

# **LMCL** (t/a **DroneSurv<sup>®</sup>** & **QuarryDesign<sup>®</sup>**)

**Consulting Engineering Geologists and Surveyors**



**Traditional Surveys (Total Station, Base & Rover GPS)  
ROV / USV / RPAS (“Drone”) Surveys and Inspections  
Point Cloud Surveys (Photogrammetric and LiDAR)  
Geological Investigations and Mapping  
Geotechnical Assessments  
Numerical Modelling**

**Land and Minerals Consulting Limited**



# LMCL



## History

**Land and Minerals Consulting Ltd (LMCL)** was formed in 2004 as a geological, geotechnical and surveying consultancy. In 2006, the Company adopted the trading name **QuarryDesign**<sup>®</sup> to promote its links with the mineral planning consultancy Quarryplan Ltd. The Company bought its first long-range high-resolution LiDAR scanner in 2010 and its first small unmanned aircraft (SUA) or 'drone' in 2012. In 2013, following the issue from the Civil Aviation Authority (CAA) of its first Air Navigation Order 2009 "*Permission to conduct aerial work*") LMCL adopted the second trading name **DroneSurv**<sup>®</sup> (a name more suited to aerial work outside of the mining and quarrying industry). LMCL have maintained their CAA permissions since 2013 and hold the current "*Operational Authorisation in the Specific Category*" for Visual Line of Sight (VLOS) flights to 1km and Beyond Visual Line of Sight with Visual Mitigation(BVLOS-VM) flights to 2km. LMCL's CAA registration number is 244 proving their early adoption of drone technology.

## Specialisms

Using their terrestrial survey systems, and survey systems mounted on ROV's (Remotely Operated Vehicles), USV's (Unmanned Surface Vessels), and RPAS (Remotely Piloted Aerial Systems) to acquire point-cloud surveys (photogrammetry and LiDAR); LMCL's Surveyors, Geologists and Geotechnical Engineers have developed a specialism in the remote acquisition of survey, geological and geotechnical data. In addition, LMCL not only has the expertise to acquire the data; but has the hardware, software and (most importantly) the experience to process that data into formats required by a wide range of industry standard surveying, geological modelling and geotechnical analysis software (and any other format that the client or end-user requires) and hydrogeological impact assessments. Furthermore, as an integrated consultancy, LMCL's geologists and engineers are able to undertake the analysis (and if required designs) for natural exposures, excavations (both surface and subterranean), embankments, tips and lagoons in both engineering soil materials and rock masses.

## Industry Sectors and Clients

LMCL have undertaken projects for a wide range of industries including Mining Companies, Quarrying Companies, Construction Companies, Media Companies, Television & Film Companies, Property & Estate Management Companies, Local Government, The Gibraltar Government and the Ministry of Defence. LMCL have worked extensively in the UK and also in Ireland, France, Germany, Spain, Portugal, Gibraltar, Sardinia, Norway, Greenland, Saudi Arabia, Senegal, Bangladesh, Chile, The Falklands and Montserrat. LMCL's high-quality, full-colour, point-cloud surveys were used in HBO's highly successful Game of Thrones series and LMCL's surveys have been used by the Extreme E worldwide electric rally race.

## Awards

Under the QuarryDesign<sup>®</sup> trading name, LMCL were awarded 'Joint Runner-up' in the Engineering Initiatives category of the Mineral Planning Association's Health and Safety Awards 2013 held at BAFTA in London for their use of 'Terrestrial LiDAR and Unmanned Aerial Systems for remote Surveying and Geological / Geotechnical mapping'.

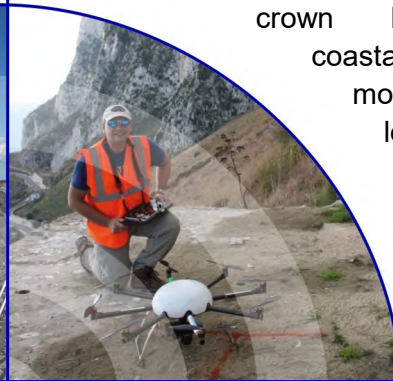
## Inspections (rock, slope and buildings)

LMCL have numerous inspection drones (small highly manoeuvrable drones with anti-collision sensors or small drones suspended in cages) that enable close inspection of both interior (and often 'confined') spaces, mine workings, exterior buildings, rockfaces and slopes in situations where manned inspections would be hazardous or expensive. The following image shows one of LMCL's Geotechnical Engineers commencing a face inspection of an open-pit mine in Norway. Other inspections have included Clevedon Pier (at low tide), the outside of historic buildings, derelict buildings and large industrial chimneys, both the outside and inside of grain and powder storage silos and inside mine and quarry crusher houses.



