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MANAGER MATERIALS ENGINEERING

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## REVISION RECORD

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ABSTRACT

This guideline is a summary of Main Roads WA techniques and aids for the investigation, location and extraction of naturally occurring roadbuilding materials in Western Australia. For road pavement construction in regional areas, the most sought after materials are natural deposits of gravels.
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1. INTRODUCTION

This guideline is intended to assist personnel involved in the search for natural materials suitable for roadworks by documenting techniques which have been successfully used in the past by experienced staff.

Because of the very significant reductions in road building costs due to the use of natural materials, the material survey or "Gravel Search" is considered to be one of the most important functions of a regional materials laboratory.

The potential saving can be illustrated by comparing the cost of crushed rock base in regional areas which is of the order of $30 per cubic metre, and more in remote locations, with the cost of natural material which is up to about $10 per cubic metre to investigate, locate, access and stockpile, and to rehabilitate the pit area.

A kilometre of typical rural road requires 3,000m³ of pavement material. The use of natural material can thus represent a saving of about $60,000 per kilometre. Approximately 15,000km of highways and sealed main roads have been constructed in Western Australia. In addition, the road network includes more than 150,000km of secondary and local roads.

Materials staff should be aware however, that a manufactured rock base is expected to be of consistent quality and to behave in a predictable and well understood manner compared to natural materials which are usually variable and carry higher risks of substandard performance. But these risks can be minimised by careful quality control during stockpiling and careful mixing during construction. Other deficiencies can often be overcome by modifying the material with small amounts of sand, lime or cement.

Despite these additional risks, significant cost savings are still possible by using naturally occurring materials.

1.1 Abbreviations

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<tr>
<td>MRWA</td>
<td>Main Roads WA</td>
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<tr>
<td>DER</td>
<td>Department of Environment Regulation (Previously DEC)</td>
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<td>DMP</td>
<td>Department of Mines and Petroleum</td>
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<td>DOL</td>
<td>Department of Lands</td>
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2. BACKGROUND

2.1 Basic Process

In order to maximise cost benefits and to minimise wastage of the very finite reserves of suitable material which remain, it is essential that correct procedures are implemented in all phases of work associated with gravel pits from the search to final usage of the material on the road.

There is no standard method for locating and evaluating road building materials, but unless the deposits are obvious, the following process should be followed:

- Desktop planning to define the search area
- Contact with land owners to gain access to the land
- Investigation to identify prospective individual deposits
- Evaluation of the deposits in detail to locate suitable deposits
- Arranging access to the material
- Extraction of the material
- Rehabilitation of borrow pits

A materials survey is usually initiated as a result of a specific project requirement, however during periods of low work demand, most regional materials laboratories carry out searches for materials for future construction programs or to secure strategic deposits in areas where materials are difficult to obtain.

The materials could be required for:

- New Alignments
- Reconstruction
- Widening
- Maintenance

The required materials will be mainly for use as basecourse or sub-base but other materials required could be for fill, primersealing, concrete or for rock armour embankment protection.
2.2 Road Pavement Structure

The wearing surface may be asphalt or bituminous seal, or in the case of an unsealed road, the upper surface of the base material. The purpose of the wearing surface is to provide a durable layer to resist deterioration of the pavement from tyre friction and to prevent water from entering the pavement.

The base is that part of the pavement which can support the load of traffic without permanent deformation and reduces stresses and strains on the subgrade to acceptable limits.

Sub-base is, in effect, an inferior basecourse material. The purpose of a sub-base is to reduce the necessary basecourse thickness and thus cost. Sub-base material may have wider grading limits, can be much coarser and does not required the same high strength as basecourse. A greater proportion of materials are therefore acceptable for sub-base with a correspondingly lower cost.

Subgrade is the material immediately below the sub-base. It may consist of the material at natural ground level, it may be material exposed in a cutting or it may be fill material.

The purpose of fill material is to raise the pavement to improve drainage or to improve the vertical alignment of the road. Where possible, granular low plasticity material should be used, however most materials may be used for fill including heavy clays.
2.3 Physical Properties Affecting Material Performance

2.3.1 Particle Size Distribution (Grading)

A material with an ideal particle size is one which, after compaction, allows each particle size to fit into the voids created by the inter-particle contact of the next larger size in the range. This condition allows a dense matrix of material to be easily compacted to a state of high stability.

A material which has an excess of fines will be difficult to compact and will have a poor wet strength. If the material is excessively deficient in fines it will cause a harsh and permeable surface which will ravel easily.

2.3.2 Clay and Silt Content

Since clay provides cohesion, some clay is desirable in a pavement especially on shoulders or unsealed pavements where the clay also tends to waterproof the material and allows water to be shed.

Too much clay however, causes the material to weaken rapidly in response to small increases in moisture content.

A high proportion of silt allows positive pore water pressure to develop at low moisture contents due to the predominance of small sized voids. This condition causes a reduction in the frictional component of a soil's shear strength which is highly undesirable.

2.3.3 Particle Shape

A moderately angular particle shape is desirable so that a good mechanical interlock is created which will resist disorientation of particles after compaction.

2.3.4 Maximum Particle Size

Maximum particle size affects both stability and workability. In general, the largest size particles which can be used and still provide a good surface finish should be used. In practice a particle size of no greater than 30mm is desirable.
2.3.5 Particle Strength and Durability

Individual particles should have sufficient strength to resist degradation due to physical effects and should be chemically durable.

2.4 Basecourse and Sub-base Material Types

The best naturally occurring gravel is generally considered to be ironstone laterite gravel. Many laterites are well graded and have similar strength characteristics and durability as a basecourse manufactured from crushed rock. Laterite gravels are very common in Western Australia however, quality varies widely and deposits are often unsuitable.

Although laterites are the most sought after gravels, natural gravels of almost every common rock type have been successfully used as basecourse in Western Australia.

Some common basecourse materials are described below. The photographs show the various material at about half natural size.

2.4.1 Laterite Gravel

The term "laterite gravel" loosely describes either laterite or bauxite gravels.

Laterite and bauxite are produced when seasonal leaching over millions of years depletes the zone between the surface and the water table of more readily dissolved minerals leaving hydrated iron oxides and hydrated aluminium oxides respectively.

In the south of Western Australia, laterite gravel is usually underfilled with low plasticity fines. Despite low tensile and cohesion strength characteristics the gravels usually perform very well. In the north of the state these gravels are more likely to be overfilled with plastic fines.

The colour can range from very pale yellow to a dark brown.

Plates 1, 2 and 3 show examples of laterite gravel.
PLATE 1
TYPICAL LATERITE FROM THE DARLING SCARP
EAST OF PERTH
PLATE 2
COARSE LATERITE GRAVEL FROM NEAR PAYNES FIND ON GREAT NORTHERN HIGHWAY
PLATE 3
FINE PLASTIC LATERITE GRAVEL FROM NEAR
MEEKATHARRA ON GREAT NORTHERN HIGHWAY
2.4.2 Limestone Gravel

Limestone gravel is formed by weathering of parent calcareous sedimentary rock which was formed in the ancient seabeds.

The gravels can be found over most of the state and are not just associated with the coastal strip.

Some limestone gravel can be similar in appearance to laterite while others are obviously of marine origin with many shell and fossil fragments present.

In the south of the state, limestone gravels are produced by quarrying and crushing coastal limestone rock.

Some examples of limestone gravel are shown in Plates 4, 5, 6 and 7.
PLATE 4
LIMESTONE GRAVEL (POPCORN GRAVEL) FROM
BULLARA STATION ON THE MINILYA - EXMOUTH ROAD
PLATE 5
LIMESTONE GRAVEL FROM WINNING POOL STATION ON NORTH WEST COASTAL HIGHWAY
PLATE 6
SHELLEY LIMESTONE GRAVEL FROM NEAR SHARK BAY
ON THE HAMELIN - DENHAM ROAD
PLATE 7
CRUSHED COASTAL LIMESTONE FROM THE
PERTH METROPOLITAN AREA
2.4.3 Scree Gravels

Scree gravel is the accumulation of material caused by mechanical weathering and gravitational transport down the slopes of hills. This gravel is mainly formed in situ with very little movement away from the parent rock.

