator boom length less the stand-off to operate; typically, about 3-4m (see Box K.5). Excavators with long booms (‘long reach’) can be used, but may be more restricted by gradient limitations, and require skilled and experienced operators.

K.27 Where there is a requirement to treat compaction and/or remove stones/non-soil debris in the basal layer, these need to be carried out along the demarcated strip prior to the laying of subsoil.

K.28 Decompaction of the basal layer can by digging with the excavator bucket (**Sheet N**) or by bulldozer drawn tines (**Sheet O**). Stone removal may require prior ripping/digging to release them from the basal material, followed by the excavator using a stone-rake bucket (the stone to be loaded on a dump truck and removed (**Sheet L**) or bulldozer with an excavator on the untreated basal layer loading the dump truck (**Sheet M**).

K.29 On completion of treating the basal layer, the loaded dump trucks reverse up to edge of the strip and tip the subsoil without the wheels riding onto the treated basal strip (**Figures K.1 & K.2**). The dump truck should not drive away until all the soil is deposited within the strip without spillage over the basal layer; this may require assistance from the excavator to ‘dig away’ some of the tipped soil. The excavator is to spread the tipped subsoil to full thickness by digging, and using the pushing and pulling action of bucket.

K.30 Each load of subsoil should be spread following tipping before another is tipped. Should the spread soil comprise of large blocks (>300mm), normally these should be broken down by using the excavator bucket to break the blocks into smaller pieces before the next load is spread. The process is repeated until the strip is completely covered with the required depth of the subsoil layer (**Figure K.2**).

K.31 The process of remedial treatment of the basal layer is repeated prior to each successive subsoil strip being soiled.

K.32 Where remedial treatment of the subsoil is required, either this is achieved one strip at a time (as for the basal layer) using excavators standing on the untreated basal strip (**Sheets L & N**) or by bulldozer methods (**Sheets M & O**) working on the subsoil surface where several strips are placed (see K.34 below).

K.33 Following the completion of the subsoil remedial treatments strip by strip, the topsoil is either tipped strip by strip when using the excavator options (**Sheets L & N**) or if several strips of subsoil are placed the topsoil is tipped along the final leading edge of the treated subsoil layer when using the bulldozer treatment options (**Sheets M & O**). In the latter the maximum number of subsoil strips to be soiled depends on the effective distance the low ground pressure bulldozer can push and spread the topsoil to depth the soil (with the minimal number of passes) from the advancing edge of the strips.

K.34 Where the remedial treatments are to be undertaken on the finished subsoil surface it is generally limited to the bulldozer option (**Sheets M & O**) because of the risk of further compaction from the excavator and dump truck option (**Sheets L & N**), although it is possible to arrange for the operations so that there is minimal trafficking and the retreating excavator treats any compacted areas. There is also the option of ripping with bulldozer tines (**Sheet O**) to treat compaction in the top- and subsoil layers together.

K.35 The sequentially tipped topsoil on the strips is pushed out to the final level of the subsoil by the minimal number of passes possible (**Figure K.3**) or from the mound on the leading edge of a series of subsoil and treated strips.

K.36 Where there is a requirement for remedial treatments in the topsoil layer, this is undertaken on the finished topsoil surface.

Whilst it is generally limited to the bulldozer option (**Sheets M & O**) because of the risk of further compaction from the excavator and dump truck option (**Sheets L & N**), it is possible to arrange for the operations so that there is minimal trafficking and the retreating excavator treats any compacted areas. There is also the option of ripping with bulldozer tines (**Sheet O**) to treat compaction in the top- and subsoil layers together.

K.37 On completion of the topsoil layer the processes outlined above should be repeated for the next block of strips until the whole area to be restored is completed. Before the operation starts the basal layer should be to level and clean.

K.38 At the end of each day the current strip must be completed if rain is forecast. If during a day it is evident that a full strip cannot be completed, then complete the part of a strip that has been started.

K.39 At the end of each day, or during the day if interrupted by rain, make provisions to protect base of restored strip from ponding/runoff by sumps and grips, and also clean and level the basal layer. At the start of each day ensure there is no ponding in the current strip or operating areas, and the basal layer is to level with no ruts.

