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Abstract

Airborne Laser Scanning (ALS) Was first used in 1993 by Geodan Geodesie B. V. as a cheaper alternative in the collection of spatial information than traditional survey methods and photogrammetry. ALS has become important in creating Digital Terrain Models (DTM) with high precision at a far lower cost to other methods. Shoalhaven City Council employed ALS in May 200 I for the purpose of obtaining detailed survey information within budgetary constraints. The aim Was to determine the effectiveness of using ALS for coastal and environmental management by testing the accuracy of ground level points against traditionally surveyed points.

Coastal Acid Sulfate Soils are widespread throughout the Australian low- lying coastal areas. Shoalhaven City Council has received funding to improve the quality of affected land and waterways withing this hotspot. In groundwater conditions has lead to the development of management works. Due to the success that these research methods have had on the current field sites, a proposal to implement more of these structures across the floodplain has been formulated.

In order to determine the most suitable sites that would benefit most from such structures, Shoalhaven City Council employed a pilot Airborne Laser Scanning project to generate highly accurate ground elevation spot heights.

With this information, a Digital Terrain Model (DTM) was generated and used to determine the areas with the greatest likelihood of benefiting from engineering remediation works. This high-resolution imagery has aided in decision-making in managing Acid Sulfate Soils, and the DTM and digital photographs have been used in other projects within and outside of Council. This paper will further discuss the benefits sought after when deciding to use Airborne Laser Scanning instead of traditional survey methods and how it has been useful in managing Acid Sulfate Soils.

Keywords

creek, broughton, soils, sulfate, acid, applications, manage, laser, airborne, within, floodplain, coastal, scanning

Disciplines

Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

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Application of Airborne Laser Scanning to manage coastal acid sulfate soils within the Broughton Creek floodplain

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Abstract

Airborne Laser Scanning (ALS) was first used in 1993 by Geodan Geodesie B.V. as a cheaper alternative in the collection of spatial information than traditional survey methods and photogrammetry. ALS has become important in creating Digital Terrain Models (DTM) with high precision at a far lower cost to other methods. Shoalhaven City Council employed ALS in May 2001 for the purpose of obtaining detailed survey information within budgetary constraints. The aim was to determine the effectiveness of using ALS for coastal and environmental management by testing the accuracy of ground level points against traditionally surveyed points.

Coastal Acid Sulfate Soils are widespread throughout the Australian low-lying coastal areas. Shoalhaven City Council has received funding to improve the quality of affected land and waterways within this hotspot. In cooperation with the University of Wollongong, research on improving groundwater conditions has lead to the development of management works. Due to the success that these research methods have had on the current field sites, a proposal to implement more of these structures across the floodplain has been formulated.

In order to determine the most suitable sites that would benefit most from such structures, Shoalhaven City Council employed a pilot Airborne Laser Scanning project to generate highly accurate ground elevation spot heights.

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With this information, a Digital Terrain Model (DTM) was generated and used to determine the areas with the greatest likelihood of benefiting from engineering remediation works. This high-resolution imagery has aided in decision-making in managing Acid Sulfate Soils, and the DTM and digital photographs have been used in other projects within and outside of Council. This paper will further discuss the benefits sought after when deciding to use Airborne Laser Scanning instead of traditional survey methods and how it has been useful in managing Acid Sulfate Soils.

Introduction

The collection of survey data to be used in coastal and floodplain management has until recently not been cost efficient. Areas of low-lying land (<10m Australian Height Datum) have often been neglected in traditional surveying methods due to cost limitations. This has created restrictions on the ability to attain data of high accuracy.

Coastal Acid Sulfate Soils (CASS) have become a major environmental soil problem in the past 20 to 30 years. The developments into managing this problem continue to evolve over time. The majority of CASS lie below 4m AHD (Dent, 1986) and high-resolution data for these areas is often not available.

Airborne Laser Scanning (ALS) or Light Detection and Ranging (LIDAR) was first used in 1993 by Geodan Geodesie B.V. as a cheaper alternative in the collection of spatial information than traditional survey methods and photogrammetry. ALS has become important in creating Digital Terrain Models (DTM) with high precision at a far lower cost to other methods. Shoalhaven City Council employed ALS in May 2001 for the purpose of obtaining detailed survey information within budgetary constraints. The ALS of Broughton Creek operated as a pilot project in cooperation with AAM Geodan, a joint venture with AAM surveys and Geodan Geodesie B.V. The aim was to determine the effectiveness of using ALS for coastal and environmental management by testing the accuracy of ground level points against traditionally surveyed points.