The suitability of scree gravel depends on the type of rock from which it was formed.

Parent rock which has good prospects of producing scree suitable for basecourse includes quartz, chert and ironstone.

Scree gravels formed from basic igneous rocks such as basalt are usually unsuitable because of high plasticity.

Scree gravels often include large quantities of oversize material which needs to be removed before use.

Three examples of scree gravels are shown in Plates 8, 9 and 10.
PLATE 8
BANDED IRONSTONE SCREE GRAVEL FROM THE
ORD RANGES OF PORT HEDLAND
PLATE 9
IRONSTONE SERR A GRAVEL FROM NEAR
NEWMAN ON GREAT NORTHERN HIGHWAY
PLATE 10
QUARTZ AND CHERT SCREE GRAVEL FROM
NEAR WICKHAM
2.4.4 Decomposed Granite

This highly weathered material is sometimes suitable as basecourse, however deposits are usually variable in both quality and depth.

PLATE 11
DECOMPOSED GRANITE FROM NEAR CRANBROOK
ON ALBANY HIGHWAY
2.4.5 Hardpan

Hardpan is a layer of cemented material often found just below the surface in flat arid areas. The material is brown to red in colour with a coarse, sandy texture. Hardpan is a laminar material which occurs in layers of varying thicknesses. In Western Australia the cementing agent is usually of siliceous origin (silcrete).

Hardpan is ripped out in blocks with a bulldozer and then crushed with the tracks of the machine. With experience the correct amount of working can be judged and a basecourse quality material produced. The material continues to break down while being worked and care must be taken that it does not break down too much to be useful.

Plates 12 and 13 show examples of hardpan which have been prepared ready for use on the road.
PLATE 12
PLASTIC HARDPAN FROM NEAR MEEKATHARRA
ON GREAT NORTHERN HIGHWAY
PLATE 13
NON PLASTIC HARDPAN FROM NEAR CUE
ON GREAT NORTHERN HIGHWAY
2.4.6 Sand Clay

Well graded sand with small amounts of clay has been extensively used as basecourse in the North West of the State. The red coloured sands are often referred to as “pindan” and the yellow coloured sands are sometimes called “wodgil”.

PLATE 14
RED SAND CLAY FROM NORTH WEST COASTAL HIGHWAY
SOUTH OF CARNARVON
2.4.7 River Shingle

River shingle is sometimes found in the banks of rivers or deposited in ancient river beds. The shingle can occur in well graded deposits with suitable fines to be used as basecourse. It is more usual however for the material to benefit from screening or crushing and often requires the addition of suitable fine binder.

PLATE 15
RIVER SHINGLE FROM THE JONES RIVER
EAST OF ROEOBURNE ON NORTH WEST COASTAL HIGHWAY
3. DESKTOP PLANNING TO DEFINE THE SEARCH AREA

3.1 Define Material Requirements

Search area boundaries must initially be clearly established. The cost of alternative material such as crushed rockbase must be known in order to establish maximum cartage distances. Haul road cartage, construction and maintenance are important cost factors which must be considered in advance.

Since man made road building materials are assumed to behave as first grade materials and natural gravels are much more unpredictable, the use of natural materials must represent a substantial cost saving in order to be justified.

Time is an important factor which must be considered so that resources are available and deployed in such a way that the job can be completed on time.

Approximate material requirement estimates can be made even if detailed plans and profiles are not available. This is simply done by determining the length and width of the proposed pavement and calculating the volume by using a pavement thickness based on regional experience.

It is advisable to multiply this figure by a factor of at least 1.3 to eliminate apparent material losses due to compaction from pit density to road density and unavoidable wastage due to other factors.

Job files and previous reports in the Regional office should be thoroughly researched for existing information of material deposits and sources.

Discussion with as many people as possible who may have existing background knowledge can identify prospective areas with minimum effort. Some obvious examples are:

- Surveyors
- Construction personnel
- Other government departments
- Local governments
- Private consultants
- Landholders
Land ownership, zoning and any special regulations must be considered. It is essential that any areas which must be excluded from the search area due to special land zoning or other regulations are excluded at the very beginning of the project before time and resources have been wasted on them.

3.2 Land Tenure

Under the Land Act, there are basically three categories of land:

- Crown Land
- Reserves
- Alienated Land

Crown land and reserved land is owned by the Government and alienated land is privately owned. Crown land can be either vacant Crown land or leased Crown land. A reserve is an area of Crown land which has been vested in an authority for a particular purpose. Some of these are: reserves for Aborigines, reserves for drainage, educational institutions, golf links, cemeteries, water, gravel and rubbish disposal.

Alienated land can have been granted in a number of ways including:

- Freehold
- Conditional purchase lease
- War service grant
- Early grants
- Aboriginal grants

Other Acts can give secondary tenure over the three basic classes of land. For example, water catchment, forestry or mining tenure. Where land is held under a specific Act, the consent of the management authority must be obtained before any activity can commence on that land.
For Crown land where there is a risk of mining companies applying for mining tenements, it is recommended that Main Roads WA applies to the DMP to grant a protection under Section 19 of the Mining Act which allows the Minister for Mines to exempt the Crown land from mining. This can only be done on land not already subject to a mining tenement.

3.3 Entry to Land

Main Roads WA has authority under the following Acts to enter land for purposes related to public roadworks:

- Main Roads Act 1930
- Land Administration Act 1997

Prior to entering any land, contact must be made with the owner, occupier or management authority of the land to inform them of our intentions and to ensure inconvenience is minimised and legal requirements are met.

See Operational Guideline 95 and 97 for procedures on land entry and extraction of materials.

3.4 Establishing Ownership of Land

In some instances, especially on vacant land, ownership is difficult to establish. The first step is to obtain the relevant cadastral map of the area in question.

Cadastral maps are maps which show land subdivisions and are available for the entire state at various scales depending on the density of development of the area concerned. The maps are produced by DOL and copies are generally kept in Regional offices.

If maps are not available locally, copies can be purchased from Central Map Agency, DOL, Midland.

The cadastral map is then matched with the area of interest on a topographical map which is often available at the same scale.

This procedure will provide sufficient information to identify the status of the land in question and enable ownership to be established using one of three main methods.
(a) In each Region there is a computer system called Land Information Access which has online search facilities to DOL. This system is used to establish ownership of Freehold land and Crown Reserves.

(b) For Pastoral Leases, contact should be made with DOL. If any problems or issues arise, the Land Tenure Manager in MRWA, Don Aitken Centre should be consulted.

(c) The local Shire office can also provide ownership details from their records of ratepayers. Shire personnel generally give Main Roads WA very good service in this regard.

3.5 **Restrictions on the Removal of Material**

Once the ownership of the land in question has been established, the next step is to determine whether or not it is practicable to remove material.

There are many areas of land which are covered by individual Acts or Agreements which restrict the removal of road building materials:

(a) Township or suburban blocks are never entered for the purposes of obtaining materials for road building.

(b) Some Crown Grant lots have been granted under sections of the Lands Act which do not provide for removal of material for public works. These grants can be either township or rural land granted before 1899.

(c) State Forest and environmental conservation areas must have the consent of DER for removal of materials.

(d) National Parks are generally not available for access for extraction of materials.

(e) Vacant Crown land or land vested in the Crown is generally available after approval from DOL.

(f) Vested reserves for construction material may have been vested in four different ways:

- Vesting in Main Roads with exclusive rights
- Shared Vesting

- Vested in another authority (eg Shire) which has exclusive rights

- Unvested (meaning anyone may use the material but it must not be offered for sale).

(g) Aboriginal Sites - Aboriginal sites are protected by law under the Aboriginal Heritage Act 1972.