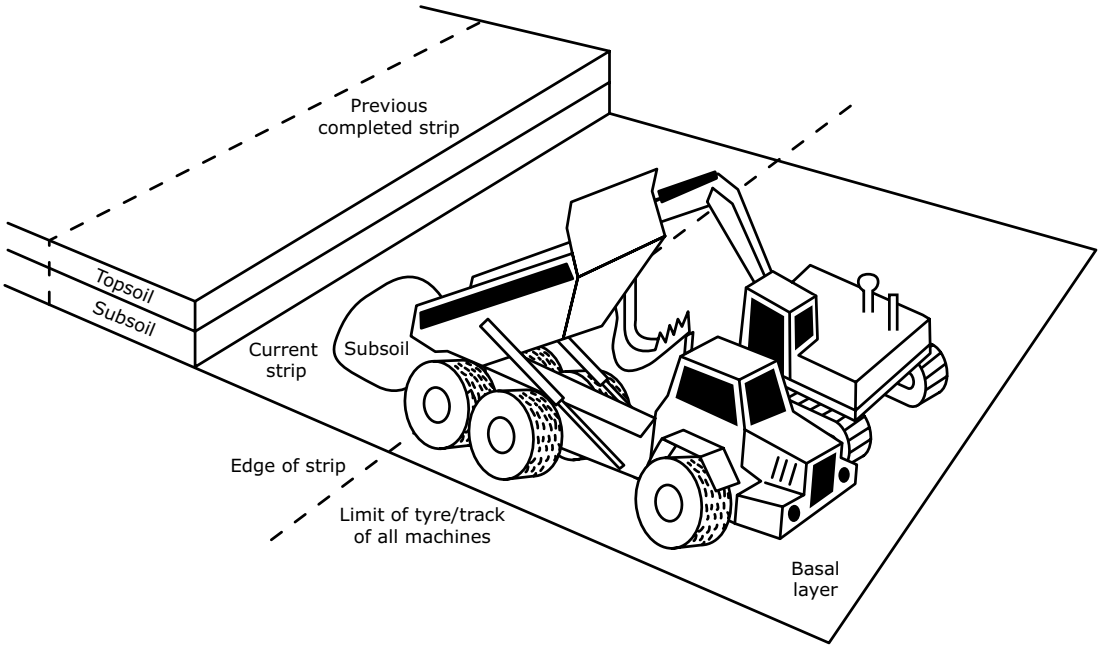

Figure K.1: Soil replacement with excavators and bulldozers using hybrid method: Subsoil.

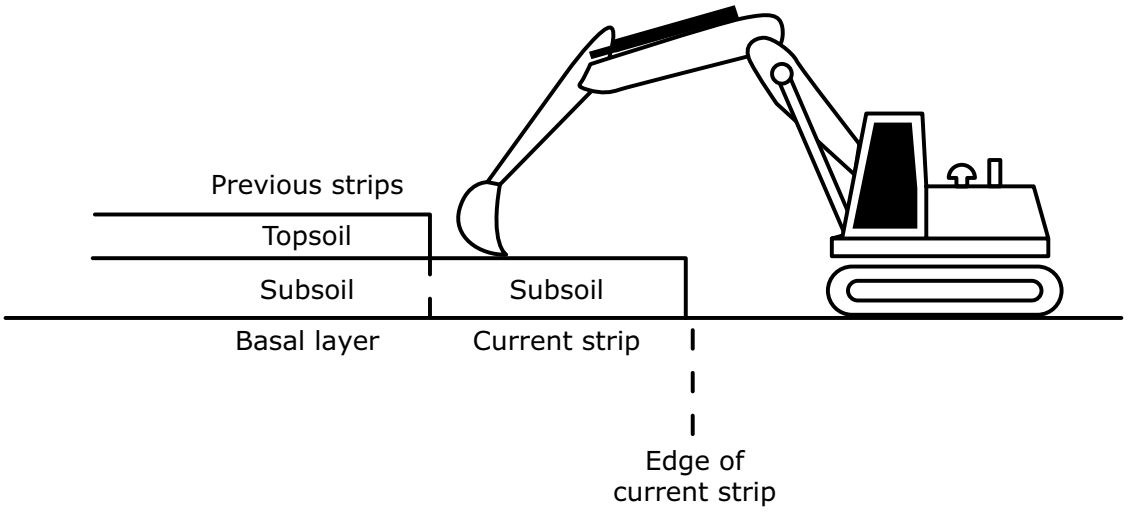

Figure K.2: Soil replacement with excavators and bulldozers using hybrid method: Subsoil.