In managing for the problems of CASS within the Broughton Creek Floodplain, documented in 10 years of collaborative research with the University of Wollongong (Pease, 1994; Buman, 1995; Blunden, 2000; Glamore, 2003), Shoalhaven Council trialled the use of ALS in capturing high accuracy survey data. The aim of collecting the ALS data was to improve the management of an environmental problem with greater level of

certainty. This data collected was a catalyst for determining what management techniques to use and where to apply them.

Coastal Acid Sulfate Soil

Coastal Acid Sulfate Soils are widespread throughout the Australian low-lying coastal areas with specific attention given to areas between Southern Queensland and Southern New South Wales. The State Government has provided funding to address the seven 'hotspot' areas within the State of NSW. Six sites in Northern NSW were designated hotspots and one in the south, this being the Broughton Creek Floodplain.

The formation of Coastal Acid Sulfate Soils has been linked to lowland drainage schemes that aim to increase surface runoff after large rainfall events (Sammut et al., 1996). CASS pose a significant threat to the health of the environment and the industries that operate within these areas, as a result of the discharge of large volumes of sulfuric acid and other pyrite oxidation products into estuarine waterways.

The gradient of the subsurface drainage causes groundwater to end up into the flood mitigation drains. When the groundwater falls below the pyritic soil layer, atmospheric and biotic oxidation is enacted and the process of pyrite oxidation begins. Pyrite is oxidised into sulfuric acid and dissolved iron (Fe^{2+}), and this leaches into waterways after rainfall events. This causes a dramatic decline in the pH of the soil and soil-water to around a pH of 3, and releases other exchangeable cations into the water (Aluminium, Manganese), which have dramatic effects on aquatic flora and fauna.

In order to quell the effects of the acid and dissolved iron reaching the flood mitigation drains, management strategies such as weirs to maintain the level of groundwater above the pyritic layer (Blunden, 2000), modification of floodgates to allow tidal buffering (Glamore, 2003) and neutralizing techniques such as lime injections and lime columns, have been trialled in areas of the North and South Coast of NSW.

Airborne Laser Scanning

ALS is a process of collecting point height data from a typical aircraft that has historically been used for photogrammetry. In ALS, advanced Global Position System (GPS) satellites determine the location of the aircraft in respect to the ground location. A GPS receiver in the aircraft is referenced to the GPS positioning satellites above and GPS receivers on the ground. The attitude of the aircraft is determined by the inertial measurement unit of the plane and referenced in the process. The flight time is accurately measured for rectification purposes. During the flight, a laser scanner emits laser beams of wavelength 1.047 microns, and collects the reflections.

Some scanners can record the beam divergence of the scan, which can either be a wide or narrow beam and others use the pulse system, which measures ground heights (last pulse) and objects above the ground (first pulse). This method has been employed in determining the height of buildings in urban areas (Tao and Yasouka, 2002). The flying height of the aircraft is generally around 900 metres above the ground and the scan width is approximately 500 metres wide, dependent on the equipment used. There are up to twenty scanlines every second and up to 250 measurements every scanline, therefore making it possible to collect 300,000 points per minute.

In processing the data, the attitude of the aircraft and the laser scanners range is used to produce the DTM based on ellipsoidal heights. The local geoid-spheroid separation factor is necessary to convert the points to orthometric heights. In the process of creating the DTM of the Broughton Creek Floodplain, the Australian Height Datum (AHD) heights were obtained by applying a correction with geoid information using AusGeoid 93 or AusGeoid 98.

The DTM produced from the ALS spot height points was used to delineate the drainage patterns of the Broughton Creek Floodplain and to determine the effective locations to install remediation works to alleviate Acid Sulfate Soil leachate entering Broughton Creek. The DTM was also rectified to a 1:25,000 aerial photograph to obtain digital photographs of the study area. The photo was of 0.5m pixel definition (Figure 1). As part of the study, a higher resolution image was produced for the township of Berry for general management purposes. Currently all Council employees can use the intranet GIS to gain access to photos which resulted from this pilot project.

Accuracy of ALS data

Most point densities in standard operations are seen to be too small (1 point per $10m^2$) and therefore not accurate enough to be used effectively in land management (Mass and Vosselman, 1999). The ALS survey taken by AM GeoScan was designed to achieve an average spacing of four metres from fifteen overlapping swathes. In all, this equated to 10,600,000 ground points and 3,600,000 non-ground points. Base station data from the GPS unit at the

Shoalhaven Council Offices was used as well as approximately 1500 ground truth points recorded in ISG projection (Zone 56/1). The accuracy of the ground truth points was +/- 0.03m and the accuracy of the ALS data was a derived standard error of 0.16m. However to adhere to specific risk assessment guidelines in surveying at Council, the standard error was adjusted to +/- 0.3m.

