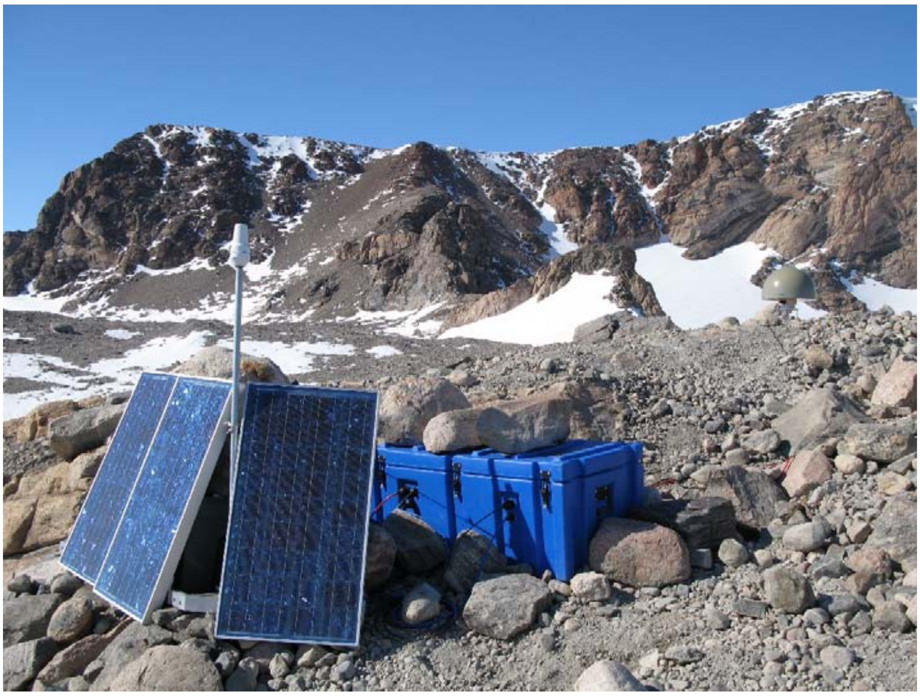
Antarctic Geodesy Field Report 2006/07



GEOSCIENCE AUSTRALIA
RECORD 2009/32

by

N. Brown and A.Woods

Australian Government
Geoscience Australia

National Geospatial Reference Systems Project, c/- Geoscience Australia GPO Box 378 Canberra ACT 2601

Department of Resources, Energy and Tourism
Minister for Resources and Energy: The Hon. Martin Ferguson, AM MP
Secretary: Dr Peter Boxall

Geoscience Australia
Chief Executive Officer: Dr Neil Williams PSM

ISSN 1448-2177
ISBN web 9781921672255

GeoCat # 69570

Bibliographic reference: Brown, N. and Woods, A., 2008. Antarctic Geodesy 2006 – 2007 Field Report. Geoscience Australia, Record 2009/32. 77pp.

Contents

Introduction

In recent years, Geoscience Australia (GA) has increased its capability on the Antarctic continent with the installation of Continuous Global Positioning System (CGPS) sites in the Prince Charles Mountains and Grove Mountains. Over the course of the 2006/07 Antarctic summer, Alex Woods and Nick Brown from Geoscience Australia (GA) collaborated with Dan Zwartz of the Australian National University (ANU) to install new CGPS sites at the Bunger Hills and Richardson Lake and perform maintenance of the CGPS sites at the Grove Mountains, Wilson Bluff, Daltons Corner and Beaver Lake.

The primary aim of the CGPS sites is to provide a reference frame for Antarctica, which is used to determine the long-term movement of the Antarctic plate. Data from Casey, Mawson and Davis is supplied to the International GPS Service (IGS) and in turn used in the derivation of the International Terrestrial Reference Frame (ITRF). The sites also open up opportunities for research into post-glacial rebound and plate tectonics.

In many respects CGPS sites in Antarctica are still in their infancy. Since the mid 1990's Geoscience Australia and the Australian National University have been testing new technology and various methods to determine the most effective way of running a CGPS site in Antarctica.

A more detailed review of Australia's involvement in Antarctic GPS work can be found in (Corvino, 2004)

In addition, a reconnaissance survey was undertaken at Syowa Station to determine whether a local tie survey could be performed on the Syowa VLBI antenna in the future. Upgrades were made to the Davis and Mawson CGPS stations and geodetic survey tasks such as reference mark surveys, tide gauge benchmark levelling and GPS surveys were performed at both Davis and Mawson stations. In addition, work requested by Geoscience Australia's Nuclear Monitoring Project, the Australian Government Antarctic Division (AGAD) and the University of Tasmania (UTAS) were completed.