An aboriginal site can be any of the following:

- A place where artefacts have been left

- Any sacred, ritual or ceremonial site

- Any place which has been associated with aboriginal people which is of historical, anthropological, archaeological or ethnographical interest.

Areas which have a high potential for being a site are near watercourses, springs, caves, rock shelters and any unusual geological formations.

Major works have generally been cleared by the Museum or its consultants but if a site is discovered it should not be disturbed and its importance should be assessed by trained and informed staff.

(h) Native Title

For Crown Land and Pastoral Leases Native Title may exist or issues may be relevant. Clearance is required though DOL.

(i) Mining Tenements:

- Prospecting Licence (Small areas)
- Exploration Licence (Large areas)
- Mining Lease (mineral deposit)
- General Purpose Lease (Mining plant, tailing dumps)
- Miscellaneous Licence (pipeline easements etc)
The holder of a mining tenement has rights to all minerals including sand, gravel and rock. Section 112 of the 1978 Mining Act reserves to the Crown the right for free access to construction materials on areas covered by Prospecting and Exploration Licences. This right is not extended to areas covered by Mining, General Purpose or Miscellaneous Licences. Extraction of any material in these cases is subject to negotiation with the tenement holder.

(j) Consent of the relevant water authority is required for material removal in water catchment areas.

3.6 Broadly Define Prospective Areas

Prospective areas are defined with the use of various maps, aerial photographs and with the use of remote sensing methods such as the Landsat System.

This phase is very important because apart from providing likely gravel prospects, often large areas of land can be excluded from the search corridor.

A good understanding of the use of maps and aerial photographs, their availability and information they can provide is essential if an effective search is to be carried out.

3.7 Maps

3.7.1 Topographical Maps

A topographical map is one which shows surface features of an area of land. Man made as well as natural features are detailed on the maps.

The maps are produced in various scales and a listing of common maps is available from the DOL website.

The 1:100 000 scale topographical maps are probably the most useful since they are generally the most recent and include the Australian Map Grid (AMG) reference system. This latter aspect is important since the AMG system is the one used by Main Roads. Use of the AMG system is discussed later in this section.
Features which are shown on the maps include:

- Roads
- Towns
- Buildings
- Railway Lines
- Rivers
- Swamps
- Land Use
- Natural Vegetation
- Contour Lines

Symbols are used on maps to draw the users' attention to significant features which would not be easily recognised if they were drawn to scale.

A key to the symbols is usually included on the marginal information - an example is shown below.

**FIGURE 2**

_Some Typical Topographic Map Symbols_
3.7.1.1 Australian Mapping Grid (AMG) Reference

Because latitude and longitude lines on most maps are curved, it is difficult to pinpoint a position on the ground. For this reason maps are provided with an easier system of squares called a grid where the ground distance between the squares is quoted on the map margin.

On a 1:100 000 scale map, the distance between grids is 1 000 metres.

The values quoted for the grid lines are their distance from a specified point that is outside and to the bottom left of the map so that the numbers increase to the east for the north-south lines and to the north for the east-west lines.

The values of the grid lines running north-south are therefore called eastings and those running east-west as northings.

In grid references eastings are always quoted first.

The full grid value is always shown in the margins for the grid lines closest to the sheet edges with two of the numbers being heavier than the rest. For the remainder of the grid lines only the two heavier numbers are shown.

An AMG grid reference of a location is always represented by six numbers which are derived as follows:

- Read the two figure grid value at the north or south margin nearest to the left of the point and then estimate in tenths its distance from that grid line to the next one. This provides the first three figures (eastings) of the six figure grid reference.

- Read the two figure grid value appearing in the left and right margins, of the grid line closest below the location point, and then estimate in tenths its distance from that grid line to the one immediately above it. This provides the last three figures (northings) of the six figure grid reference.
Example: From the map extract on the next page, the grid reference for Mt Clarence is:

81 4/10 East 814
23 7/10 North 237

Therefore the grid reference is:

814237

When quoting a grid reference, the name and number of the map sheet from which it is derived should also be quoted.

The full reference for the position of Mt Clarence becomes:

ALBANY 2427/814237

3.7.1.2 Contour Lines

Contour lines can easily be understood if the ground is considered to have base line of zero at sea level. If the ground is then sliced parallel to sea level into equal thicknesses, the upper face of each slice becomes a contour plane that contains all the points on the map of equal elevation i.e.; contour lines are the intersection of the contour planes and the natural surface.

On the 1:100 000 topographical maps, contour lines are shown every 20metres (i.e.; contour interval = 20m).

Where the ground is steep, the contours are close together and where the ground slope is more gentle the contours are further apart.
3.7.2 Forestry Maps

Topographical maps of the forest areas in the South West of WA are also available at a very useful scale of 1:50 000. The maps are produced by DER.

3.7.3 Geological Maps

Geological maps have been produced for the whole of WA. They are an important aid in gravel searching and every laboratory should have a set covering its region.

These 1:250 000 scale maps are available in several forms. The most useful are coloured and contain a geological explanation.

The 1:250 000 maps have the same scale as the topographical maps known as Army Survey maps (4 mile to the inch).

The full range of sheets in print are readily available from:

Department of Mines and Petroleum
Mineral House
66 Adelaide Terrace
PERTH WA 6000

Geological maps cover 1½° of longitude and 1° of latitude which is six times the area of the 1:100 000 series topographical maps. These two maps should always be used in conjunction with each other. The simplest way to use them together is to fold the geological sheets into size as described below.

- First fold the map in half lengthwise with the detail outward.
- Fold it across the other way into three equal sections concertina fashion.
- Then each folded section of the geological map corresponds to a full 1:100 000 topographical map.

Geological maps are useful because they provide a clear indication of the various rock types. Some rocks are likely to produce good pavement materials, others are not.
It is essential that an understanding of the relationship between rock type and the materials which are a product of those rocks be developed.

A simple way of developing this experience is to mark all known existing pits in an area accurately on the relevant geological map.

If topographical maps and aerial photographs are used in conjunction with the geological sheets, the association of suitable deposits with rock type and landform will quickly be appreciated.

Once suitable rock types are established, the occurrence is matched to suitable topography on the 1:100 000 topography maps or aerial photographs.

A good start is to locate all tertiary rock outcrops on the geological maps. These outcrops are often flat topped hills which are remnants of the old tertiary land surface.

The tertiary erosion plain in WA often carries a crust of laterite. Therefore the flat topped remnants can be expected to have laterite on top and laterite scree on the flanks.

Prominent hill slopes should be matched with outcrops of suitable type of rock. For example in the north west part of the State, useful scree gravel slopes can be expected near outcrops of chert, quartzite and banded ironstone.

In the south of the state laterite deposits are indicated on the maps with the most useful gravel generally occurring on the low slopes between the massive rock outcrops near the top of the ridge and the unsuitable fine material in the valley.

Deposits of gravel on slopes over dolerite, basalt and other dark igneous rock should be treated with caution because of highly active (montmorillonitic) clays which almost always occur in the gravel fines or overburden.

The maps often provide information which allows large areas to be eliminated from the search area. Coastal clay and silts are unsuitable even if they overlay granular materials. The maps do however, only indicate surface geology and suitable deposits can sometimes be located under unlikely surface material. For instance old alluvial deposits overlain by more recent wind deposited fines are sometimes a source of suitable material even though they do not appear on the geological maps.
Geological changes indicated on the maps are usually highly accurate but scale limitation should be remembered. An area of 6 hectares which would be the size of a good sized gravel pit would not be shown on the maps (an area of less than 1mm²).

Care must be exercised with the coding of the maps. For example a coding indicating scree gravel or outwash gravel near a certain outcrop will represent a completely different material when associated with a different outcrop of rock.

3.7.4 Cadastral Maps

Cadastral maps are maps showing land subdivision. They are available for the entire state at various scales depending on the density of development of the area concerned.

The maps are produced by DOL and are available from the Central Map Agency if they are not held in Regional offices.

