Surveying for the Newcastle Light Rail Project

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ABSTRACT

In June 2017, Monteath & Powys were engaged by Downer as the survey managers for the Newcastle Light Rail Project (NLR). The 2.7 km long dual track was designed to run partially within the former heavy rail corridor from Wickham / Newcastle West and then along Hunter and Scott Streets through Newcastle's central business district to Pacific Park near Newcastle Beach (Newcastle East). As survey managers, Monteath & Powys were responsible for establishing a high-accuracy survey control network for the whole project, along with implementing measures to manage the preservation of survey infrastructure (POSI) requirements for cadastral reference marks and permanent state survey marks within and adjacent to the project. In addition, it was our responsibility to oversee construction quality control and conformance on behalf of Downer as the managing contractor. As part of the role, Monteath & Powys were required to liaise with all stakeholders, including Transport for NSW (TfNSW), Newcastle City Council (NCC), NSW Spatial Services, and survey sub-contractors engaged by the construction contractors, to coordinate survey control, sub-surface utility investigation (SUI), quality control, conformance and other contract requirements. Separately, we were engaged to carry out construction surveying for each of the six tram stops and the maintenance depot as well as weekly aerial photography across the whole of the site utilising a commercial helicopter due to restrictions on the use of Remotely Piloted Aircraft Systems (RPAS). This paper details Monteath & Powys' involvement in the project for over 18 months, utilising 46 individual staff members and carrying out over 12,000 man hours of work. The diversity, intensity and integrity of the work carried out was recognised at the 2019 Excellence in Surveying and Spatial Information (EISSI) Awards, with the award for most outstanding Infrastructure & Construction Project and also for the most outstanding overall project.

KEYWORDS: *Newcastle Light Rail, infrastructure, TfNSW, surveying, construction.*

1 INTRODUCTION

In June 2017, Monteath & Powys were engaged by Downer as the survey managers for the Newcastle Light Rail Project (NLR). The 2.7 km long dual track was designed to run partially within the former heavy rail corridor from Wickham / Newcastle West and then along Hunter and Scott Streets through Newcastle's central business district to Pacific Park near Newcastle Beach (Newcastle East).

As survey managers, Monteath & Powys were responsible for establishing a high-accuracy survey control network for the whole project, along with implementing measures to manage the preservation of survey infrastructure (POSI) requirements for cadastral reference marks and permanent state survey marks within and adjacent to the project (NSW Spatial Services, 2020). In addition, it was Monteath & Powys' responsibility to oversee construction quality control and conformance on behalf of Downer as the managing contractor.

As part of the role, Monteath & Powys were required to liaise with all stakeholders, including Transport for NSW (TfNSW), Newcastle City Council (NCC), NSW Spatial Services and survey sub-contractors engaged by the construction contractors, to coordinate survey control, sub-surface utility investigation (SUI), quality control / conformance and other contract requirements.

Separately, Monteath & Powys were engaged to carry out weekly aerial photography across the site and construction surveying for each of the six tram stops and the maintenance depot. A total of 43 individual staff members from Monteath & Powys were involved in the project in some capacity, including surveyors, draftspersons and administration staff. This paper details our involvement in the project.

2 CONSTRAINTS AND COMPLEXITY

The Newcastle Light Rail Project is 2.7 km long with our involvement commencing on the construction site from June 2017 for an intense 18-month construction period with light rail services commencing on 17 February 2019. One of the reasons Monteath & Powys were engaged on the project was the proximity of our head office to the subject site, as well as our large survey capability and the ability to scale our resources up and down as required.

With the light rail running across several major road corridors, previous heavy rail sites and along operating roadways, there were many complexities and time constraints involved. This led to many intense workload periods where Monteath & Powys personnel were required to work nights and weekends to minimise disruption to the public and ensure our clients met the required time schedule. Minimising disruption to the public was very important to Transport for NSW and Downer on this project, i.e. the construction program was strategically staged so that major components of the project were completed in specific sections to ensure each section was completed as quickly as possible with minimal disruption to traffic flow, business owners and the public in general.

This created several complexities to Monteath & Powys, particularly related to survey control, where we were generally confined to a very narrow corridor, with the entire road infrastructure including footpaths being demolished and replaced. A lot of our time on this project was spent ensuring survey control was fit for purpose and able to be issued to all sub-contractors on site with a great deal of confidence as well as ensuring our works outside of the construction zone did not impact on the public.