Continuous GPS Installation

BUNGER HILLS

On the 23/12/06, a C212 aircraft landed on Transcipcy Lake and taxied to the Edgeworth David campsite. Reconnaissance was undertaken to identify the best site for the station. Approximately 275m SSW from the campsite at Edgeworth David is the site BHIL. The site was established on a prominent piece of granite bedrock, and supports an excellent sky view and a flat area on which to place the solar panel frame and wind turbine.

Position of Apples Campsite (WGS84): *66°14'59.8"S 100°36'14.1"E (Handheld).*
Position of GPS Monument (WGS84): *66°15'04.9"S 100°35'54.9"E (Handheld).*

On the 25/12/06, the survey mark along with reference marks and solar panel equipment were installed. The survey mark is a "Twilley pod" design, that is, a stainless steel plate (*c.*15cm in diameter), *c.*17cm long, with three stabilising rods and a 5/8" spigot sitting aloft. A rotating shim is attached to survey plate and the GPS antenna is screwed onto the shim.

The installation of the survey monument was a simple process. A 20 cm deep hole for the survey mark was drilled along with three 10 cm deep holes for the stabilising rods. Three 8cm deep holes were also drilled for the three reference marks using the *Hilti* Drill and *Honda* generator. The drilling equipment showed no signs of distress in the cold conditions. To ensure the epoxy for the survey mark, stabilising rods and reference marks set in place rapidly, it was kept warm for 12 hours prior to application using body warmth. Upon use, the epoxy was warm and pliable and it set within 45 minutes of application at a temperature of *c.* 0° C.

Figure 1 and 2: *Left: Bunger Hills, Nick next to survey mark (Photo looking North with apple huts in background). Right: Bunger Hills, antenna with snow dome attached.*

All GPS field units, tripods and the total station were being used at Mawson station during the installation phase; therefore, an accurate reference mark survey could not be completed. The distances and bearings indicated on Figure 3 were measured using a compass and piece of steel cable (for a higher degree of precision over a longer distance). The steel cable readings were later measured using a box tape.

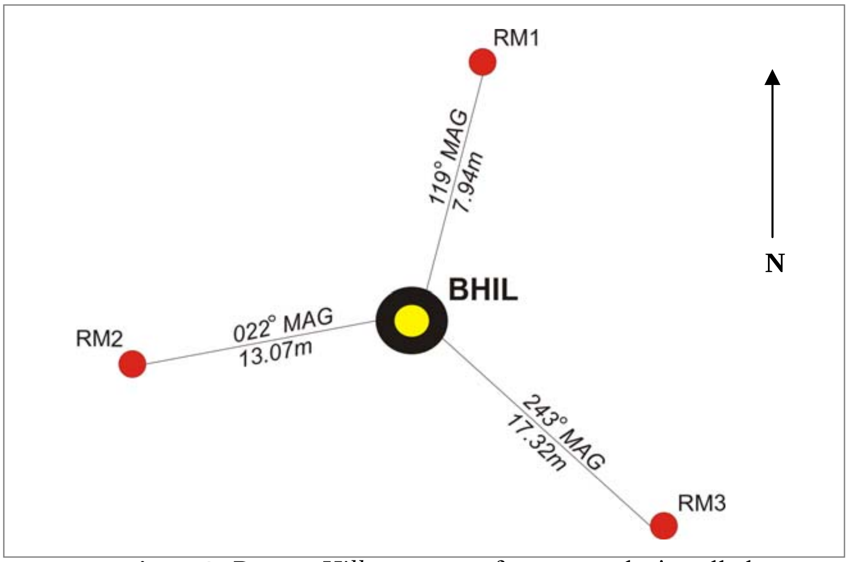


***Figure 3**: Bunger Hills, s*urvey reference marks installed

Comments

- The Reference marks (RM's) are not perfectly level due to the fact that the only level bubble available was on the survey mark at the time of installation. However, a bubble from a compass was set on the RM's as they were being installed to ensure the marks were as level as possible. The implication is that in future RM surveys a tribrach should be attached to the survey marks prior to screwing on a GPS antenna to ensure it is level.