The most convenient cadastral maps are those that also contain topographic detail, however, if the topographical detail is not included, the maps must be matched with a topographical map of the same scale.

Cadastral maps are essential for establishing details of land ownership.

Figure 4 is an example of a section of a cadastral map. Privately owned land is usually recognised by the letters CG (Crown Grant) under which the number of the Crown Grant appears. The other numbers provide the size of the block.

Government reserves are identified by the broad arrow symbol.
# ABBREVIATIONS USED (OR HAVE BEEN IN USE)
## ON LANDS AND SURVEYS PUBLIC PLANS

<table>
<thead>
<tr>
<th>Term</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aboriginal Affairs Protection Authority</td>
<td>AAPA</td>
</tr>
<tr>
<td>About</td>
<td>Abt or abt</td>
</tr>
<tr>
<td>Acres</td>
<td>acrs</td>
</tr>
<tr>
<td>Acres Roads Perches</td>
<td>a r p</td>
</tr>
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<td>AGD</td>
</tr>
<tr>
<td>Australian Height Datum</td>
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<tr>
<td>Australian Map Grid</td>
<td>AMG</td>
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<td>BM</td>
</tr>
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<td>Brook</td>
<td>(name)</td>
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<td>Central Meridan</td>
<td>CM</td>
</tr>
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<td>Certificate of Title</td>
<td>C/T or C/T (No)</td>
</tr>
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<td>CL. RD</td>
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<td>Commercial Employees Housing Authority</td>
<td>CEHA</td>
</tr>
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<td>Condition Purchase</td>
<td>CP</td>
</tr>
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<td>Control of Off Road Vehicles Act</td>
<td>C of V</td>
</tr>
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<td>CA</td>
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<td>Co-operative Bulk Handling</td>
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</tr>
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<td>CWA</td>
</tr>
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<td>Crown Grant</td>
<td>CG</td>
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<tr>
<td>Department</td>
<td>DEPT.</td>
</tr>
<tr>
<td>Department of Industrial Development</td>
<td>DID</td>
</tr>
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<td>Diagram (Survey)</td>
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<td>Exempted from Sale and Occupation</td>
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<td>Res or</td>
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<td>r</td>
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<td>Saw Mill Site (Under Mines Act)</td>
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<td>Special Occupation License</td>
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<td>Spring</td>
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<td>m²</td>
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<td>SEC</td>
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<td>State Forest</td>
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<td>State Housing Commission</td>
<td>SHC</td>
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<td>State Large Scale Series</td>
<td>SLSS</td>
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<td>SR</td>
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<td>Suburban Lot</td>
<td>S (No) or Sub (No)</td>
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<tr>
<td>Tailings Lease (Under Mines Act)</td>
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</table>
Temporary Reserve (Under Mines Act)  TR (No)
Transmission Line  Trans Line
Trigonometrical Station  Trig Stn
True North  TN
Universal Transverse Mercator  UTM
Vacant Crown Land  VCL
War Service Land Settlement  WSLS
Withdrawn from Sale or Leasing  W/D
Workers Home (Now State Housing Commission)  WH
3.7.5 Mining Tenement Maps

Mining tenement maps are available for most of the State at various scales depending on the level of mining activity of the area concerned.

The maps show mining claims together with basic topographical detail. To be used effectively, the maps need to be used in conjunction with cadastral maps.

Care must be taken when removing material from land covered by a mining restriction because, once a lease has been granted, compensation must be paid for any material removed.

Mining tenement maps are available from DMPon its online database called Tengraph.

DMP will also advise ownership and address of the leaseholders or claimants providing the following information is given:

- name of mineral field
- name, number and scale of map
- number (and name if available) of the lease

Mining tenement maps are sometimes produced without a key to the symbols used. Figure 5 shows the commonly used symbols and abbreviations.

Figure 6 is an example of an extract from a mining tenement map.
### COMMON SYMBOLS USED ON MINING TENEMENT MAPS

<table>
<thead>
<tr>
<th>SYMBOLS</th>
<th>ABBREVIATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldfield boundary</td>
<td>Mineral lease, claim ... NL ... NL</td>
</tr>
<tr>
<td>Goldfield district boundary</td>
<td>Machinery lease, area ... ML ... ML</td>
</tr>
<tr>
<td>Land district boundary</td>
<td>Tailings lease, area ... TL ... TL</td>
</tr>
<tr>
<td>Tenement boundary</td>
<td>Residence lease, area ... RL ... RL</td>
</tr>
<tr>
<td>State forest boundary</td>
<td>Water lease, right ... WL ... WL</td>
</tr>
<tr>
<td>Pastoral station boundary</td>
<td>Dredging lease, claim ... DL ... DL</td>
</tr>
<tr>
<td>Unsurveyed boundary (Mines)</td>
<td>Miners homestead lease ... MH</td>
</tr>
<tr>
<td>Unsurveyed boundary (Lands)</td>
<td>Trench lease ... TVL</td>
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<tr>
<td>Surveyed boundary</td>
<td>Alluvial claim ... AC</td>
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<tr>
<td>Shire boundary</td>
<td>Extended alluvial claim ... EAC</td>
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<tr>
<td>Agricultural area boundary</td>
<td>Lode claim ... LC</td>
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<td>Coastal cable (underground)</td>
<td>Reward claim ... RC</td>
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</tr>
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<tr>
<td>Track</td>
<td>Prospecting area ... PA</td>
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<tr>
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<td>Quarry area ... QA</td>
</tr>
<tr>
<td>Tramway</td>
<td>Washing area ... WA</td>
</tr>
<tr>
<td>Fence</td>
<td>Pipe track water right ... JPFWR</td>
</tr>
<tr>
<td>Trunk line</td>
<td>Numerals of gold mining leases have no prefixes.</td>
</tr>
</tbody>
</table>

**FIGURE 5**
3.8 Aerial Photography

3.8.1 Availability and Use

Aerial photographs are available in several forms. The most useful are east-west runs across 1:250 000 sheets. The scale of the photos vary depending on the location. Photo mosaics are also available, but because there is no overlap, they lack the three dimensional (3D) effect.

Aerial photographs are available for the whole State and are usually specially flown over any new proposed alignment. Photographs which are flown in single runs offer only limited use to a gravel search since there is insufficient coverage off the road.

The selection of relevant photographs can be a tedious process, where the proposed gravel search areas has to be matched with flight run indexes, however, the benefits are well worthwhile.

The photographs can be used to study formations such as scree slopes, flat topped tertiary deposits, alluvial fans and banks of likely material in river bed systems. Vegetation differences show up as different shades of grey on black and white photos and as various greens and browns on colour photos which, in turn, imply soil changes.

3.8.2 Interpretation of Aerial Photographs

Since we have two eyes which are separated we view everything from two slightly different perspectives. The two different views are fused by the brain to provide a perception of depth. When aerial photographs overlap, they also provide two views taken from separated positions. By viewing the left photo with the left eye and the right photo with the right eye a three dimensional image of the terrain is obtained.

Aerial photos normally overlap each other by about 60%. This overlap results in an exaggerated model where hills are too steep and valleys too deep. This defect is also an advantage since landforms become more prominent and easier to identify. Stereoscopic viewing and interpretation is very much a matter of practice and experience.
Stereoscopes are optical instruments used to aid 3D viewing of aerial photographs. The two common types are the lens type and the mirror type.

3.8.3  Lens Stereoscopes

Lens stereoscopes are small, portable and cheap viewing instruments usually having folding legs. The instruments have a magnification of from x 1.2 to x 2.5. Only a small field in the centre of the view can be used for observation. It is a very basic, pocket type unit which is easily carried into the field.

3.8.4  Mirror Stereoscopes

The mirror stereoscope uses mirrors and prisms where the image is magnified up to x 4. The area of view can take in the entire overlap on a standard 23cm x 23cm plate. This wide area of observation is a great advantage, but the instruments are bulky, expensive, and are only suitable for office use.