Completing this work in such a manner also destroyed the majority of survey marks within the road corridor, requiring a unique and structured approach in consultation with NSW Spatial Services in regards to the preservation of survey infrastructure. Additional complexities came from the client's request to provide aerial photography on a regular basis along the project route. Civil Aviation Safety Authority (CASA) requirements stipulate that an Unmanned Aerial Vehicle (UAV) or Remotely Piloted Aircraft System (RPAS) cannot be operated within 30 m of the public or an occupied building, i.e. a unique solution had to be devised to provide weekly aerial updates.

The other major complexity of this project was the existence of underground services and the requirement for an underground services model to be continually maintained and provided to Transport for NSW upon completion. Given the age and nature of the centre of Newcastle, the existing underground services had a lot of uncertainty with much of the original construction dating back to convict days. Monteath & Powys utilised a variety of techniques to locate and maintain the services model.

Additional complexities came towards the end of the project in relation to the accuracy requirements of the as-built conformance data. Monteath & Powys were able to utilise a rail trolley to accurately and confidently model the as-built rail locations to ensure conformance with the specifications provided. Much of the complexities came from the tight timeframe, long narrow shape of the project area and the location of the project itself, being the middle of a working city.

3 SURVEY

3.1 Survey Control

Prior to construction, Monteath & Powys established survey control throughout the project with a nominal spacing of 50 m between adjacent marks. Due to the required construction tolerances for the light rail track (slab track), control was required to be accurate to within ±3 mm in Easting, Northing and height. As a result, control was established using a high-accuracy total station (Leica TS30) with an angular accuracy of ±0.5” and distance measurement accuracy of 1 mm + 1 ppm to carry out the traverse to a combination of ground marks, fixed prisms and retro targets.

Heights for all ground marks were established by differential levelling using a Leica DNA03 digital level, with an accuracy of 0.3 mm established throughout. Ultimately the control network consisted of 400 marks, with the observations adjusted using Compnet least squares adjustment software, to provide confidence in the accuracy of the marks placed.

One of the major complexities on this project was the fact that the light rail was constructed in sections where the road would be demolished, including all footpath infrastructure, for an entire block at a time. This meant all survey control would be destroyed in this area, leaving only the survey control on either side. Given the tight accuracy tolerances, it was not possible to use retro targets on walls, and at each section additional control had to be re-instated from one side of the current construction area to the other.

This meant the site survey control was continually being updated and re-issued to the sub-contractors on site, i.e. communication was incredibly important between all stakeholders, including our client and the sub-contractors as well as the sub-contractors’ survey teams.

3.2 Preservation of Survey Infrastructure

As previously mentioned, when each section of light rail was to be constructed, the entire road corridor including footpath infrastructure was demolished. From our initial discussions with the client, we understood this to be the case where all existing survey marks on public record were to be destroyed.

As part of the project, Monteath & Powys were required to prepare a Preservation of Survey Infrastructure (POSI) strategy in accordance with the Surveying and Spatial Information Act and Surveyor Generals Direction No. 11 (NSW Spatial Services, 2020) due to the proposed or potential disturbance or destruction of multiple cadastral reference marks and permanent survey marks during the construction of the light rail. Consultation with NSW Spatial Services commenced on the same day that Monteath & Powys were awarded the contract in late June 2017, due to the tight timeframes to complete surveys of existing marks and gain approval for mark destruction prior to construction commencing in September 2017.

A robust approach to POSI was created in consultation with NSW Spatial Services, which required substantial initial survey work to locate all survey infrastructure from our newly created survey control network. Marks were also placed from the survey control network into side streets, allowing direct relationships to be established from the previous location of survey infrastructure to survey control that is still on site today following construction. This gave us a lot of confidence in re-instating survey infrastructure and producing POSI plans that are now available on public record. Our survey control techniques were also suitable for the re-instatement of state survey control marks, which, combined with the POSI plans, will leave the survey infrastructure along the Newcastle light rail route in a far superior state to pre-construction. Over 100 survey marks were included in the POSI survey.

3.3 Sub-Surface Utilities

Sub-surface utilities were a major part of this project, gaining an understanding of what was currently in the ground over the 2.7 km route and accurately producing a 3D model, which was able to be updated on a regular basis and issued to all stakeholders. Many of the underground services through the older area of the city were completely unknown with several of the structures and in particular drainage being constructed during the convict era. A lot of works had already been completed prior to construction commencing, with Monteath & Powys having some involvement early on. We were able to compile all of the existing information, which was checked for spatial accuracy in relation to our newly created survey control network and produced in 12D software, which became a standard on this project.

The Australian standards were also adopted for sub-surface utility classing with Monteath & Powys becoming the single point of contact for all service locations. Several of the service locations were completed by other sub-contractors on site with Monteath & Powys creating a standard procedure for providing these services back to our dedicated services surveyor, ensuring every service discovered on site was included into the overall survey model along with any relevant attributes including the class.