## Mountain and cliff surveys

LMCL undertake highly detailed surveys of steep, difficult to access or hazardous environments using a number of multi-rotor drones employing a wide-range of surveying and mapping sensors (dSLR cameras, multi-spectral cameras, infra-red thermal cameras and LiDAR). The image below shows a Surveyor about to undertake a particularly challenging survey of high limestone cliffs and sand slopes in Gibraltar using one of their large Octocopters. LMCL have undertaken numerous surveys of sink holes, crown holes, landslides, coastal erosion sites, mountains and cliffs, low-lying swamps, and flood surveys.



## Large area surveys

For large area surveys, fixed wing systems with greater flight times are more suitable than multi-rotor systems. LMCL have several such drones including Sensefly's small lightweight eBee (for use near or over 'congested' ground activities) and the larger vertical take-off and landing (VTOL) drones such as Quantum System's Trinity (pictured taking off). The latest Trinity-F90+ with post processing kinematic (PPK) technology means that large hazardous working environments (such as open-pit mines and quarries) can be accurately surveyed without the Surveyor setting foot in the mine / quarry. With a 35 knot flight speed and a 90 minute flight duration, Trinity can undertake very large area surveys quickly and safely.



## High precision LiDAR surveys

When precision is required, LMCL are able to produce highly precise surveys by employing one of their ILRIS or Polaris LiDAR scanners from Teledyne-Optech. These scanners have an exceptional long range (up to 2,500m in the case of Polaris), narrow beam divergence and high range-accuracy characteristics making them particularly suited to geological / geotechnical surveying and mapping. The image above shows one of LMCLs' Geotechnical Engineers at an open pit mine (quarry) with an ILRIS LiDAR scanner obtaining a point-cloud survey to assess the stability of a large wedge failure (this particular example will feature throughout this brochure).



## Vehicle Mounted LiDAR

LMCL's HeronTwin LiDAR system can be vehicle mounted, worn as a backpack or hand-held. It's most notable survey to date was a 3D point-cloud survey of a highway in Derbyshire. The brief was to collect the locations of all street furniture (road signs etc), road markings, dry stone walls and the locations of 9,000+ trees for a 50m wide corridor along a 3km valley section of the road. In places, the road was sinuous with poor line of sight. The acquisition took just two 9-minute passes to collect the data (compared with two surveyors taking a fortnight, and working in a potentially hazardous environment). 360° video captured by HeronTwin was essential in coding the survey with the correct road signs.



## Building and Infrastructure surveys

LMCL's suite of long-range terrestrial and mobile LiDAR, and drone mounted survey systems provide accurate and highly detailed building and infrastructure surveys. These survey systems can be integrated to produce high-quality exterior and interior surveys. A combination of the two has proved invaluable when construction, and indeed demolition, works have been required on buildings and plant with no 'as constructed' surveys or drawings. Works of this nature have included the Cable-car Station in Gibraltar (pictured), Power Station Cooling Towers, Quarry Processing Plant, a Mineral Milling Plant and many Heritage Building surveys (inside and out).

## Subterranean surveys

LMCL's Polaris LiDAR scanner with a 360° angle of rotation and a 75° look-up and 45° look-down angle makes it suitable for detailed subterranean surveys of large natural caves and mines. For smaller subterranean spaces (tunnels and adits), LMCL's HeronTwin LiDAR is particularly well-suited when worn as a backpack or hand-held. For even smaller voids, HeronTwin can be mounted on a ROV. In addition to collecting high-quality survey data and 360° video that can be used for fracture mapping and routine inspections; the HeronTwin software also compares 'live' LiDAR data as it is being collected with a preloaded previous point-cloud survey and shows any displacement that may have occurred between the survey intervals.