- The stabilising rods were not installed exactly perpendicular to the survey mark plate, due to small imprecision in the survey mark thread. Therefore, the rods where angled in slightly toward the centre. As a result the holes drilled in the ground for the stabilising rods (which were perpendicular to the plate) were not wide enough for the rods to fit. The rods pressed against the inside of the holes rather than sitting in the middle of them. This is not believed to be a cause for concern; the survey mark was very stable.

Figure 4*: Bunger Hills, solar panel frame set up, view north west.*

The solar panel frame was installed approximately 10 meters to the north west of the survey mark. The newly designed aluminium frame which is ~2m along the back of the base and ~1m wide was shipped in eight pieces (2 x parts of the base, 2 x panel holders and 4 x struts) and constructed on site.

No rocks were placed on the base of the solar panel frame to allow wind and blowing snow to move freely through the underside of the frame. This wasn't a major concern at this site, as it is believed to be free of ice year round. The space cases sitting behind the framework should not cause a build up of snowdrift on the southern side and their close proximity to the solar panel frame minimises the amount of cable exposed to the elements. The prevailing wind at the Bunger Hills is an easterly. Guy wires were therefore attached to predrilled holes in the top of the solar panel frame struts on the eastern and southern sides.

<u>*Comments*</u>

- One nut and bolt was missing to connect the western most solar panel to the solar panel frame. The panel was joined to the frame at this junction (bottom right corner) using two metal cable ties. The first pulls the panel down toward the ground and the second pulls the panel back toward the back of the frame on a 45° angle. This made the panel very sturdy and no vibrations were observed in moderate to high winds (*c.* 50 kts).

- The subtle difference in the size of bolts and nuts was a source of some frustration. Some required an 18" spanner and some were a 19". This was an inconvenience, but did not cause any major problems.

The wind turbine frame is located ~7m to the west of the solar panel frame and sits ~1m below the height of the survey mark. It has ~100kg of rocks on the base of each leg making it stable enough to jump on and shake it without it shifting.

Figure 5*: Bunger Hills, wind turbine, view west*

The iridium antenna cable, connected to the modem in the blue space box, protrudes through one of the holes in the box, up through the steel pipe, attached to the solar panel frame, to the white receiver / transmitter which is threaded onto the top of the steel pole. Neither end of the co-axial cable had a detachable fitting, so one of the valves had to be removed from the space case and the cable was placed through the hole. The remaining space was filled with amalgamation tape.

The modem was powered through a cigarette lighter connection into a power converter (set at 4.5 volts), which was connected to the battery bank. The modem was connected directly into the new *Leica* GPS receiver (RX port) via a null modem cable, mini adaptors and port cable as shown in Figure 6.

Upon installation, communication problems between the *NAL* iridium modem and *Leica* receiver were experienced. Although the cause of the problem is still unknown, the *Leica* receiver was logging data and has the capacity to hold approximately two years worth of data.

A list of identified site design problems and suggestions for deep field work has been prepared and is attached in Appendix B: Remote Field Work Recommendations.

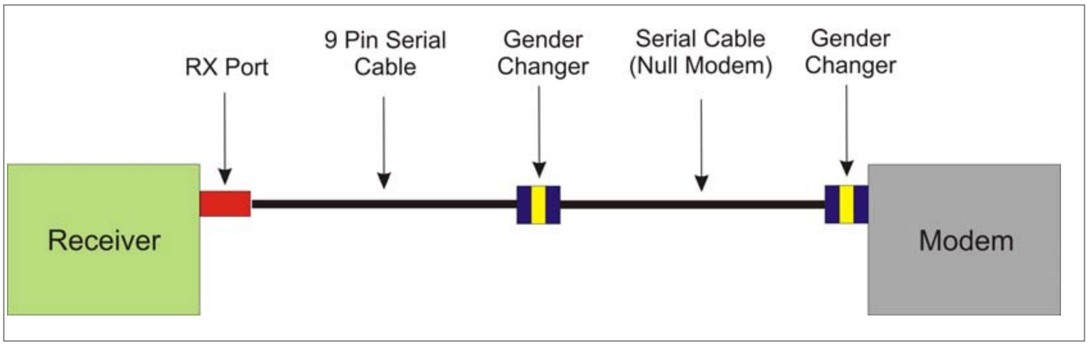


Figure 6*: Remote CGPS site, connection between the receiver and the Iridium modem.*

Prior to departing Canberra, some of the problems with the modem testing were fixed with a hard reset of the modem, that is, turn it on and off. Therefore, timers were fitted between the modem and battery bank and set to turn on and off once a day. For this site, the timer was set to turn off at 15:16 and turn on again at 15:17 (DAVIS time) or 11:16 / 11:17 AEST.

