

## **Impacts of Blasting on Groundwater**

### **1 Introduction**

- 1.1.1 Both geology and soils play an important part in determining the environmental characteristics of a region. The underlying geology has a major influence on landform, and rocks provide the parent material from which soils are created. The nature of the rock helps to determine not just the nature and chemistry of the soil, but also the rate at which it forms. This in turn strongly affects the vegetation that will grow naturally and the type of agriculture or horticulture that can be sustained.
- 1.1.2 The available information on the existing conditions of the rock mass along the AWPR route indicates that the excavation methodology of the successful contractor may include the use of explosives in the cutting areas of the route. Successful blasting produces well broken rock material which is easily removed, leading to high excavator productivities, shorter programmes, less uncertainties in having to deal with 'unforeseen ground conditions' and rippability variations, and increases options for excavation in different areas. The economics of the construction phase, therefore, can be significantly influenced by this option.
- 1.1.3 The AWPR proposes a number of deep cuttings where groundwater levels will be above the final base of the cuttings. In some cases, these cuttings are in relatively close proximity to contaminated landfill sites. This assessment considers the risk of increased vulnerability of the bedrock aquifer to pollution incidents as a result of blasting operations during AWPR construction.
- 1.1.4 This assessment addresses only the impacts of blasting on the rock mass itself and its hydro-geological characteristics. Vibration impacts are addressed in general terms within the Disruption due to Construction chapters of this Environmental Statement (Chapters 8, 33 and 48).

### **2 Baseline**

- 2.1.1 The existing ground conditions include a variable rock mass which comprises weathered schist, gneiss, granite, microdiorite, pelite (a commonly used term to describe metamorphosed argillaceous [fine grained] sedimentary rocks) and psammite (metamorphosed arenaceous [coarser grained] sedimentary rocks). Where this is weathered and weak, the materials will be excavatable using standard excavators and rippers. The rippability will vary from easy ripping in the weak, foliated, highly weathered rocks to hard ripping in the moderately strong or better, slightly weathered gneisses and granitic rocks. The ease of rippability will essentially depend upon the fracture index and compressive strength of the bedrock rock mass. However, there will be areas in the deep cuttings where slightly weathered strong granite and gneisses occur at depth which will prove very hard to rip and blasting will be the alternative method of excavation. In this situation it may be more economical to blast the whole of the cutting as opposed to local ripping and blasting.

### **3 Potential Impacts**

#### **3.1 General Impacts of Blasting**

- 3.1.1 Considering the rock mass itself, case histories and studies indicate that there are three major mechanisms whereby rock blasting can impact on the nearby rock structure, including the generation of new fractures in previously intact rock, the dilation of existing joints and discontinuities by the action of high pressure explosive gases, and the promotion of slip along unfavourably oriented joints and fracture surfaces. The generation of new fractures in previously intact rock and the dilation of existing

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joints and discontinuities are essentially vibration controlled and are generally termed 'near-field' effects which occur close to the blast zone. The third effect of initialising slippage along unfavourably oriented joints are also vibration effects and can occur hundreds of metres from the blast, and are called 'far-field' effects.

- 3.1.2 The role of vibration has been studied in terms of both acceleration and velocity effects, with damage potential from blast induced vibration expressed in terms of both 'peak particle acceleration' (ppa, in mm/sec<sup>2</sup>) and 'peak particle velocity' (ppv in mm/sec). Studies concerned with near-field effects where the amplitude of vibration is sufficient to induce fracturing of the rock mass, are generally concerned with peak particle velocity, while those concerned with far-field effects are generally concerned with peak particle acceleration.
- 3.1.3 Unsuccessful blasting which does not achieve its objectives can lead to increased production costs in the form of secondary breakage requirements, loading and removal costs and machine maintenance costs. In order to reduce the likelihood of unsuccessful blasting, some operators in the past have tended to over blast. Over-blasting can create unacceptable instability and permanent damage to the rock mass, together with other structures and utilities within influencing distance of the blast.