A 0.5m and 1m DTM was generated by ESRI Australia from the ALS data, using Inverse Distance Weighted (IDW) Interpolation of the some 11 million points (Figure 2). The IDW analysis used a high power (4) and a low number of points (6), with the aim of ensuring the grid cells, at a spot height location, reflected the measured value while maintaining good interpolation between points. Although this method of interpolation can cause a shift in object boundaries, by having greater point coverage, this shift can be reduced. In generating the DTM, ESRI used multiple $3km^2$ tiles and patched them together.

Pilot Project: Application to Coastal Acid Sulfate Soil Management in Broughton Creek Floodplain

The effectiveness of the ALS was tested in a pilot study on Broughton Creek Floodplain. The pilot study site is located at 34°50'S, 150°40'E (central point of reference), which is approximately 150km south of Sydney. The study site contains approximately 230km of drains and encompasses an area approximately $70km^2$. The study site is prone to large rainfall events, tidal overbank flooding and surface water flooding. Broughton Creek tributary feeds directly into the Shoalhaven River, which enters the Pacific Ocean via the Shoalhaven and Crookhaven Heads. The main source of industry within Broughton Creek floodplain is dairy and beef cattle and Manildra Starches (25%). The associated industries are the oyster and fisheries industries that depend immensely on the environmental quality of the rivers and creeks. Acid Sulfate Soils have become a major problem in the Broughton Creek floodplain. With the installation of flood mitigation drains in the late 1960s, early 1970s, soil conditions have turned quite acidic and have affected the neighbouring industries. Reduction in the fish and oyster population has been the result of acid leachate entering Broughton Creek and eventually the Shoalhaven River.

Council has been involved in integrated research with the University of Wollongong, EPA, Fisheries, Sustainable Natural Resources and landholders for the past 10 years through the Shoalhaven River Acid Drainage Working Group (SRADWG) (Pease, 1994; Buman, 1995; Blunden 2000; Glamore

2003; Morgan, 2003*). In gathering such survey data via the ALS, the accuracy to which Acid Sulfate Soils are managed within the Broughton Creek Floodplain increased.

Figure 1. Digital photograph of Flood Mitigation Drain P6D1.

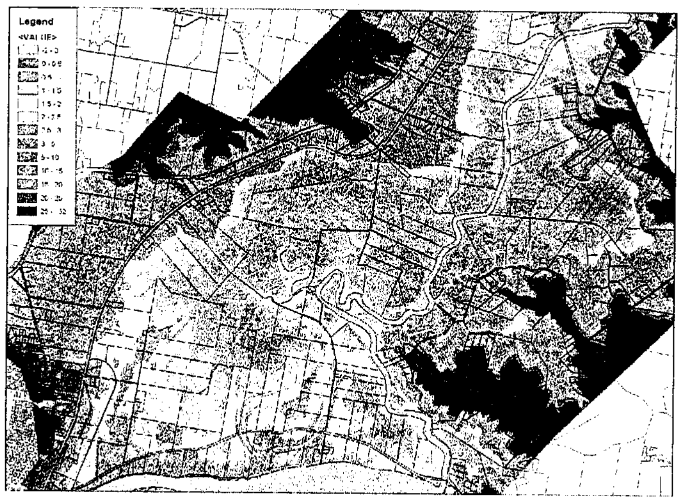

Figure 2. DTM of Broughton Creek Floodplain produced from ALS.

Shoalhaven Council has received funding to further improve the quality of affected land and waterways within this hotspot. In cooperation with the University of Wollongong and SRADWG, research on improving groundwater conditions has lead to the modification of floodgates at existing flood mitigation drains and the installation of self-regulated tilting weirs (SRTW) further upstream from the floodgates (Blunden 2000; Indraratna 2002; Glamore 2003). SRTW maintain a high water table ensuring that the Acid Sulfate Soil is inundated thus avoiding further atmospheric oxidation of the potential acid layer. The modified floodgates aim to reduce the influx of acid leachate into Broughton Creek by generating a natural tidal buffering regime. The brackish water from Broughton Creek is let up the drains through a small aperture cut into the floodgate. This aperture is closed and opened dependent of the water height downstream and upstream of the floodgate. The existing trial modified floodgate has successfully buffered the drain water. Due to the success that these research methods have had on the current field sites, additional remediation methods such as deep subsurface lime injections as well as a proposal to implement more of these structures across the floodplain was developed.