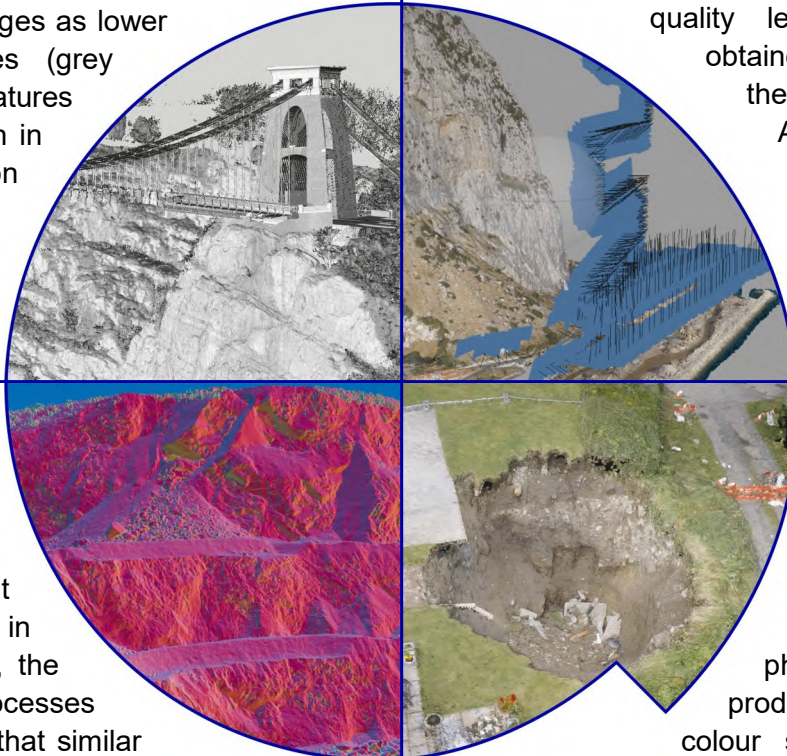
## Bathymetric surveys

LMCL have developed their own Unmanned Surface Vessels (USV's) to safely acquire bathymetric surveys and environmental data for inland rivers, ponds, lakes, silt settlement lagoons, tailings lagoons and shallow coastal waters. As LMCL can produce their own hulls; USV's can be fabricated and be tailored to whatever environmental sensor is required (e.g. depth, water temperature, conductivity). In the case of the bathymetric surveys, the multi-beam sonar returns a 'hardness' of the river/lake/sea bed and has also provided an indication of the thickness of accumulated silt. LMCL are currently developing a micro-USV capable of accurate location capabilities in GPS denied environments (flooded confined spaces).

# Processing of data

## 'Confidence' post processing

As well as investing in the necessary hardware, LMCL have also invested in software to process the data into formats that make the subsequent mapping and analyses easier. Their point-clouds can be post-processed and the points re-coloured with regards to a 'confidence' in the quality of the data. Point clouds processed in a greyscale confidence scheme generate a visually sharper and crisper survey. From a geological and geotechnical point of view; joint faces tend to be expressed as high confidence features (white points) and joint edges as lower confidence features (grey points). These features can be clearly seen in this scan of Clifton Suspension Bridge.



## Processing photogrammetrical surveys

LMCL use various photogrammetric processing software to process photographs captured by tripod mounted terrestrial and drone mounted cameras. From these software, coloured point clouds, meshes, and orthorectified photographs can be produced. The case study shown in the image below shows the locations of the 1,500 photographs taken of the north buttress of Gibraltar in 2015 from our large octocopter. In order to capture photographs of sufficient quality LMCL used a high quality dSLR with an exceptionally high quality lens. LMCL also obtained permission from the Director of Civil Aviation and the Ministry of Defence to fly within 600m of the airport and to a height of 1,000 feet.

## 'Inclination' post processing

As well as post processing point cloud surveys in confidence colours, the software also processes the point cloud so that similar oriented points are coloured similarly. The image above is an 'Inclination' post-processed point-cloud of the wedge failure that was shown being scanned in the previous section on data Acquisition. When post-processed in inclination colours, joint planes become more easily discernible. This makes the mapping of joints and subsequent geotechnical analyses easier that if the point-cloud had been left in the raw monochrome, reflectance or RGB colour schemes. 'Reflectance' values are also a useful post-processed scheme for mapping strata and water seepages.

