The quarry design process as an essential framework for sustainable planning and operation of aggregate quarries

Ruth Allington
President European Federation of Geologists
Joint Senior Partner, GWP Consultants LLP
EFG mission*

- Contributing to safer and more sustainable use of the natural environment and responsible exploitation of natural resources by:
  - Promoting excellence in the application of geoscience
  - Creating public awareness of the importance of geoscience to society

* The purpose of the organisation describing why it exists and what it does to achieve its vision
EFG Values*

• Public safety, responsible use of natural resources and sustainable development are best served by well educated and trained professional geoscientists working transparently with other professionals and communicating effectively with the public.

* What do we believe?
GWP Consultants LLP

- Designing open pits for more than 35 years (RA for 30 years this month)
- Engineering geology, geomorphology, hydrogeology, geotechnical and mining engineering
- Environmental impact assessment:
  - Impact on water
  - Impact on landscape
  - Impact of blast vibrations
  - Impact on security of land
Design objectives – achieving an appropriate balance

COMMERCIAL OBJECTIVES
BUSINESS PLANNING AND MANAGEMENT, FINANCIAL RISK ASSESSMENT, AND OPTIMISATION OF RESERVE QUALITY AND ASSET VALUES BASED ON ROBUST DESIGNS THAT CAN BE COSTED

ENVIRONMENTAL IMPACT
ENVIRONMENTAL ASSESSMENT, MITIGATION AND ENHANCEMENT AT DESIGN STAGE, MANAGEMENT AND COMPLIANCE AT OPERATIONAL STAGE, AND ENVIRONMENTALLY SUSTAINABLE FINAL RESTORATION AND AFTER-USE SCHEMES

QUARRY DESIGN

SAFETY AND EFFICIENCY
INHERENTLY EFFICIENT, SAFE AND SECURE OPERATIONS (INCLUDING AFTER CLOSURE FOR PUBLIC AND WORKERS) THROUGH DESIGN THAT DELIVERS COMPLIANCE WITH APPROPRIATE REGULATIONS AND BEST PRACTICE.

GWP consultants
earth & water resources
What’s in it for the operator?

- A robust business plan for an operation that will be profitable and provide a return on capital
- Detailed operating plans that can be followed with ‘no surprises’
- Plans and supporting data suitable for compliance with laws and regulations
- Social licence to operate
What’s in it for the public?

- Existence of a detailed working and restoration plan that can be monitored and against which the operator can be called to account
- A design that minimises impacts on the environment and communicates to them what will happen
- An operator who is confident to engage with the public
### After D. Shields SARMa conference Ljubljiana 20 September 2011

<table>
<thead>
<tr>
<th>SARM</th>
<th>Sustainable Aggregates Resource Management</th>
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<tr>
<td>SSM</td>
<td>Sustainable Supply Mix</td>
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#### SQP
Sustainable quarry practices

#### MCSD
Quarrying and Materials Contribution to Sustainable Development

<table>
<thead>
<tr>
<th>ACTIVITIES DIRECTED TOWARDS SECURING</th>
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<tr>
<td>ENVIRONMENTAL IMPACT</td>
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<th>LAWS AND REGULATIONS WITHOUT CONFLICT WITH COMMUNITIES</th>
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<td>INHERENTLY SAFE AND SECURE OPERATIONS (INCLUDING AFTER CLOSURE) THROUGH DESIGN THAT DELIVERS COMPLIANCE WITH APPROPRIATE REGULATIONS AND BEST PRACTICE</td>
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<tr>
<th>PLANNING, STRATEGIC AND POLICY FRAMEWORK WITHIN WHICH THE INDUSTRY OPERATES AND IS REGULATED</th>
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SITE SELECTION AND STRATEGIC ISSUES
- CONTROL OF LAND
- RESOURCES
- DEMAND
- PLANNING STATUS AND CYCLES
- HUMAN/ENVIRONMENTAL CONSTRAINTS
- TECHNICAL CONSTRAINTS
- RESTORATION OPTIONS
- AFTER-USE AND LONG TERM ASSET VALUE

CONCEPTUAL DESIGN AND FEASIBILITY STUDY
Selection of preferred option for working up into a planning application and/or detailed operating and restoration plans

DESIGN STAGE (i): DETAILED DESIGN OF FINAL VOID AND RESTORATION SCHEME
Decision to go forward with investment and the preparation of a full planning application and ES