RICHARDSON LAKE

The installation of the ANU Richardson Lake CGPS site in Enderby Land is of particular significance to the geodetic community as global models of gravity show anomalies in the area which are currently unexplained. Therefore, apart from providing data of the long-term movement of the Antarctic Plate, it will also provide invaluable information for gravity research and programs such as the Gravity Research and Climate Experiment (GRACE).

Two CASA aircraft landed on Lake Richardson on the 4th of January. On arrival to the site a campsite was selected on a snow bank on the western edge of Richardson Lake at the base of Mt. Riiser-Larsen, *c.* 150m from the survey mark, which is located in the saddle.

Nick Brown from Geoscience Australia installed the survey mark along with three reference marks on 5th January 2007. Reference mark survey results are shown in Table 1.

Table 1: AUSPOS results for Richardson Lake survey and their one sigma uncertainties. From AUSPOS Jobs #50799, #50895, #50896, #50897

SITE	LATITUDE (DMS)	LONGITUDE (DMS)	ELLIPSOIDAL HT (M)	ABOVE EGM96 GEOID HT (M)
RICH	-66°45'14.3852" (0.004m)	50°37'12.2151" (0.003m)	60.377 (0.004m)	25.938
RM1	-66°45'13.9357" (0.004m)	50°37'12.4890" (0.012m)	60.003 (0.005m)	25.564
RM2	-66°45'15.1771" (0.012m)	50°37'13.3338" (0.012m)	58.943 (0.005m)	24.502
RM3	-66°45'14.6193" (0.010m)	50°37'11.1718" (0.002m)	58.913 (0.013m)	24.474

Survey equipment used in reference mark survey:

RICH Survey Mark Antenna
Part number ASH 701945-02 rev E
Serial number CR620022604

Reference Mark Survey
RM1: Blue Space Case (6/1/07)

- Yellow Topcon Tribrach (*Ashtech* turning mount)
- Height = 71mm (ground mark to antenna reference point)
- Antenna – *Leica* AT504
  - S/N – 103318
  - ART No. – 667132
- Reciever – *Thales* UZCGR8
  - S/N – UC2200524009

RM2: Grey Space Case (6/1/07)

- Olive *Leica* Tribrach (*Ashtech* turning mount)
- Height = 76mm (ground mark to antenna reference point)
- Antenna – *Leica* AT504
  - S/N – 103316
  - ART No. – 667132
- REC – *Thales* UZCGR8
  - S/N – UC2200302005

At ~12:30 DAVIS time the equipment at reference mark 2 was moved to reference mark 3 and the equipment at reference mark one was left running.

RM3: Grey Space Case (7/1/07)

- Olive *Leica* Tribrach (*Ashtech* turning mount)
- Height = 76mm (ground mark to antenna reference point)
- Antenna – *Leica* AT504
  - S/N – 103316
  - ART No. – 667132
- REC – *Thales* UZCGR8
  - S/N – UC2200302005

The equipment at reference marks 1 and 3 were packed up on 8/1/07.

For further information regarding the details of the site, please refer to Paul Tregoning, ANU.

WILSON BLUFF

In mid-January 2007 Alex Woods and Nick Brown, geodetic surveyors from Geoscience Australia, visited Wilson Bluff located in the southern Prince Charles Mountains. The aim was to repair and upgrade the continuous GPS station, which had been out of operation for several years. In addition, Dan Zwartz from the Australian National University (ANU) visited the site to repair and upgrade a seismic station located approximately 100m north of the GPS station.

Two CASA aircraft transported freight and personnel to the site, landing on blue ice, free of crevasses approximately 1km northeast of the site. The pilots taxied the aircraft to within a few hundred metres of the campsite that was set-up approximately 50m east of the GPS station in a depression between two ridges of moraine, which provided shelter from the wind.

The survey monument (AUS368) is a stainless steel plate with a 5/8" spigot and three stabilising screws drilled into bedrock. Established in the summer of 2002/03 by Geoscience Australia surveyors during the Prince Charles Mountains Expedition of Germany and Australia (PCMEGA), it was fitted with GPS equipment the following summer by Adrian Corvino and Henk Brolsma. ANU geophysicist Anya Reading visited the site in mid January 2004 and confirmed that the site was still operating.