As the project progressed, additional services were placed and also included in the model, as well as several services becoming redundant. The services model became a live document that was continually updated and at the end of the project was able to be delivered to our client as a full and accurate underground services model for the entire route to be utilised on any future project.

3.4 Rail Conformance

A major part of Monteath & Powys' role was conformance checks on all works completed by both Downer and sub-contractors on site. The rail conformance was arguably the most critical conformance survey completed with a tolerance of ±3 mm. Monteath & Powys are fortunate to have a lot of rail experience and were able to utilise an Amberg GRP 1000 rail trolley to capture all as-built rail information with confidence. The Amberg GRP 1000 software allows us to record all required survey information in a single pass and produce a report highlighting any errors in a safe and efficient manner (Figure 1).

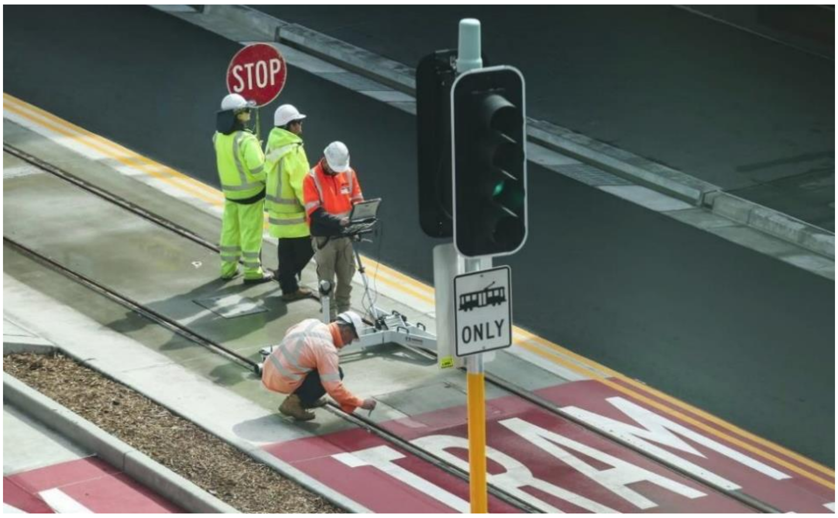

Figure 1: Monteath & Powys staff operating an Amberg rail trolley for conformance of the track prior to running the first light rail vehicle (image courtesy of Newcastle Herald).

3.5 Deformation Monitoring

During construction of a replacement large sewer main using micro tunnel methods, groundwater had to be reduced in the area of the launch and receival pits by using a dewatering process. Due to the proximity to the water table (street level being only about 2 m above mean sea level), the ground conditions consisting of a sandy loamy soil and the age of many of the buildings surrounding these sites with the potential for sub-standard (by current standards) foundations, engineers were concerned that the dewatering and construction process may lead to ground deformation of up to 50 mm and subsequent damage to surrounding buildings.

To manage this process, Monteath & Powys proposed a deformation monitoring program in parallel with other structural dilapidation assessments carried out by engineers to help inform the project during the dewatering and construction phases. This consisted of two initial precise digital levelling surveys to establish a reference baseline before dewatering commenced, followed by around-the-clock surveys during the dewatering phase, with a Trigger, Action, Response Plan (TARP) developed with the project team to manage to any eventuality. Once the dewatering reached a steady state and construction commenced, monitoring progressively reduced to daily and weekly surveys.

These surveys played a critical part of managing construction activities in close proximity to businesses and the general public, ensuring that the work could be carried out with as little disruption and risk to safety and property damage as possible.

3.6 Heritage Preservation and Interpretation

Several heritage items were also identified along the way, which were able to be captured in a fast and efficient format. An example was the requirement for 3D laser scanning on heritage items that were exposed along the route, which needed to be captured as quickly and as accurately as possible. Conventional surveys were also completed on items such as the original Burwood Railway, which was exposed when excavating Hunter Street (Figures 2 & 3).