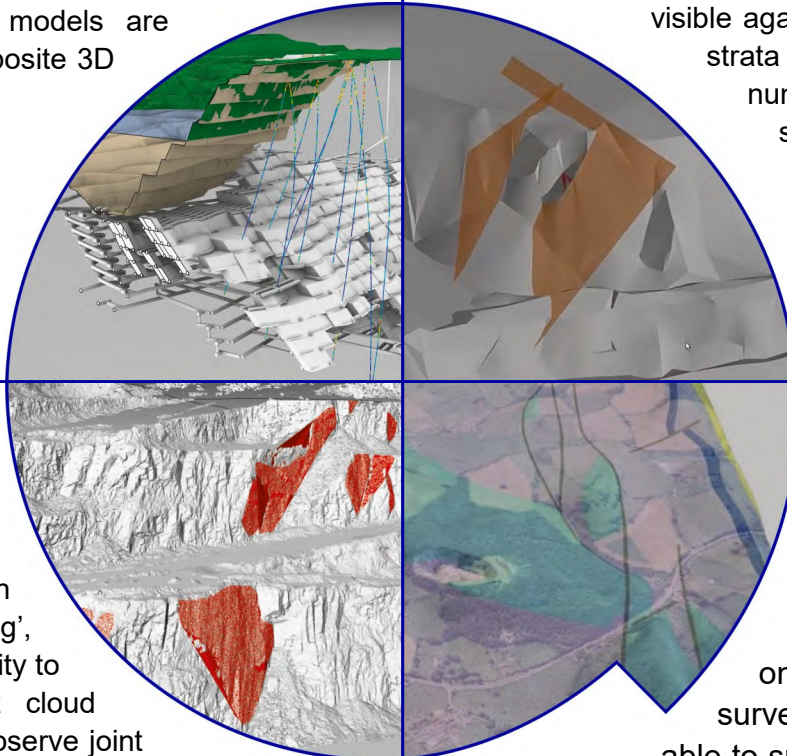
## Detailed RGB point-clouds

LMCL's point-clouds can be coloured from photograph images to produce high quality full colour surveys (both from our photogrammetrically derived point clouds and our LiDAR derived point clouds). These point cloud surveys have a wide range of uses and LMCL's Surveyors find that these are the easiest point clouds from which to digitise feature break-lines and spot levels to produce their topographical surveys. These surveys can be used in a wide range of engineering and CAD software. In the case of the crown hole survey (shown above) the volume of concrete backfill needed to infill the void was easily calculated but needed an accurate survey upon which to calculate the void volume.

# Geological and Geotechnical Mapping

## Underground mines and caves

LMCL have the expertise and software to produce detailed geological and geotechnical maps from exposed strata and from borehole data. Their Polaris and HeronTwin LiDAR scanners are particularly suited to scanning underground caves and mines. In the example below, LMCL's Geotechnical Engineers have combined their Surveyor's open pit mine survey with the Geologist's directional borehole investigation to undertake a geotechnical assessment of a possible deep mine design. All surveys, geological mapping data and mine design models are shown in one composite 3D model.



## Fracture mapping

As discussed in the previous section on data 'Processing', LMCL have the ability to false colour point cloud surveys to better observe joint planes and joint edges enabling their Geotechnical Engineers to easily map fractures. The above image shows fractures being mapped (shown on a 'Confidence' coloured point cloud survey). These joints can then be exported as polygons into any CAD package and the dip and dip direction of the joints can be exported into RocScience's software to determine joint sets, undertake kinematic analysis and to undertake stability analyses.

## Mapping (and projection) of joints

Once the joint pattern has been determined (see Inclination Processing page), software enables LMCL's Engineers to extrapolate the joint planes and determine where such planes may daylight. The image below shows the same wedge failure that was shown being scanned in the Acquisition Page and shown being processed in inclination colours on the Processing Page. Strata have also been mapped based upon the reflectance values recorded by our LiDAR scanners where low reflectance strata (shales) are clearly visible against high reflectance strata (sandstones). The number of points with similar reflectance values can be summed to determine the percentages of each strata.