Assessment of site

Upon arrival in 2007, the site was severely damaged and a comprehensive rebuild was required to get the station back into operation.

On the 13th of January 2007, an analysis was undertaken to identify what had been disturbed at the GPS site, and decisions were made as to what could be repaired and what needed to be replaced. A number of photographs were taken of the site with particular attention paid to the damaged equipment. In addition, all details of site disturbance were noted and ideas on how to avoid similar failures were discussed. A detailed list of the state of equipment on arrival is provided.

Wind turbine:

- Frame not disturbed, rocks in place over supports and still rigid, nuts and bolts still attached and tight;
- Turbine mount still firmly connected to stand;
- Turbine no longer connected to mount. It sheared apart at connection to mount, splitting all the cables;
- Bolt connecting turbine to mount not pushed all the way in, possibly not connected properly initially or simply worked loose by strong winds;
- Turbine blades broken and missing;
- Positive and negative cables still running out of base of turbine stand, along ground and into battery box, earth cable still buried under rocks and earth, alongside wind turbine stand.

Figure 7 and 8: *Wilson Bluff, damaged wind turbine and stand, view south, and close-up of turbine on ground.*

Solar panel frame:

- Frame overturned. Receiver and computer box still attached;
- Frame still in relatively good condition. Foot supports loose at hinges and one foot support broken off at weld points;
- Three solar panels shattered. All three reading 20+ volts when tested individually;
- One solar panel in good condition. Reading 20+ volts when tested;
- Some solar panel cables split but still operational;
- Nuts and bolts connecting solar panels to frame still attached;
- Junction box still in good condition;
- Junction box cable to battery box cut off with wires exposed. Probably happened when solar panel frame fell.

Figure 9: Wilson Bluff, o*verturned solar panel frame, view south east.*

Receiver / computer pelican case:

- Pelican case still secured to solar panel frame with rope;
- All cables connected within box;
- No ice build up or visible damage;
- Antenna cable still connected to GPS antenna;
- Computer power cable still connected;
- *Ashtech* Z-XII receiver power disconnected at connections (metal connection outside). Most likely yanked apart when solar panel frame fell.
- No power to receiver or computer

Figure 10 and 11: *Left: Wilson Bluff, pelican case containing receiver and computer. Right: receiver power cable on arrival.*

Survey monument (AUS368) and GPS antenna:

- Survey monument stable;
- Shim flush with survey plate and tight;
- GPS antenna attached to shim but loose and rotating on spigot. It possibly came loose when solar panel frame fell, yanking on the antenna cable which was connected to the receiver in the pelican case;
- Snow dome still in good condition. Firmly attached to choke ring antenna with all bolts connected tightly.

Figure 12: Wilson Bluff, *survey monument (AUS368) and GPS antenna*

Battery box:

- Stable with rocks still stacked on top;
- Connections within box still attached;
- Turbine switch toggled to charge;
- Regulator rusting and covered with ice;
- Batteries terminals corroded and covered with ice;
- Bottom and sides of box frozen with ice. Moisture probably got in where amalgamation tape was gone or not applied appropriately;
- Dump box connected with cables in good condition and dump box not disturbed a few metres away from site.


Figure 13 and 14: Wilson Bluff, *left and right side of the battery box. Notice the drift snow and corroded terminals.*

The 12-volt computer and *Ashtech* Z-XII were removed from the site and returned to Australia while all other damaged equipment and batteries were removed from Wilson Bluff and RTA as rubbish. The data collected by the receiver prior to the equipment failure was downloaded prior to leaving Antarctica.

Upgrade and maintenance of site

Once a detailed analysis of the site condition was complete, broken equipment was set aside as rubbish to be returned to Australia. Damaged equipment was then repaired and new equipment was installed on the 13th and 14th of January 2007. The details of the reconstruction of the site are listed below.

The wind turbine frame was not disturbed and still in good condition and was therefore left in the same position, 10m west of the GPS antenna. The *Air Industrial* wind turbine was constructed in the polar pyramid, connected to the new mount and carried to the site.

After passing the cables through the frame, the blades of the turbine were tied down to prevent them spinning while the mount and turbine were attached to the frame. The earth cable was re-buried into the ground and the positive and negative cables were attached to the batteries in the primary battery box. After removing the rope, and shifting the wind turbine switch box to the free spin position, the wind turbine appeared stable and was spinning freely in windy conditions.