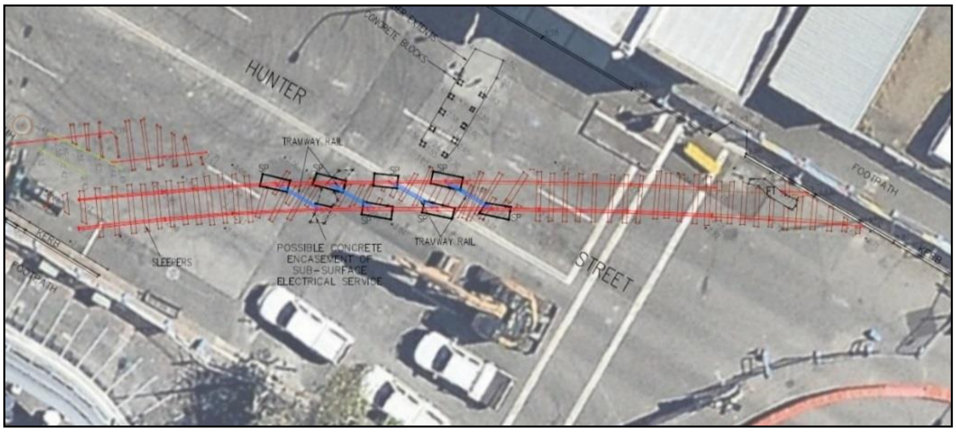

Figure 2: Overlay of heritage survey of Burwood Railway Line – Hunter Street, Newcastle.

Figure 3: Archaeology excavation of the Burwood Railway Line – Hunter Street, Newcastle.

Monteath & Powys were able to create a spatially accurate 3D model of these items, providing an accurate historical record for future use. A variety of challenges were overcome by using a range of progressive technical solutions on such a high-profile project.

4 AERIAL PHOTOGRAPHY

4.1 Initial Approach

Early in the project, it was requested to provide aerial imagery over the proposed light rail depot site near the former Wickham railway station using UAV technology. Due to the location of the site, several restrictions existed for the operation of RPAS (or drones) in the area due to the close proximity to several helicopter landing areas and the built-up urban environment. As a CASA-approved RPAS operator, we reviewed these restrictions and undertook a risk assessment of the proposed work in order to mitigate some of the safety risks and to manage legislative requirements under the Civil Aviation Act 1988. The outcome required an application to be made to CASA for approval to fly with a nominated restricted zone. Part of this approval process was to consult with operators of helicopter landing areas and gain their permission to operate.

The approval from CASA was forthcoming and was granted with strict conditions, such as our in-house operator maintaining radio contact with aircraft in the area and not overflying people or flying within 30 m of buildings. To fly within 30 m of buildings, CASA required landholder consent, which would be next to impossible in an urban environment like the Newcastle CBD with multiple high-density apartment buildings. A small section of the corridor complied with the requirements and this portion was captured successfully within the geographical and operational limits of the CASA approval, providing aerial imagery and Digital Terrain Model (DTM) deliverables.

Following this initial work, Transport for NSW enquired about the possibility of providing regular aerial photography across the entire project to document the progress and assist with forward planning. The use of a UAV was considered, but due to CASA restrictions on flying within 30 m of people and buildings, this would not have been possible within the legislated requirements for the majority of the corridor. Therefore, an alternative solution was required.

4.2 Alternative Approach

After some research, it was proposed that photography would be captured from a helicopter and an orthorectified image created. A local helicopter was chartered and using a high-resolution digital SLR camera, handheld photography was captured at a near-nadir orientation from approximately 1,100 feet above the ground, almost 3 times the maximum flying height for a UAV (Figure 4). A typical flight captured approximately 1,800 images with a combined file size of 20 Gb and took approximately 45 minutes to complete from take-off to landing. Processing was then completed by uploading the images and setting up the control on a dedicated computer, with the final processing taking place overnight.

Figure 4: Surveyor Matt Richardson demonstrating the method of aerial imagery capture.

4.3 Equipment

We utilised a Canon 5D DSLR camera and 135 mm fixed focal length L-series lens. Aerologistics, a local helicopter company, was engaged and provided a Robinson R44 4-seat helicopter with the doors removed to allow a clear working area. A number of complications were overcome to ensure reliable imagery was captured every time with consistent image overlap. The relationship between the speed of the camera and ground speed of the helicopter were critical to ensuring consistent overlap.

The frequency at which photos could be captured was directly proportional to maximum flying speed and therefore had a significant impact on the flight times and charter costs. While shutter speed was not much of an issue, the processing speed of the camera and remote trigger was a significant source of delays. High-speed SD cards were used to minimise file write times, and a smartphone-based camera trigger system with a customisable interval timer was used to capture photos with a delay of approximately 0.35 seconds between frames, which allowed for a ground speed of 15 knots while ensuring sufficient image overlap.

Due to the location of the corridor adjacent to many multi-storey buildings, shadowing across the site was also an issue. Flights were undertaken around midday to minimise shadows, but the exact timing was varied throughout the year as the seasons changed. In addition, Adobe Photoshop was used to adjust the lighting and minimise the impacts of shadows in the final orthoimage.