3.8.5  Unaided Stereovision

With practice, stereoscopic vision can be achieved without the use of stereoscopes. The ability to view photographs in 3D unaided is very convenient for field use. The resultant image is vertically in scale, not lens distorted, and the eyes can scan the entire stereo overlap.

Stereovision can be practised on the pyramids below. The upper pyramids are positive and upright, and the lower, negative and inverted. Holding the page at arms length parallel with the eye axis, look at the pyramids but focus the eyes as if looking at a very distant object past the page. The two pyramids will appear as three with the centre one floating in space and in 3D. It takes time until the pictures fuse or "jump" into 3D.
The upper pyramids appear positive and upright, the lower pyramids negative and inverted.

FIGURE 7
(from AEROGEOLGY Horst von Bandat 1962)

To view stereo photographs with the unaided eye, the photos are first matched and then separated until the same points are about 60mm apart.

On the photos below concentrate on a common outstanding feature like a river-bed or a distinct landform by pointing to it with a pencil on both photos. Try to fuse the features or pencil points into one. The example gives full stereoscopy because the photographs have been cut out and arrange for the purpose. Full size pictures must be viewed with overlap as with a lens stereoscope.
FIGURE 8
(from AEROGEOLGY Horst von Bandat 1962)
3.9 Landsat Imagery

Landsat imagery is based on information collected by a series of American satellites which have been placed in orbit since 1972.

Landsat records reflected light from the earth's surface using a variety of sensor systems. Information is sent to ground receiving stations and recorded on magnetic tape as a series of numbers.

Reflected light from a dark area may be recorded as zero while the reflection from a bright sand dune may be 256. All shades of grey can be converted to a digital value between 0 and 256. This data can then be converted to black and white photograph like images by effectively reversing the process. The black and white images from the various bands can then be coloured with filters and superimposed to produce a false colour composite which simulates colour infra red film.

The most useful imaging sensor is currently the Enhanced Thematic Mapper (ETM) which has seven spectral bands with a resolution of 30m x 30m, and an additional panchromatic band with a resolution of 15m x15m.. High contrast linear features can be observed down to a size of less than two metres.

One ETM image covers 185 x 185km and contains 190 million picture elements or pixels.

The full potential of Landsat data to provide information can only be realised after computer processing. Numerical data is commonly collected from various bands from a feature of interest such as a known gravel deposit (otherwise known as a training site). Each unknown pixel on the scene is then compared to the training site and an output is produced showing areas of similar spectral response as the training site.

Landsat data will become more important as an aid to gravel searches as standard image processing techniques are developed.

Imagery and data processing is available from DOL at:
65 Brockway Road, Floreat WA 6014.
4. CONTACT WITH LANDOWNERS

4.1 Initial Contact

Wherever possible, personal contact should be made with the owner of property on which a materials investigation is to be carried out. If handled in a sensitive manner, this initial contact will often result in a good relationship with the landowner and permission to enter the land will readily be given. The landowner should be given assurances that all care will be taken of his stock, fences, water supply, etc and should accidental damage occur, it will be made good.

If the landowner objects to entry to his land, leave the property and advise the Regional Manager.

For details of land entry requirements see Operational Guidelines 95 and 97 (Online in IRoads/Forms and Docs/Online Documents).

4.2 Compensation

Every effort should be made to minimise damage to the landowners property during the materials investigations.

All claims for compensation are to be referred to the Regional Manager.

4.3 Disputes

Materials personnel should not become involved in disputes with landowners. Disputes can almost always be avoided by acting in a tactful, reasonable manner. Realise that the landowner may see your presence as a threat to his means of making a living, or at least an invasion of his privacy. If a dispute cannot be resolved onsite, leave the property and refer the matter to the Regional Manager.
5. FIELD INVESTIGATIONS

5.1 Safety in the Field

During gravel searches, testing personnel could be expected to operate in remote areas where the chance of a breakdown or becoming lost is very real. The highest risk to life in the West Australian outback is caused by heat and dehydration.

Under Main Roads SHW Standards and Rules, as shown in the online document in IROADS “Working Alone and in Isolation”, regions are required to document a safety procedure customised for its region. Refer to this document as part of your planning for working in remote areas. Wherever possible, work in remote areas should not be done alone but regardless of that, the regional procedure should be followed.

Consult experienced regional people for advice for the development of your Journey Management Plan which can be accessed via TRIM link D14#222051.

Serious problems can generally be avoided if the following rules are adopted.

(a) Maintain a regular contact with the regional office or other Main Roads person using a sat phone or two way radio.

(b) Carry as much drinking water as practical. With sensible usage a person can survive for a long time provided they have water. Water containers must be opaque to sunlight. Clear containers are unsuitable because light which reaches the water allows the growth of algae in a few days.

(c) Carry suitable clothing, a tent fly, first aid kit, matches, and a spare battery for the vehicle if possible. This is additional to normal vehicle spares and tools. Other useful items include:

- Compass and or GPS unit
- Maps of the area
- Flares and or EPIRB
- Plastic sheets for collecting water
- Water purification tablets
- Knife
(d) If operating from a camp, advise someone in your camp of your approximate
daily location. If nobody remains in camp, a note should be left with a map
which clearly marks the general area in which you are operating. **This MUST
be done daily and DON'T alter your plans.**

(e) Become familiar with basic Australian bushcraft. A useful reference is “Outback
Survival” by Bob Cooper, published by Hachette Australia, 2012.

### 5.2 Identifying Individual Deposits

This phase of the gravel investigation is where individual search areas are
identified.

The initial field work should consist of a reconnaissance of the search area by the
Regional Materials Manager and those officers who will carry out the detailed work
later.

A properly equipped vehicle to suit the terrain is the main requirement. Basic hand
tools, compass and maps detailing prospective areas also need to be carried. Due
regard to field safety also needs to be exercised (see Section 10).

The objective of this initial reconnaissance is to become familiar with the entire
search area and to systematically check all likely prospects which were located
during the earlier second stage (Section 4).

### 5.3 Indications of Gravel

Further prospects will be located as the field party becomes familiar with the search
area.

Soil types and landform of all nearby old pit areas should be studied and similar
areas checked for suitable deposits.

Indications of gravel exposed by erosion are often observed on the surface and
other indications may appear as a result of man made disturbance.

Insects and small burrowing animals often bring subterranean material to the
surface.
Uprooted trees often allow subsurface material to be conveniently observed.

The flanks and low ridges of rock capped hills should be checked for suitable material. Rocky ridges are unsuitable. Hollows and generally low ground is usually unproductive because of water deposited fine, highly plastic material.

5.4 Vegetation

Since vegetation changes reflect soil differences, there is generally a good ecological association between natural vegetation and gravel deposits. Unfortunately, this association is very localised, only applying over small areas of land and often over only a few square kilometres.

The following vegetation/gravel associations have been reported from various parts of the State and have been included for interest.

- Areas of Jarrah forest are often an indication of laterite in the South West as is Tamar Scrub.
- Banksia indicates deep sand.
- Tuart trees on the coastal plain indicate that limestone is too deep to be economically used.
- Dense Blackboy stands are a good laterite indication on the Brand Highway.
- Minerichie scrub can indicate gravel in the north of the State.

5.5 Investigation of Prospective Sites

All the prospects confirmed during this initial reconnaissance will require further investigation. The purpose of the next phase of the gravel search is to enable a decision to be made as to which of the areas justify more detailed work.

Each of the prospects or possible prospects must be assessed with a small number of pilot test holes. At this stage, just sufficient holes should be excavated to enable a very general idea of gravel quantity and quality to be made. A coarse grid of perhaps 100m by 100m is sufficient. The pilot holes should, if possible, be located in such a way that they can become part of the final detailed test hole grid of the
deposit. Details of all test holes should be recorded and logged in accordance with AS 1726 (SAA Site Investigation Code).