Utilisation of ALS and GIS in Acid Sulfate Soil Management

In order to determine the sites that would benefit most from such structures, Shoalhaven City Council integrated the desire to test ALS for its use in surveying and coastal management generally, and employed ALS to generate highly accurate ground elevation spot heights over a trial area which included Broughton Creek Floodplain. With this information a DTM was generated and used to determine the drainage pattern within the floodplain and the areas with the greatest likelihood of benefiting from engineering remediation works.

The placements of the SRTW and modified floodgates were dependent on the elevation of the land surrounding the flood mitigation drains. High-resolution 2D images with elevation intervals of 0.2m were developed for every drain in the Broughton Creek floodplain (Figure 3). Council together with the members of SRADWG reviewed every drain and decided on the drains that were candidates for further analysis in order to apply management options to improve the environmental water and soil quality. SRADWG's technical knowledge on CASS was combined with detailed survey data obtained from the ALS to determine what further analysis was needed before any management options could be employed.

Drains with very low-lying land adjacent to them were eliminated for the purposes of installing SRTW, due to potential for flooding adjacent land (Figure 4). Drains with levee banks high enough to avoid being overtopped were included for the possibility of having floodgates modified (Figure 5). 2D simulation GIS modelling was employed to ensure that the amount of water that could be let into the drain would not overtop the levee banks (Figure 6) (Morgan, 2003). The drains to be modified were determined by SRADWG following a more detailed soil survey of the acid sulfate layer in close vicinity to the drains, and a cross sectional surveys of the drains was developed to understand the flow characteristics of the drains. (Broughton Creek Management Plan, 2002).

Other than being an invaluable tool for use by SRADWG in determining how the drains are to be managed, ALS Survey data has been quite invaluable when presenting the problem of CASS and possible management solutions to landholders who have concern as to what effects the implementation of such works will have to their land. The hotspots project relies on the continual support of landholders throughout the process of determing areas for implementation, conducting the works and monitoring the results. The project is currently in the final stages of implementation of the capital works.

Other Uses of ALS Data

Shoalhaven Council has employed the ALS into everyday management of land within Council boundaries. Every employee at the Council, who has access to a computer, also has access to the results of the pilot ALS project through the Council intranet, which displays the digital aerial photograph which was rectified to the DTM (Figure 7). The DTM data is also available for use through the IT department in Council for specific projects dealing with the management of the Broughton Creek Floodplain.

The ALS has not been exclusively used by Council in management of the Broughton Creek Floodplain. Manildra Starches has purchased data from Council to assess the suitability of new areas for effluent irrigation. By determining the elevation of the land, Manildra can determine the application rate of the effluent they use to irrigate and determine what areas would be suitable to receive the effluent. This has proved to be extremely useful in their irrigation planning.

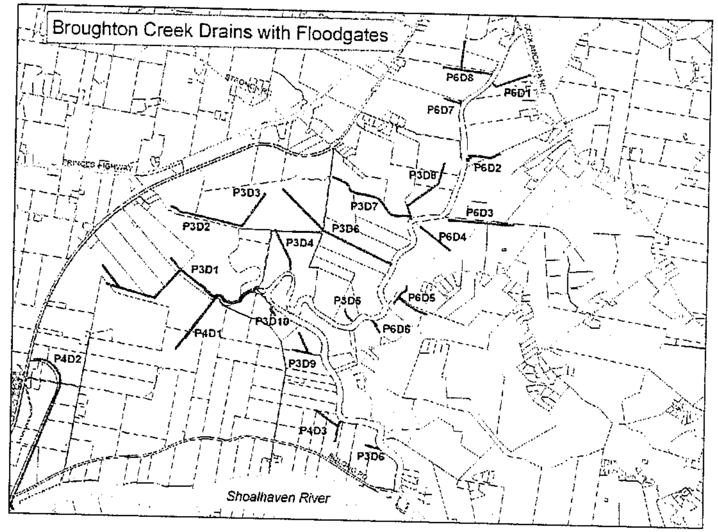

Figure 3. Flood Mitigation Drains within Broughton Creek.