4.4 Risk Management

A rigorous risk assessment was completed in consultation with the helicopter provider for this task and a number of controls were developed to eliminate or minimise any risks to a safe level. Following initial training for working with the helicopter, a system was developed to tether all equipment and ensure the potential of falling objects was safely eliminated.

4.5 Processing

The images were downloaded straight after completing the image capture and sorted to remove any poor quality or unnecessary photos. The photos could then be imported into AgiSoft MetaShape and aligned using an automated alignment tool based on pixel matching before the control points were manually added.

AgiSoft MetaShape is a ‘structure from motion’ based photogrammetry package that was found to have a number of specific advantages over other UAV focused photogrammetry packages. Many modern photogrammetry programs require Global Positioning System (GPS) and Inertial Measurement Unit (IMU) data to calculate an initial fix, while MetaShape uses image sequencing and a bulk-matching routine to complete this initial fix. Additionally, most photogrammetry packages create orthoimages that are derived from colouring each individual mesh triangle with a ‘mean’ colour, whereas MetaShape has the ability to create a true orthomosaic with the raw imagery projected onto the mesh triangles.

Unlike UAV imagery, the digital SLR photos did not have GPS or IMU details to help with the initial orientation and alignment. The initial alignment was by pixel-matching between all 1,800 images. This process can be streamlined by capturing the images sequentially, flying along the corridor with minimal changes of direction. The average initial alignment time was around 3-4 hours.

The ground control used consisted of existing physical features, which had been located during the early works detail survey. Objects such as manholes, pit corners and pram ramp corners were able to be used as ground control, which were easily visible within the photos and did not require placing any additional survey marks across an already congested site. One consistent issue was the loss of survey control as demolition of entire sections of road and footpath occurred. The photogrammetry ground control was updated with new features as they were installed, and as-built surveys were completed.

With the control added, a final adjustment could be run prior to generating a point cloud model overnight. From the point cloud, an orthomosaic image was extracted, resulting in a very large TIFF file (about 4 Gb) with a pixel size of approximately 25 mm on the ground and horizontal accuracy of ±0.1 m. This resolution was high enough to count reo-starter bars within the concrete slabs. AutoCAD was used to combine the high-resolution orthomosaic with standard-resolution Nearmap background imagery.

4.6 Deliverables

The final image was produced in a variety of formats (including TIFF, DWG and KMZ), allowing the image to be opened in a variety of software packages, the most accessible of which was Google Earth. These KMZ files could be converted into Google Earth super-overlays, allowing multiple weeks of imagery to be loaded into Google Earth and switched between with the click of a button. This allowed easy visual checking of progress and change tracking, with engineers being able to step back through time week-by-week without reloading any files.

The processes were streamlined to the point where we could fly the site on Thursday and provide multiple 4 m long orthorectified image prints and electronic files to the clients by Friday lunch time to display on their office walls (Figure 5). This gave our clients the ability to quickly and easily inspect any part of the site and enable project discussions to take place with current data in a readily identifiable format.

Figure 5: An example of the deliverable image provided to the client.

5 CONCLUDING REMARKS

This paper has outlined Monteath & Powys' involvement in an iconic project for Newcastle over a period of 18 months (Figure 6), amounting to over 12,000 man hours of work between 46 individual staff members. We were required to liaise with all stakeholders and survey sub-contractors engaged by the construction contractors, to coordinate survey control, sub-surface utility investigation, quality control, conformance and other contract requirements.

This project allowed Monteath & Powys to demonstrate the company's capability on a large infrastructure project in an urban environment with numerous challenges that required the application of many different surveying specialities. Given the high profile of this project, we were aware of community expectations and our responsibility to conduct our activities in a professional manner. The project's location meant we were incredibly visible to the public, which was evident when our survey team featured in the local media. It was a credit to our staff members on the ground, the way they conducted their daily tasks and the professional manner they dealt with all community interactions.

Figure 6: Delivery of the first light rail vehicle.

ACKNOWLEDGEMENTS

Monteath & Powys would like to acknowledge the role of the Managing Contractor for the project, Downer, and the project team overseeing the construction. We would also like to acknowledge the good work and support provided by each of the surveying sub-contractors involved in various stages of the project and contributing to its success: Aurecon, Scope Surveying, Veris, DeWitt Consulting and RPS.

REFERENCES

NSW Spatial Services (2020) Surveyor General's Direction No. 11: Preservation of Survey Infrastructure, https://www.spatial.nsw.gov.au/surveying/surveyor_generals_directions (accessed May 2020).