## **3.2 AWPR Impacts**

- 3.2.1 In relation to impacts on rock-mass and hydrogeology, there are a number of issues that will need to be addressed if the contractor opts for the use of explosives in the excavation of the cuttings along the route. There are a number of deep cuttings, where groundwater phreatic surface levels will be above the final base of the cuttings, and where there are sensitive receivers, for example, contaminated landfill sites in relatively close proximity.
- 3.2.2 The following list identifies sensitive receptors and outlines the potential impacts of blasting operations. The detailed studies required in the next phase of the development are described.

### **Existing contaminated landfill sites**

- 3.2.3 **A.** In relation to the landfill sites there are a number of issues that will need to be addressed. These include the effects on the hydraulic conductivity within the rock mass in terms of near-field effects, and the movement of groundwater in the vicinity of the landfill and sensitive receivers. In relation to this the contractor or blasting specialist will be required to assess the stress and strain in the rock mass induced by the high vibration levels near the blast. The distance from the blast where creation of new fractures and dilation of existing discontinuities ceases will need to be determined, typically assessing rock mass parameters including an examination of the tensile strength of the rock mass, its Young's modulus, peak vibration levels, and p-wave velocity. Literature searches indicate the onset of cracking of rocks at ppv levels of around 635mm/sec (Hoek & Bray, 1981: 'Rock Slope Engineering'. Revised 3<sup>rd</sup> Edition) and 700-1000mm/sec for hard igneous rocks (Holmberg, R. & Persson, P.A., 1979: ' Design of Tunnel perimeter blasthole patterns to prevent rock damage'. *Proc . IMM Tunnelling '79 Conference, London*). The level of vibration at any distance , X, from a blast hole can be determined from examination of the scaled distance (the radial distance to the structure divided by the square root of the weight of explosives) and site specific rock mass constants. These constants are derived from plots of the measured received ppv against scaled distance.
- 3.2.4 However, the literature suggests that the distance over which the near-field permanent damage to the rock slope in the form of breakage of intact rock and the formation of new fractures is limited. For a 100Kg charge weight, Hoek and Bray (1981), for example, suggests the onset of rock breakage to be within around 20m of the blast hole. Similarly, Holmberg and Persson (1979) estimate for a 110kg ANFO single hole blast, a vibration level needed to break hard igneous rock (700+ mm/sec) would be

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within 20m of the blast hole. This is based on a relationship between the peak dynamic strain in the rock induced during blasting, the ppv and the p-wave velocity of the rock mass. The actual levels of vibration induced in the rock mass must be measured in the field using geophones.

- 3.2.5 In the case of the effects on the hydraulic conductivity within the surrounding rock mass, it may be necessary to produce fracture contouring around the blast hole. These contours are established by examining the vibration propagation characteristics of the rock mass and the relationship between vibration and strain within the rock mass. These contours represent the zone around a blast hole in which fresh fracturing will occur as a direct result of vibration from the detonating explosive in the blast hole. Such a contour diagram provides a good indication of the amount of damage to the rock mass and helps determine spacing between blast holes to limit damage. It also indicates the zone of the rock mass where the hydraulic conductivity will have been permanently altered.
- 3.2.6 **B.** The effects of the blasts on existing landfill liners, especially where clay liners have been used. Any dried clay liners close to the blast site may be damaged in the form of cracking through the liner.
- 3.2.7 **C.** The effects on the stability of any loose landfill side slopes. Vibrations within the loose fill slopes can induce failure, including liquefaction failure.
- 3.2.8 **D.** The effects on any exposed man-made soil or rock slopes within the landfill site.