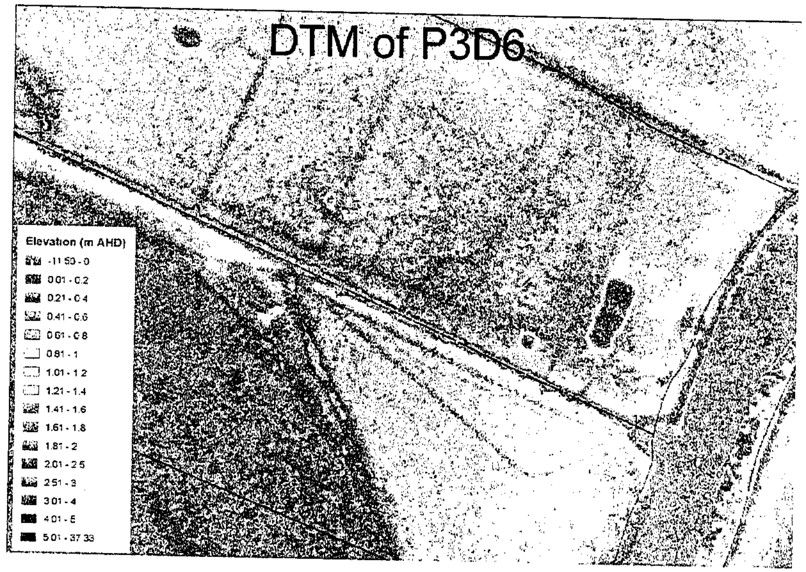

Figure 4. 0.2m DTM of Drain P3D6.

Benefits and Limitations of using ALS in Coastal and Environmental Management

ALS as a survey technique has the ability to acquire accurate ground elevations beneath overtopping vegetation. ALS can also capture ground and non-ground points simultaneously. The ability to capture large areas with high density point coverage with a much lower cost than other traditional methods makes ALS attractive to areas of environmental management that often require remote monitoring and analysis. Using ALS in the management of Acid Sulfate Soils has been very positive, as lower elevation variations were more easily detected. Due to the close proximity of the potential acid layer to atmospheric oxygen, lower lying land is often the most severe land in Acid Sulfate Soil country. Soil bores were taken in the lowest areas of the floodplain. The potential and actual acid sulfate layers were determined from this soil analysis and were used to decide on which areas should be targeted first. Due to limitations in funding, the desired outcomes of developing a more comprehensive 3D model that simulated the flow patterns within the floodplain was not completed. However, a 2D simulation model based on the DTM was developed to determine the physical heights of the water that can enter the drains without overtopping the banks and the data is currently being used for sub-surface analysis on a wider scale for future floodplain management (Figure 6).

ALS data has also been combined with traditional surveyed data of drains as well as bathymetric data collected on Broughton Creek using an Echosounder. This has increased the understanding of the dynamics of the floodplain. Data integrated into the spot height data has created a DTM with accurate drain depths, which was not represented in the original DTM.

ALS is limited by the interpretation of the laser signals. Attempting to determine what constitutes the ground and what is vegetation often requires complex classification software to process the signals into the suitable classification. This noise can detract in providing accurate data. The sheer size of the data that is produced can also be an issue for organisations that don't have the capacity to process large datasets. ESRI Australia was employed to create the DTM for this pilot project due to the immense volume of spot height data that was created. Therefore, the ALS survey data is dependent on the organisation that conducts the survey and the methodology used to interpret the laser signalling.

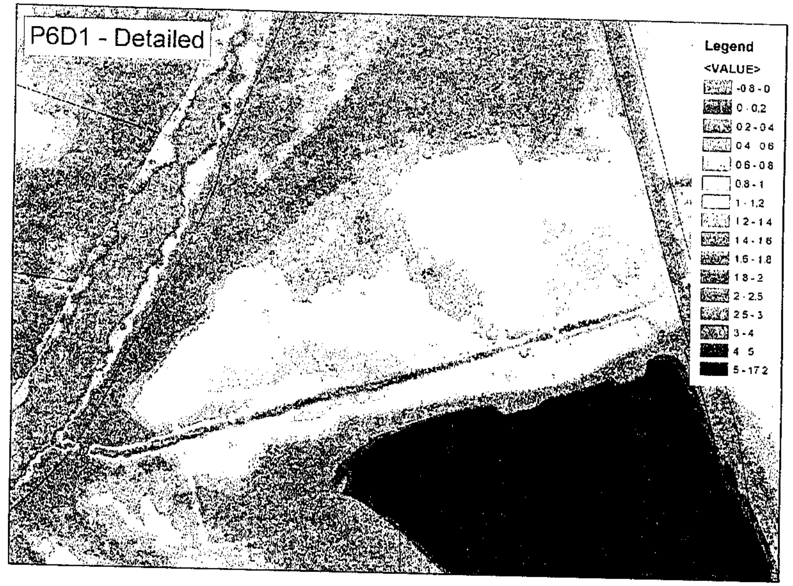

Figure 5. 0.2m DTM of Drain P6D1.