Appearance of the completed pit area should be considered from the viewpoint of the travelling public. The reinstated pit area must be aesthetically acceptable, and in most cases this means the pit area should be out of sight of the road. Try to work on the back of ridges or make certain a substantial screen of vegetation is left in place.

With the information gained in this phase, and a consideration of the most economical haul distances, a plan should be developing as to how much material will be required from each prospective pit area.

5.6 Equipment

Equipment required for the preliminary investigation depends on the size of the job, however, a suitable vehicle, test hole excavating machinery and probably suitable camping facilities will be needed.

The following comments regarding machinery should be considered.

5.6.1 Backhoe

A backhoe is the most useful machine for digging test holes. Its advantages are:

- It can quickly excavate hole to a depth of at least 3m.
- The various horizons are readily identified.
- The exposed face is easy to sample (safety first! consider the stability of the excavation).
- The machine is very mobile.
The machines disadvantages are:

- Staked tyres can be a serious problem, especially in burnt out scrub.
- The machine requires an experienced operator.
- It is unsuitable in hard material.

5.6.2 Bulldozer

The advantages of a bulldozer are:

- The machine can rip fairly hard rock.
- The stockpile produced at the end of the test gullet gives a realistic, as stockpiled, indication of the gravel.
- Since it is a tracked vehicle it is reliable in dense scrub or rocky country.
- The exposed face is easy to sample.

The machine's disadvantages are:

- Very slow at digging.
- Less mobile - cannot travel long distances or on roads.
- Expensive to hire and operate.
- Requires an experienced operator.
5.6.3 Proline Borer

This auger device is not very useful for digging test holes, however, it has some special advantages:

- The machine can be mounted on a standard vehicle and is therefore very mobile.
- Does not require an experienced operator.
- Is inexpensive to buy and operate.

The machine's disadvantages are:

- Causes undesirable mixing of horizons.
- Breaks up the material.
- Does not permit proper sampling since there is no exposed face.

5.7 Field Assessment of Material

Field assessment of material to judge the suitability or otherwise for roadmaking is very much a skill which is developed through experience.

The individual stone particles must appear dense and sound and should not be able to be broken with the fingers. Visually the material should appear to be well graded. The wet fines (<1.0mm) should feel very gritty when rubbed through the fingers and a small amount of clay should discolour the hands. If the material sticks to the hands or feels greasy it probably contains too much clay.
5.8 Testing

5.8.1 Test Limits

All the pilot test holes are sampled and after testing, a decision can be made as to the suitability of the material for basecourse or sub-base.

The following test limits have been reproduced from the NAASRA Publication: "Pavement Materials Part 2 - Natural Gravel, Sand-clay and Soft and Fissile Rock".

Clay increases cohesion which helps to ensure adequate strength and resistance to wear. These properties are especially important on unsealed roads and is the reason why plasticity limits for unsealed roads are higher.

5.8.2 Particle Size Distribution

See following graph:

The suggested particle size distribution is given in the figure below:

![Particle Size Distribution Graph]

FIGURE 9
5.8.3 Plastic Limit

A value in excess of 20% may indicate the presence of undesirable components.

5.8.4 Liquid Limit

The following values have been used in specifications:

Unsealed base or shoulders 35% max
Sealed base or shoulders 25% max

5.8.5 Plasticity Index

5.8.5.1 Gravel

The following have been used in specifications for gravel:

- Unsealed Base/Shoulder 4% min 15% max
  (<400mm Annual Rainfall)
  4% min 9% max
  (>400mm Annual Rainfall)

- Unsealed Sub-base 18% max (<400mm)
  12% max (>400mm)

- Sealed Base/Shoulder 10% max (<400mm)
  6% max (>400mm)
5.8.5.2 Sand Clays

The following values are suggested for sand clays when used in areas of <400mm annual rainfall:

- Unsealed Base/Shoulder 5% min - 15% max
- Unsealed Sub-base 3% min - 20% max
- Sealed Base/Shoulder 5% min - 12% max
- Sealed Sub-base 3% min - 15% max

5.8.6 Linear Shrinkage

The following values have been used in specifications:

- Unsealed Base/Shoulder 6% max (<400mm) 3% max (>400mm)
- Unsealed Sub-base 8% max (<400mm) 5% max (>400mm)
- Sealed Base/Shoulder 4% max (<400mm) 2% max (>400mm)
- Sealed Sub-base 5% max (<400mm) 3% max (>400mm)

5.8.7 Maximum Dry Compressive Strength

The following values have been used in specifications:

- Unsealed Base/Shoulder 2 800 kPa min
- Unsealed Sub-base 1 000 kPa min
- Sealed base/Shoulder 1 700 kPa min
- Sealed Sub-base 1 000 kPa min
5.8.8 WACCT

The following values are suggested at expected in situ moisture and density conditions:

- Unsealed Base: 2.3 max class number
- Sealed Base: 2.0 max class number
- Sub-base: 3.0 max class number

5.8.9 California Bearing Ratio

The following values are commonly used in specifications for basecourse.

- Unsealed Base: 60% min
- Sealed Base: 80% min

These minimum values are intended to apply at the expected insitu moisture density conditions.

6 EVALUATING DEPOSITS IN DETAIL

This is the final phase of the gravel search. All pit sites established earlier will require detailed gridding, sampling and the estimation of reserves.

6.1 Gridding

Test holes should always be excavated in an accurate grid pattern so that the material reserves can be accurately estimated, the pit boundaries can be determined and meaningful samples can be collected.

Generally a 25 metre square grid will provide sufficient detail, but in variable deposits a much closer spacing may be needed. To ensure that the grid remains square, a compass or an optical square should be used to set the grid out. Fences or roads provide suitable baselines, however, often a baseline must be pegged away from the pit area itself.
Individual test holes should be clearly marked with an identifying number. The gridded area should be carefully sketched on graph paper and show a scale, description of the locality and the AMG grid reference.

All test holes and costeans should be logged in accordance with AS 1726 (SAA Site Investigation Code).

6.2 Sampling

The number of samples required from a deposit will depend on the variability of the material and the purpose for which the samples are taken. The following table provides guidelines for the minimum testing frequency for assessing basecourse and sub-base materials.
MINIMUM TESTING FREQUENCY FOR ASSESSING BASECOURSE AND SUBBASE ROAD BUILDING MATERIALS

<table>
<thead>
<tr>
<th>Investigation</th>
<th>TEST</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Search Basecourse and Subbase</td>
<td>PSD</td>
<td>1 per 500 m³</td>
</tr>
<tr>
<td></td>
<td>PI</td>
<td>1 per 500 m³</td>
</tr>
<tr>
<td></td>
<td>LS</td>
<td>1 per 500 m³</td>
</tr>
<tr>
<td></td>
<td>MDCS*</td>
<td>1 per 500 m³</td>
</tr>
<tr>
<td></td>
<td>CBR</td>
<td>1 per 5 000 m³</td>
</tr>
<tr>
<td></td>
<td>MDD</td>
<td>1 per 5 000 m³</td>
</tr>
<tr>
<td>Basecourse Stockpile</td>
<td>PSD</td>
<td>1 per 500 m³</td>
</tr>
<tr>
<td></td>
<td>PI</td>
<td>1 per 500 m³</td>
</tr>
<tr>
<td></td>
<td>LS</td>
<td>1 per 500 m³</td>
</tr>
<tr>
<td></td>
<td>MDCS*</td>
<td>1 per 500 m³</td>
</tr>
<tr>
<td></td>
<td>CBR</td>
<td>1 per 2 500 m³</td>
</tr>
<tr>
<td></td>
<td>MDD</td>
<td>1 per 2 500 m³</td>
</tr>
<tr>
<td>Subbase Stockpile</td>
<td>PSD</td>
<td>1 per 1 000 m³</td>
</tr>
<tr>
<td></td>
<td>PI</td>
<td>1 per 1 000 m³</td>
</tr>
<tr>
<td></td>
<td>LS</td>
<td>1 per 1 000 m³</td>
</tr>
<tr>
<td></td>
<td>MDCS*</td>
<td>1 per 1 000 m³</td>
</tr>
<tr>
<td></td>
<td>CBR</td>
<td>1 per 5 000 m³</td>
</tr>
<tr>
<td></td>
<td>MDD</td>
<td>1 per 5 000 m³</td>
</tr>
</tbody>
</table>

PSD - Particle Size Distribution
PI - Plasticity Index
LS - Linear Shrinkage
MDCS - Maximum Dry Compressive Strength
CBR - California Bearing Ratio
MDD - Maximum Dry Density

* MDCS testing is only required if the material is non-plastic.
Horizons within a test hole which can be visually detected should always be sampled separately. Even when the full face of gravel appears uniform it is good practice to sample some holes in 0.5m layers.