DESIGN STAGE (ii): DESIGN OF PHASED WORKING AND RESTORATION SCHEME
Preparation and submission of full planning application and ES and quarry development plans supporting the business plan and compliant with all regulations

DESIGN RISK ASSESSMENT
LIMITING
- ENVIRONMENTAL UNCERTAINTY
- OPERATIONAL UNCERTAINTY
- COMMERCIAL UNCERTAINTY
Design risk assessment framework

1. Description of action
2. Hazard identification
3. Identification of consequences
   - Estimation of magnitude of consequences
   - Estimation of probability of consequences
4. Risk Estimation
   - Risk perception
5. Risk Evaluation
6. Risk Assessment
7. Risk Management

Data collection and definition of input assumptions
Data assessment and predictions of risk
<table>
<thead>
<tr>
<th>Probability matrix</th>
<th>Magnitude</th>
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<tbody>
<tr>
<td></td>
<td>Catastrophic impact</td>
</tr>
<tr>
<td>Very High</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
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<tr>
<td>Low</td>
<td></td>
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<tr>
<td>Very Low</td>
<td></td>
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<tr>
<td>Negligible</td>
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Key to the shading used in the probability/impact matrix

<table>
<thead>
<tr>
<th>Shading</th>
<th>Description</th>
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<tbody>
<tr>
<td>Red</td>
<td>Unacceptable risk – immediate action required to improve control</td>
</tr>
<tr>
<td>Orange</td>
<td>Acceptable risk – close monitoring is required and cost effective risk control measures should be considered</td>
</tr>
<tr>
<td>Green</td>
<td>Acceptable risk – no action now but review periodically and consider possible low cost control improvements</td>
</tr>
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</table>

Figure 6-4  Example of a probability/impact matrix
Conceptual design

• Basic objectives:
  - Establish limits of working within the chosen site and estimate recoverable resources
  - Identify major environmental constraints
  - Decide on working methodology
  - Decide on final restoration and after-use objectives
Initial estimate of resources

Excavation area considered in site selection resource estimate

Site boundary – area of which operator can gain control

Resources estimated using the following approach:

\[(\text{Excavation area} \times \text{mineral thickness} \times \text{in situ density}) \times F\%\]

Where F% is a factor allowing for:

- geological uncertainty
- processing and quarrying waste
- mineral that cannot be worked beneath excavated slopes and haul roads
- Reduction in the working area to allow for establishment of infrastructure and environmental standoffs
Resources estimated using the following approach:

\[(V - \text{in situ waste}) \times \text{in situ density}\] – processing waste

Where V is \textit{in situ} volume directly measured from:

- detailed 3D site design plans depicting the final excavation geometry of the operation
- accurate surface models of all key geological surfaces (including water table, rockhead and base of mineral)
Choosing the working methodology

Open pit quarry - method 1

Benches are worked successively, such that the entire excavation area is disturbed throughout the operation.

Overburden, soils, quarry waste and any material that cannot be sold directly must be stored outside the excavation limit, for which storage space is required.

Method is suitable for bulk minerals where there is plenty of out of pit tipping space for overburden, soils, waste and stock storage, or in small sites where method 2 is impractical.

Open pit quarry - method 2

A void is created to the full depth of the deposit (1) and then full faces are advanced (2) then (3) at multiple bench levels.

This method allows progressive replacement of overburden and soils in low level restoration or backfilling with landfill as soon as the faces have advanced sufficiently to create space for this to happen.

The overburden, soils, and quarry waste from the initial void (1) must be stored outside the excavation limit, but the space required will generally be smaller than for method 1.
**Excavation and restoration of a hard rock quarry - Option 1**

Key quantities and issues for Option 1

Extraction volume: 1,050,000m³ of virgin ground, of which 157,500m³ is waste.

Groundwater management required. The floor is below the maximum inferred groundwater levels (which vary seasonally). At the eastern extent, to exploit a particularly valuable bed, the floor is lower still and will always be below the water table.

Blasting is required to extract the basal bed.

Restoration option 1: Low level restoration and battering of slopes to a lesser gradient. Some faces have been left exposed to provide geological conservation areas. The floor level to the west of the site is raised above the maximum inferred groundwater table, with no backfill to the eastern extent to create a lake.
Excavation and restoration of a hard rock quarry - Option 2

Key quantities and issues for Option 2

Extraction volume 1,515,000\(\text{m}^3\) of which 256,300\(\text{m}^3\) is waste. The extraction area includes previously quarried ground to the south west of the site. The proportion of waste to mineral is substantially higher in this area, providing more material for restoration.