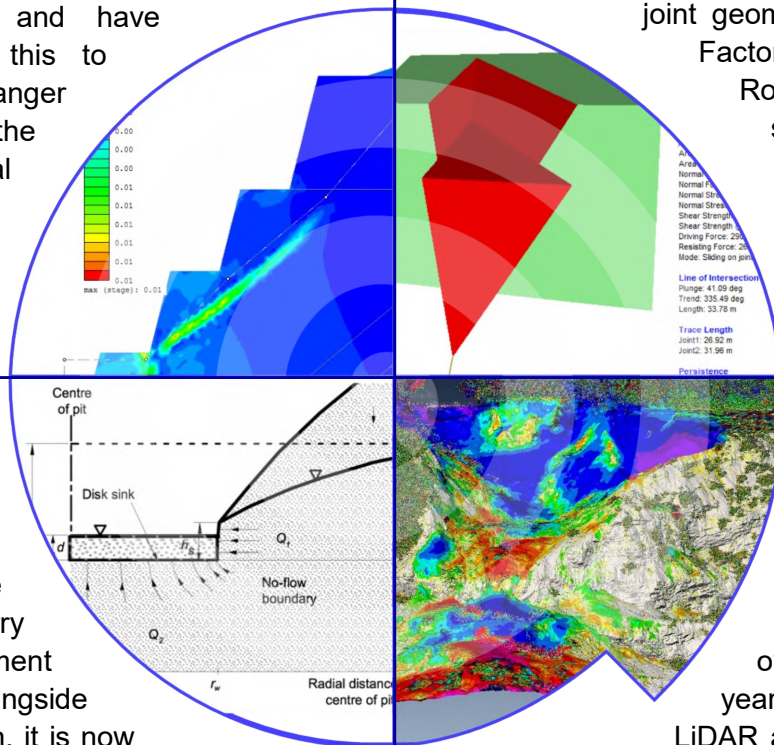
## Regional geological mapping

As well as localised mapping on point cloud surveys, LMCL are also able to supervise geological investigations and analyse the results of such investigation to produce local or regional conceptual geological maps and models. Our hydrogeologists are then able to overlay groundwater datasets upon the geological models to produce hydrogeological conceptual models, which form the basis of understanding groundwater related challenges. The image above shows a regional 3D geological interpretive presentation of Whitmans Hill Quarry Nature Reserve at the northern end of the Malvern Hills in Worcestershire.

# Data Analysis

## Finite / Discrete Element Analysis

LMCL have a wide variety of discrete and finite element modelling software for their Geotechnical Engineers to use to interpret a wide range of geological and geotechnical scenarios. They own the full suite of RocScience software including RS<sup>2</sup> (see image below) that generally works well for rock environments and for soil environments they have a licence for Palxis. Following detailed point-cloud surveys on the 230m high cliffs at Qiddiya (Saudi Arabia), LMCL have calibrated the input values for 3D Rockfall analysis software and have successfully used this to demark rockfall danger zones around the base of many natural cliffs and open pit side-walls.



## Groundwater Assessments

Changes in our climate are exacerbating quarry water management challenges. Alongside enhanced regulation, it is now increasingly important that sites hold appropriate permits and licences for their on-site water management. LMCL are able to design and undertake suitable hydrogeological monitoring to allow the collection of pragmatic datasets, such as the groundwater flow net presented above. This data is then fed into the conceptualisation of quarry voids, excavations or wellfields from which a range of assessments and can be undertaken. Typical projects include calculating quarry void inflows and undertaking Hydrogeological Impact Assessments to support an abstraction licence application.

## Limit Equilibrium Analysis

The image below shows the final stage of the wedge failure survey and analysis that has featured in each of the preceding pages 'Acquisition', 'Processing', 'Mapping' and now 'Analysis'. In the first instance a high quality LiDAR scan was obtained. This was post-processed to produce an 'Inclination' coloured point-cloud upon which the joint sets were mapped. These joint sets were subsequently extrapolated to determine where they would daylight beyond the quarry boundary. The last stage is to use the quarry survey and joint geometry to determine a Factor of Safety in RocScience's 'Swedge' software (or any other software that may be required).

## Slope Monitoring

LMCL have been monitoring slope and face failures over a number of years using their own LiDAR and photogrammetric data as well as commercially available InSAR data. The image above shows a displacement map of an open pit mine / quarry where a large scale circular type failure occurred. LMCL have subsequently been monitoring the failure using their various long-range LiDAR scanners at 6 monthly intervals from fixed concrete survey stations.

LMCL also have a number of NavStar's GPS/Tilt meters and Extensometers and NavStar's continuous monitoring software GeoExplorer. If movement is detected, an e-mail alert is sent to a pre-determined group of recipients.



# LMCL



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