**Existing rock, soil and fill slopes within influencing distance of the blasts, either existing road cuttings or other slope cuttings**

- 3.2.9 In these cases each existing slope will need to be studied for existing stability and stability after blasting. Vibrations induced by blasting produces particle acceleration which tends to reduce the coefficient of friction of unfavourably oriented joint planes within a rock slope, which can lead to failure, and to create vibration and failure in weak soil and liquefaction in loose fill slopes. For each feature the allowable peak particle velocity and acceleration will need to be determined and this then related to detailed blast design including maximum charge weight per delay and the linear charge loading term which relates to the charge density and hole diameter. The contractor will be expected to complete detailed stability analyses of each slope using suitably approved methods, such as static, dynamic and pseudo-static analyses where vibration effects are modelled as disturbing forces.

**Existing Utilities and services**

- 3.2.10 Each utility, in particular gas mains, power cables, pylons, and water mains will have allowable peak particle velocities that the service provider or utility company may be able to provide. These must be used in the blast design to limit charge weights as outlined above. Allowable vibration limits for utilities will be relatively low, typically 10-15mm/sec.

**3.3 Mitigation**

- 3.3.1 If the successful contractor opts for blasting in any of the cuttings, these will need to be designed in full cognisance of the current British Standards and regulations currently in force. These include, but not limited to, BS5228, which covers noise and vibration control on open construction sites and the Scottish Development Department Planning Advice Note 50 [PAN 50] Annex D 'The Control of Blasting at Surface Mineral Workings'.
- 3.3.2 The use of explosives on the site will be governed by the current explosive regulations, including the 'Manufacture and Storage of Explosives Regulations 2005' and the 'Control of Explosives Regulations 1991'. Other related regulations include 'Control of Major Accident Hazard Regulations 1999',

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‘Ammonium Nitrate Materials (High Nitrogen Content) Safety Regulations 2003’ and ‘Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004’.

3.3.3 The contractor will also be expected to adhere to the requirements of the The Health and Safety Executive when using explosives

### **3.4 Blasting Designs**

3.4.1 The contractor will be expected to carry out a detailed blasting assessment to include all of the above requirements, together with trial blasts to determine site specific parameters and blasting constants.

3.4.2 The blast designs will need to include a monitoring regime for all adjacent structures, utilities, slopes and landfill sites and his blast design will need to include measures to reduce blast vibrations to a minimum. The design will be an iterative process, with each blast being studied and fine-tuned.

3.4.3 Measures to limit vibration levels and rock mass damage are expected to include:

1. The use of pre-split holes behind the production holes to limit the damage contours from the bulk blast.
2. Closer blast hole spacing
3. Use of delay intervals
4. No stemming in the blast holes
5. Reduced burden
6. Low explosive loading densities to reduce peak blasthole pressure – reduction of the effective explosive density can be achieved by diluting the explosive with inert material, decoupling the explosive from the rock,( charge diameter less than blast hole diameter), air decking or use of low density explosives.
7. Blasting pressures maintained to around the compressive strength of the surrounding rock.
8. Careful determination of the minimum standoff distance between the final face and the nearest blasthole, (if more than 1 row of blastholes is required).
9. Inclined faces.

3.4.4 The blasting assessment and monitoring will also need to determine other environmental considerations, including air-overpressures created by the blast, measured in decibels and fly rock following blasting.

### **3.5 Residual Impacts**

3.5.1 There is a high likelihood that the vibrations induced by any blasting operations can be controlled so as to minimise the effects on the surrounding rock mass and the hydro-geological behaviour adjacent to the landfill sites. The contractor will be expected to adhere to the above design principles as well as the guidelines and standards and to design his blasts to remove or minimise rock mass damage. The effects on the rock mass in terms of creation of new fractures and widening of existing discontinuities are near-field events and landfill sites a substantial distance away, say over 50m, should not be significantly affected. Landfill sites between 0m and 50m from the blast should be examined as part of the detailed design and an assessment of likely impacts, if any, made at that time, so that contamination of the groundwater by the landfill can be avoided. A full monitoring programme will be specified to monitor each blast so that the effects of individual blasts can be used to re-design future blasts. An Independent Blasting certifier can be specified if the dangers are considered significant.