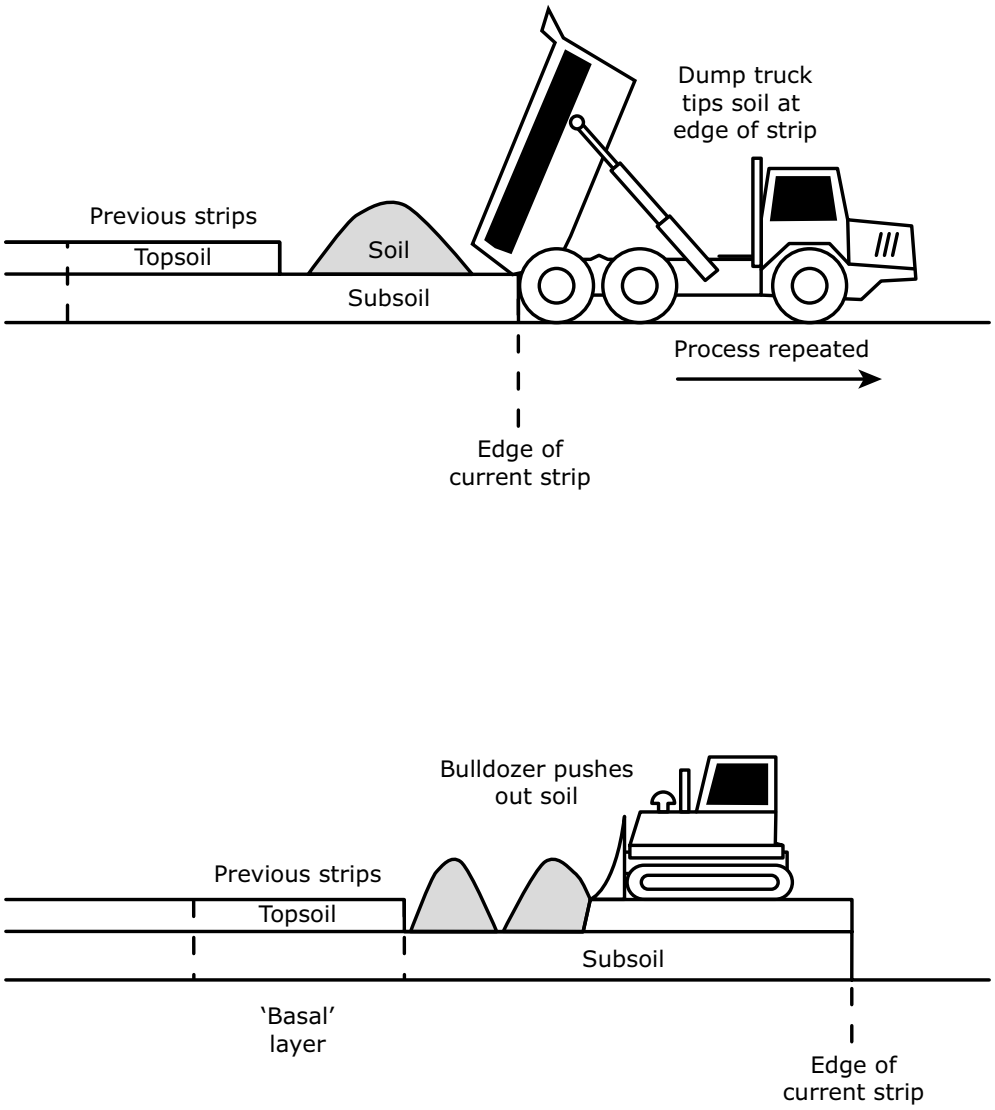

Figure K.3: Soil replacement with excavators and bulldozers using hybrid method: Topsoil.