Figure 15: *Wilson Bluff, repaired wind turbine, view south.*

The solar panel frame was repositioned a few metres north of the GPS antenna, resting on a flat surface, on the leeward side of a small rock wall. The new position of the frame, against the rock face, shelters the solar panel frame from the prevailing southerly wind. For greater stability, the foot supports of the frame were removed so the frame sits on the ground. This may result in the build up of snowdrift, but it was decided that the stability of the frame was of greater importance. To provide further support to the solar panel frame, a dynabolt was inserted into the rock behind the solar panel frame and two guy wires were attached to either end of the frame.

Two of the smashed solar panels were removed and replaced with two new *BP* solar panels. The solar panel frame is designed to hold slide-in solar panels, however, only one new slide in solar panel was available. Therefore, holes were drilled into the support frame to hold a new flat bed style solar panel with bolt connections. The undamaged solar panel was left in place and the least damaged solar panel (still fully operational), with a smashed glass cover, was also left in place.

Once the site was up and running an additional battery box containing three gel tech batteries and a large number of heavy rocks were placed on the solar panel frame. It is hoped that in the new position the solar panel frame will stay in place, especially with the additional weight on the frame and guy wire supports. The junction box for the solar panels was left in the original position at the back of the frame, as this was the only location where all four solar panel cables could reach the junction box.

All frayed cables and connections to the junction box were secured with self-amalgamation tape. The wires connecting the battery bank to the junction box were also stripped back and battery connections were replaced using a crimping tool. All cables running from the solar panel junction box were tested and proved to be transferring energy from the solar panels.

Figure 16 and 17: *Wilson Bluff, repositioned and repaired solar panel frame, modem antenna, primary battery box and GPS antenna, view south (left) and view north (right).*

Prior to this visit, only one battery box containing three 74 Amp hour *Gel Tech* batteries was on site. During the upgrade, another bank of three 74 Amp hour batteries were added in an additional battery box and connected in parallel to the existing battery bank. The additional battery box was stored on the base of the solar panel frame.

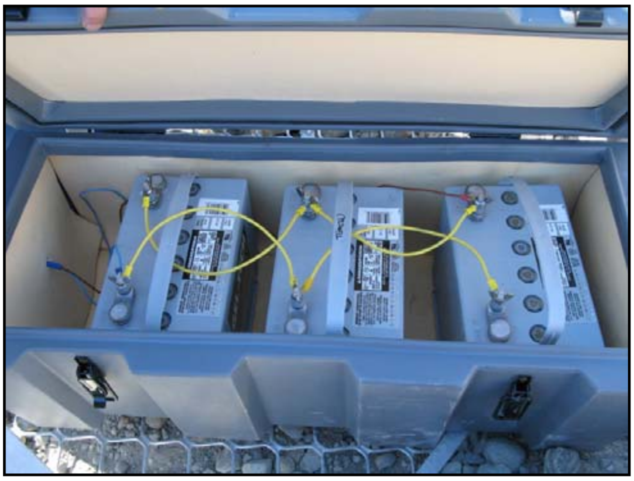


Figure 18*: Wilson Bluff, inside second battery box.*

The stainless steel survey plate was not disturbed and noted to be stable and in good condition. The 30.5mm stainless steel shim with turning mount was left attached, although the turning mount could potentially rotate in the strong Antarctic winds. This element could possibly be removed from the GPS station design in the future.

After inspecting the survey mark and shim, the *Thales* choke ring antenna (701945-02 Rev E1, s/n: CR6200326012) with SCIGN snow dome was re-attached to the shim and aligned to true north (75 degrees magnetic bearing). The shim turning mount was then tightened as hard as possible and a new 10m long GPS antenna cable was attached to the antenna before applying self-amalgamation tape at the connection to form a watertight seal.

Figure 19*: Wilson Bluff, GPS antenna, snow dome, survey monument (AUS368), view east.*

A new Iridium *NAL* (A3LA-D) (IMI: 300124000316030, AGSO: 0029915) satellite modem was also installed at the site in the same manner as described earlier in the report.

The numbers of the Wilson Bluff Iridium are:

Analogue phone number:	0011 8816 214 13965
Data phone number:	0011 8816 931 13965

As was the case at the Bunger Hills, the power and GPS receiver communication connections into the modem were extremely loose. Rope was used to secure the connections because the gender changers and cable connections did not have screws to fasten them together.