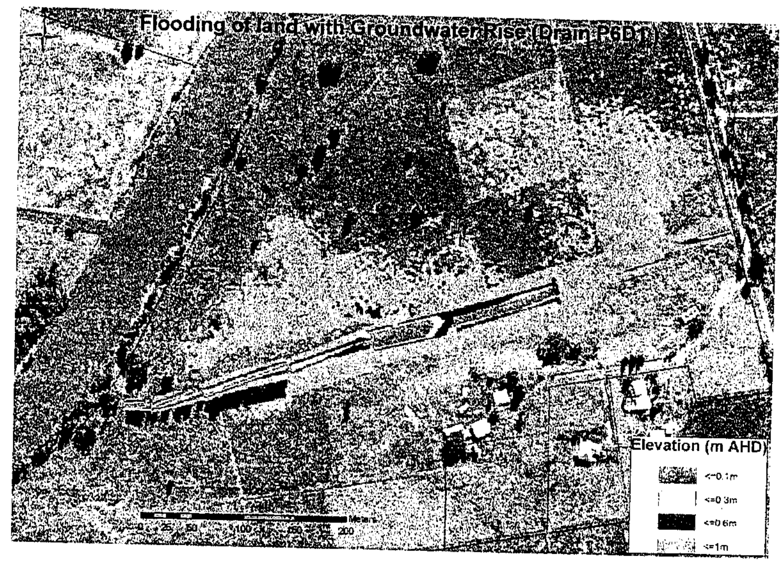

Figure 6. 2D Groundwater Simulation Model of Drain P6D1.

In processing the data further, Council purchased new hardware to run such massive data sets. This limitation could restrict the use of ALS within organisations that lack these resources. However, the cost associated with collecting ALS data compared with traditional survey methods far outweighs the cost needed to upgrade computer equipment to run large data sets.

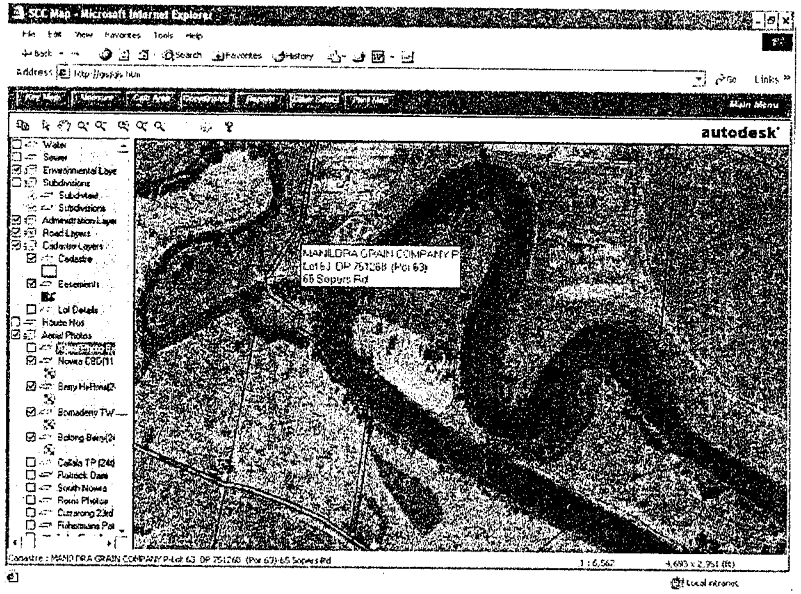

Figure 7. Councils Intranet GIS Page.

ALS for Future Projects

Shoalhaven Council's success with the pilot project on Broughton Creek floodplain has provided an understanding of the effectiveness of traditional survey methods versus ALS. ALS data and the processed DTM have been invaluable in determining where to implement suitable capital works to reduce the impact of acid drainage in the Broughton Creek Floodplain. For future management of acid sulfate soils in coastal areas and for the management of other areas of land within the Shoalhaven Council boundaries, ALS will be looked upon as a viable alternative to traditional surveying.

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Abstract

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Introduction

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