The depth of overburden and depths sampled should be carefully measured and recorded. Since the depth of the deposit is the most critical measurement when calculating quantities, it is unacceptable to estimate depth values.

Care should be taken to ensure that samples are representative of the material being sampled. If a sample is not representative the subsequent test results will be misleading and decisions based on those results will be incorrect.

6.3 Estimating of Quantities

Estimates of quantities are best made from the sketch of the area which was prepared after the gridding operation.

Determine the average depth and area of the deposit and carry out a simple volume calculation to calculate the quantity available.

Remember to allow for rock outcrops and unusable material due to sudden changes in the depth of the deposit. It is much safer to underestimate the quantity available. Estimates of material quantities which are too high have the potential to create major job disruptions during the road construction process.

6.4 Public Safety

The holes should also be considered from a safety point of view. Open proline holes and deep backhoe holes are very dangerous. Proline holes should always be backfilled and backhoe holes that are left open should be prominently marked by using four suitable pegs and cordoned off using wire and survey tape.

7. ARRANGING ACCESS TO THE MATERIAL

7.1 Discussion with the Landowner

If investigations and testing confirm the suitability of the material and it is proposed to use the deposit for road construction, the landowner must be informed of our intentions.
A relatively senior Main Roads WA person such as the Materials Manager, Project Manager, Project Engineer or Regional Manager must discuss with the landowner, the proposal to extract roadbuilding material and reach agreement on conditions.

A written agreement is recommended to confirm the agreed conditions.

See Operational Guideline 95 for more details.

8. **EXTRACTION OF MATERIAL**

8.1 **General**

Refer to “Environmental Management Guideline – Pits and Quarries for Road Building Materials

"Borrow Pit" is a term used to describe an area from which material is removed for the purpose of building roads.

There are three phases involved in the operation of borrow pits:

- Opening the pit (8.3)
- Excavation of material (8.4)
- Rehabilitation of the pit (8.5)

Due to insufficient planning the operation of borrow pits is often carried out in a haphazard manner. Unless the many factors involved are considered in a logical sequence, wastage of time, wastage of labour and wastage of the finite resources of naturally occurring road building material will be inevitable.

8.2 **Factors to Consider Prior to Opening of the Pit**

8.2.1 **Economics**

The pit site should be located as close to the construction site as possible. The distance material has to be carted is the major influence of total material cost.
Material deposits in very hilly areas can often be uneconomical to use because machinery cannot operate efficiently. Terrain and natural or man-made barriers to the pit access should be carefully considered.

The cost of construction and maintenance of haul roads should be considered with special regard for seasonal weather conditions.

8.2.2 Land Ownership

Care must be taken to ensure that problems relating to right of entry do not occur. If the proposed pit area is encumbered in any way such as being part of a mining lease, a site of interest to the museum, or special reserve, then work will be wasted, bad public relations will result and compensation claims may be made.

8.2.3 Testing

The entire material deposit must be properly gridded, tested and carefully mapped. Unless this is done, the pit area cannot be efficiently opened with regard to possible future operation of the pit.

8.2.4 Machinery

There are a number of machines which may be used in the operation of a pit. In general order of importance they are: bulldozer, scraper, front end loader and grader.

Machinery to be used for the pit operation is often governed by factors over which the Regional materials team has no control, however efficient machine use should be considered and discussed with the construction personnel wherever possible. For example a grader may be more effective for stripping light vegetation or shallow overburden than a bulldozer. Scrapers are generally more effective for removing deep overburden than bulldozers. If trickle watering of the deposit is being considered then a suitable front end loader may eliminate the need for a bulldozer.

8.2.5 Test Stockpiles

Because of the soft nature of some materials, the pushing up process can change the grading and strength of the material. If the material is likely to change during
this process, then samples from ordinary test holes are not valid and test stockpiles must be pushed up for sampling and assessment. If test stockpiles are considered then they must be planned for well in advance of the full scale pit operation.

8.3 Opening the Pit

A meeting should be arranged at the pit site with the machine operator where details such as pit marker pegs, size and shape of the pit area, type of material which is being sought and the depth of the deposit can be discussed.

Factors such as prevailing wind and ground slope should be considered when finalising separate stockpiling sites for the timber, topsoil and overburden.

Other details such as the size of individual stockpiles and the push distance will depend on the depth of the deposit, proposed method of sampling and whether or not special mixing techniques are required.

Consideration should be given to the location of haul roads and the provision of an efficient truck loading area.

8.4 Excavation of Material

Careful and continuous supervision of the stockpiling operation is essential. If this procedure is not properly controlled all the previous work in establishing the pit will have been wasted. In addition the material itself will have been wasted, and worse still, the unsuitable material may be placed on the road.

8.4.1 Overburden

Stockpiles of timber, topsoil and overburden should be pushed up correctly to ensure efficient pit operation and good rehabilitation prospects (see Section 9 8.5).

Overburden depth control is important since removing too much is a waste of material and the removal of too little will alter its characteristics.

8.4.2 Depth Control
Depth control is usually the most critical aspect of stockpiling supervision. The task will have been made much simpler if careful attention was given to pegging, mapping and accurate recording of the depth of samples taken during the earlier pit investigation stage.

The floor of the pit should be kept as level as possible to facilitate loading.

Mounds of undisturbed material under stockpiles must be avoided by using correct pushing up techniques.

8.4.3 Mixing

If the material in the pit exists in different layers it will often benefit from mixing during stockpiling. As shown in figure 10, the bulldozer should work on the face combining the various layers as the blade is filled.

8.4.4 Haul Roads

Care should be taken to provide haul roads which are placed correctly with regard for economy and safety. Ensure that a satisfactory loading area for trucks is provided before the dozer is removed from the pit site.

8.4.5 Drainage

The stockpiles should be positioned in such a way that they do not become waterlogged. In most instances suitable drains must be constructed to carry away rainwater.
8.4.6 Effective Bulldozer Use

Stockpiling production is usually expressed as loose cubic metres per day. This figure is dependent on the type and depth of the material being stockpiled, the size of the machine, the number of hours worked and how efficiently the stockpiling procedure is carried out.

Production figures for various machines are available as a guide and are given in Figure 11, and some job condition correction factors are given in Table 1.

From these daily production can be estimated, but it is essential that experience be developed by materials personnel in order to judge whether a machine is being operated effectively.
FIGURE 11
**TABLE 1**
**BULLDOZER JOB CONDITION CORRECTION FACTORS**

<table>
<thead>
<tr>
<th>Condition</th>
<th>FACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TRACKED DOZER</strong></td>
<td></td>
</tr>
<tr>
<td>Operator -</td>
<td></td>
</tr>
<tr>
<td>• excellent</td>
<td>1.0</td>
</tr>
<tr>
<td>• average</td>
<td>0.75</td>
</tr>
<tr>
<td>• poor</td>
<td>0.60</td>
</tr>
<tr>
<td>Material -</td>
<td></td>
</tr>
<tr>
<td>• loose stockpile</td>
<td>1.2</td>
</tr>
<tr>
<td>• hard to drift (dry non cohesive or wet sticky material)</td>
<td>0.8</td>
</tr>
<tr>
<td>• rock</td>
<td>0.6 - 0.8</td>
</tr>
<tr>
<td>Slot Dozing</td>
<td>1.20</td>
</tr>
<tr>
<td>Visibility -</td>
<td></td>
</tr>
<tr>
<td>• dust, rain, darkness</td>
<td>0.80</td>
</tr>
<tr>
<td>Job Efficiency -</td>
<td></td>
</tr>
<tr>
<td>• 60 min/hr</td>
<td>1.00</td>
</tr>
<tr>
<td>• 50 min/hr</td>
<td>0.85</td>
</tr>
<tr>
<td>• 40 min/hr</td>
<td>0.67</td>
</tr>
<tr>
<td>Grades -</td>
<td></td>
</tr>
<tr>
<td>(See following graph)</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 12**

![Graph showing grade and factor relationship]
There are several specific buldozing technique which will improve productivity.