Groundwater management required. A particularly valuable bed on the eastern area of the pit floor is below the water table throughout the year.

Blasting is required to extract this basal bed.

Restoration option 2: Restoration nearly back to original ground levels, due to the high waste volume generated. This design also assumes the importation of materials. This option can be used for all extractions.
Excavation and restoration of a hard rock quarry - Option 3

Key quantities and issues for Option 3

Extraction volume: 532,000 m³ of virgin ground, of which 79,800 m³ is waste.

No groundwater management and no blasting required. The floor of the pit is above the maximum inferred water table and above the valuable bed, reducing the volume of recoverable mineral.

Restoration option 3: Low level restoration and battering of slopes to a lesser gradient. The floor level will be raised by about 0.3m to enable vegetation to be established. With lesser mineral and lesser waste from that mineral extracted, the previously worked area to the south west has been regraded and the ground surface lowered slightly to realise additional fill materials to complete the in pit restoration.
Example of final excavation design

DRAFT
Example of detailed working plan showing intermediate phase of working
Incomplete, ill considered or poorly communicated quarry design....

- Unacceptable environmental impacts;
- Nuisance or danger to the public;
- Danger to the workforce; or
- Additional monitoring costs for the operator and Regulators

- Cost;
- Litigation risk; and
- Loss of profit or asset value to the operator and/or landowner.
Incomplete, ill considered or poorly communicated quarry design….

- Does not achieve essential balance when implemented
- Long term damage to an operator’s or landowner’s reputation locally or with its customers;
- Distracting conflict with stakeholders;
- Difficulties getting further permissions
Quarry design is not.....

- Just a technical process undertaken by geotechnical and mining engineers, planning specialists or geologists
Successful quarry design is …..

• An inclusive and iterative process undertaken by a team of people covering a wide range of technical and commercial disciplines

• Produced by carefully chosen and well managed teams and involves or takes account of the views and requirements of all relevant interested and affected parties (stakeholders)

• Based on reliable and relevant maps and models
For more information about EFG:
www.eurogeologists.eu

For more information about GWP:
www.gwp.uk.com

To contact me:
rutha@gwp.uk.com
Some references

- **A QUARRY DESIGN HANDBOOK** (pre-publication draft 2008); This handbook, written in partnership with David Jarvis Associates, introduces the subject of quarry design and provides guidance for a wide range of stakeholder groups with involvement and interest in the subject. Available to download at [http://www.gwp.uk.com/research.html](http://www.gwp.uk.com/research.html). Hard copy publication planned subject to funding.

- **ALSF SUSTAINABLE AGGREGATES: A REVIEW OF AGGREGATES LEVY SUSTAINABILITY FUND RESEARCH PROJECTS (2007)**. This report was one of the Sustainable Aggregates series of benchmark reports and was developed to reflect the latest information and good practice from ALSF or other recent work to make them easily accessible to those who can apply them in practice. This summary report summarises the key findings of the reports and provides a sign-post to further information in the reviews. To find out more about this report or download a copy, please visit the ALSF Sustainable Aggregates website at [http://www.sustainableaggregates.com/rprts_revs/rr_summaryreport.htm](http://www.sustainableaggregates.com/rprts_revs/rr_summaryreport.htm).

- **AN OVERVIEW OF DESIGN AND MANAGEMENT APPROACHES TO REDUCING THE ENVIRONMENTAL FOOTPRINT OF THE SUPPLY CHAIN FOR LAND-WON AGGREGATES (2007)**. The overview report draws on the information in the twelve reports which have been produced as part of the thematic review of Aggregates Levy Sustainability Fund (ALSF) research projects for land-won minerals. It puts them into the context of the quarry life-cycle, specifically in relation to the various elements of environmental footprint and the stages in the supply chain for land-won aggregates. In particular, the report helps to emphasise some of the major findings of the ALSF research and describes some of the complex inter-relationships between environmental footprints at different stages of a quarry’s life.

The overview report builds on the concept of environmental footprint and, drawing on the twelve themes, shows how the design and management of the quarry has a key role to play in determining the overall balance of negative and positive environmental effects. To find out more about this report or download a copy, please visit the ALSF Sustainable Aggregates website at [http://www.sustainableaggregates.com/rprts_revs/rr_overviewreport.htm](http://www.sustainableaggregates.com/rprts_revs/rr_overviewreport.htm)