8.4.7 Slot Dozing

Slot dozing is commonly use in stockpiling operations to reduce end spillage and increase blade capacity. To use the method, several passes are made over the same area. As the depth of the slot increases, the sides of the cut hold material in front of the blade making it possible to drift larger loads. In effect, windrows should be maintained on either side of the blade whenever possible.

![Diagram of Slot Dozing](image1)

FIGURE 13

8.4.8 Working Downhill

Working downhill increases output in two ways, firstly the material in front of the dozer blade rolls ahead reducing weight and secondly gravity assists the machine thus effectively increasing power.
8.4.9 Ripping

The ripper is a tool mounted on the back of a bulldozer designed to penetrate the ground and loosen the material so it can be more readily pushed up.

Ripping should only be carried out in first gear with as many tynes as can be used without stalling the machine or breaking out large slabs. Ripping direction depends on the pit layout, wherever possible downhill ripping should be used to take advantage of the machine mass.

8.4.10 Dozer Travel

The aim should be to fill the blade in a distance of eight metres, and travel with a full blade at full motor revolutions whenever possible. The machine should always be reversed in as high a gear as is practicable.

8.4.11 Dozer Blades

For stockpiling only the straight blade or the Universal blade should be used.

An angle blade should never be use for stockpiling since it is designed for side casting of backfilling.

9. REHABILITATION OF BORROW PIT AREAS

Damage to natural vegetation and agricultural land is inevitable when borrow pits are operated. However this damage can be minimised by using techniques which simplify the rehabilitation process and conserve the native vegetation.

If extra attention is given to the following points, it will help to improve rehabilitation prospects of borrow areas:

- Clearing of the pit area should be planned so that only essential areas are stripped of vegetation.

- Top soil is the upper layer of earth which contains plant nutrients, organic matter and seeds. This material must be retained in stockpile separate from timber, overburden and gravel.
• Overburden should be stockpiled in such a way that it can be returned to the pit floor before the topsoil.

• After removal of the gravel, the sides of the pit should be graded down to a gentle batter slope and the whole area smoothed out. Ideally the finished pit profile should fit in with the general slope of the land. Overburden may be returned to the pit to assist in this procedure.

• Any unsalvageable timber should be pushed into the centre of the pit area and burnt.

• At the completion of the previous operations, the stockpiled topsoil should be spread evenly over the entire pit area to a minimum depth of 75mm.

• Lastly, the whole pit area should be ripped with a bulldozer tyne following the natural contours. This prevents erosion of topsoil, allows penetration of roots and reduces ponding of rainwater. (This final step is not carried out when rehabilitating pit areas in pastured land).

Refer to “Environmental Management Guideline – Pits and Quarries for Road Building Materials” MRWA

10. REPORTING

A report is necessary at the conclusion of a gravel search for two purposes. Firstly it is a means of providing a permanent record of what was achieved as a result of the search and secondly, the information provided will help others form opinions and allow decisions to be made regarding the gravel.

Reports must be accurate, complete and both easy to read and understand.

10.1 Parts of a Report

10.1.1 The Title

The title briefly sums up the subject matter of the report.
10.1.2 The Body

The body of the report should be complete by itself and should be able to be read without the other parts. There are five parts to the body of a report.

- Introduction

  The introduction states the purpose of the investigation and details the scope of the problem.

- Procedure

  The procedure describes the methods used during the investigation, the area covered and time taken for the job. Very detailed information is referred to and included in the Appendix.

- Results

  The results of the investigation are outlined or summarised in general terms.

- Discussion

  The discussion evaluates the results of various pits located. This includes discussion of test results, quantities and economics.

10.1.3 Conclusion and Recommendation

- The conclusion and recommendations are made from an assessment of the information.

  The end of the report is signed and dated.

10.1.4 Appendices

  Appendices may include copies of maps, detailed test results and pit diagrams.
10.1.5 Example of a Short Report

An example of a short report for the following request for work is given below:

A 5km section of North West Coastal Highway 30km north of Geraldton is due for widening in four weeks time. There is a requirement for sufficient basecourse to widen the section by 3.6m. The pavement design shows a requirement of 125mm of basecourse over the yellow sand clay sub-base.

Gravel Investigation for Widening NWCH Near SLK 30

The gravel requirement for the above section was calculated at approximately $2{,}500\text{m}^3$.

The general area from which material could be economically carted has been thoroughly investigated at various times over the past few years and the only gravel deposit between SLK 15 and SLK 45 and within 10km of the highway is the gravel deposit known as Heinricks Pit.

A backhoe was used to extend the old pit area and a grid of 25m x 25m was established over an area of 5 000m$^2$.

The depth of the deposit of laterite gravel is about 600mm so the gridded area will provide approximately $3{,}000\text{m}^3$ of material.

The samples of gravel tested show the material to be similar to previous gravel used as basecourse from the pit area. The gravel is well graded and low in plasticity and based on previous experience is easily worked and compacted on the job.

Since Main Roads WA has been granted a gravel reserve on the site, no entry or ownership problems exist.

The ideal machine for stockpiling is a D7 size tracked dozer which has sufficient power and mass to remove some boulders and break up large conglomerate lumps.
Care should be taken to ensure that sufficient topsoil is retained for reinstatement of the pit area. Test results pit diagrams and location details are given in the attached Appendix.

SIGNED
TESTING OFFICER

DATE

APPENDICES
PROPOSED EXTENSION OF HEINRICHS PIT

AMG REFERENCE
GERALDTON
1840 713339

OLD PIT AREA

PROPOSED AREA

GRID

OVERBURDEN / TOPSOIL TO BE STOCKPILED HERE

CALCULATIONS

AVERAGE DEPTH OF GRAVEL 670mm

ESTIMATED QUANTITY:

0.67 x 50 x 100

= 3350m³
<table>
<thead>
<tr>
<th>NO</th>
<th>AMG</th>
<th>OVERBURDEN</th>
<th>DEPTH (mm)</th>
<th>MATERIAL TYPE</th>
<th>USC</th>
<th>GRAVEL</th>
<th>DEPTH (mm)</th>
<th>MATERIAL TYPE</th>
<th>USC</th>
<th>SAMPLE</th>
<th>UNDERLYING MATERIAL</th>
<th>DEPTH (mm)</th>
<th>MATERIAL TYPE</th>
<th>USC</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>GERALDTON 1840</td>
<td>0-110 YELLOW CLAYEY SAND</td>
<td>110-730</td>
<td>CLAYEY GRAVEL</td>
<td>GC</td>
<td>√</td>
<td>ROCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1B</td>
<td>713339</td>
<td>0-150 &quot; SAND</td>
<td>150-900</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
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<td>&quot;</td>
<td>0-130 &quot;</td>
<td>130-740</td>
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<tr>
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<td>&quot;</td>
<td>0-150 &quot;</td>
<td>150-830</td>
<td>&quot;</td>
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<td>110-750</td>
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Comments: ROCK
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- Main Roads Act 1930
- Aboriginal Heritage Act 1972
- Mining Act 1978
- Land Administration Act 1997
- MRWA Operational Guideline 95 Extracting Roadbuilding Materials
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