A new *Leica* System 1200 GPS receiver (s/n: 0030796) was installed at the GPS site along with a new antenna cable and attachment (attachment required because the standard GPS antenna cable is not compatible with the *Leica* System 1200). Replacing the *Ashtech* Z-XII receiver, the *Leica* System 1200 negates the need for a computer due to its large data capacity (stores approximately two years of data) and capability to communicate directly with the modem.

The Iridium to receiver communication problem of the Bunger Hills was also experienced at Wilson Bluff. Further investigation into this problem will be performed upon return to Canberra. Communications aside, the GPS receiver showed three green lights once turned on and several days of data were downloaded from the receiver before leaving Wilson Bluff.

As mentioned previously, the original CGPS site set-up had only one battery bank of three 74 Amp hour batteries. These batteries sat with the wind turbine switch box and regulator in the primary battery box. Upon arrival, the space case was found in poor condition, containing ice and drift snow.

Once the space case was cleaned and the outer valves were repaired, the three old batteries were replaced with three new 74 Amp hour Gel Tech batteries and a new *Xantrex* power regulator was installed along with a new dump box. The primary battery box also houses the Iridium modem and the *Leica* receiver.

For a detailed description of the site installation wiring, please refer to Appendix A.

After connecting the receiver, modem, regulator and timer to the battery bank, and ensuring all six batteries were running in parallel, all battery box glands were wrapped with generous amounts of self-amalgamation tape. In addition, once the battery boxes were closed, sealant was applied around the rim of the lid to avoid moisture seeping into the box.

In an attempt to leave the site in the most secure manner, the primary battery box was positioned next to the solar panel frame with large rocks placed on top and all cables running throughout the site were covered with rocks.

Figure 20: *Wilson Bluff, inside primary battery box.*

Figure 21: *Wilson Bluff Continuos GPS station, view north.*

Local area reference mark survey

It was originally intended that new reference marks would be installed around the Wilson Bluff GPS station. However, this was not possible due to the lack of suitable solid bedrock in close proximity to the site. Instead, a connection was made to a survey mark already in the area, WBF0, a brass 5/8" spigot secured into rock with epoxy, approximately 60m south of AUS368.

On the 15th of January 2007, a GPS field unit was set-up over WBF0 as per the details listed below.

Site: WBF0 (60m South of Wilson Bluff CGPS station AUS368)
Vertical offset: 0.000m (entered into receiver)
Height offset measured: 0.076m (ground mark to antenna reference point)

Receiver: *Ashtech* UZ CGRS (s/n: UC2200302005)
Antenna: *Leica* AT504 (art no: 667132) (s/n: 103316)
Start time: 23.00 UTC, Day 015 (Local 16.00, 15/01/2007)
End Time: 17.00 UTC, Day 016 (Local 10.00, 16/01/2007)

Figure 22: *WBF0 GPS survey set-up, view north.*

Figure 23 and 24: *Left: Antenna and tribrach over WBF0. Right: WBF0 close up view.*

Table 2: AUSPOS results for A368 and WBF0 and one sigma uncertainties. From AUSPOS Jobs #50800, #50900

SITE	LATITUDE (DMS)	LONGITUDE (DMS)	ELLIPSOIDAL HT (M)	ABOVE GEOID HT (M)
A368	-74°17'26.0778" (0.003m)	66°47'32.0360" (0.003m)	1235.844 (0.020m)	1220.137
WBF0	-74°17'28.4362" (0.006m)	66°47'32.6326" (0.004m)	1240.485 (0.008m)	1224.782

GROVE MOUNTAINS

The Grove Mountains are a scattered group of mountains and nunataks located approximately 500km south south west of Davis station and 160km east of the Mawson escarpment. After a two-year hiatus, the purpose of the trip was to repair the CGPS site and withdraw the ANU seismic station *c.* 500m west of the GPS site.

One CASA aircraft transported a reduced cargo of freight and personnel to the site, landing on blue ice approximately 1km west of the camp site, which was established at the base of a broad snow bank adjoining the western flank of the nunatak. The pilots taxied the aircraft to within a few hundred metres of the campsite. Two quad-bikes left behind by a previous science field party were located. One quad bike was used to haul the work and living equipment to the camp site. The other quad bike was returned to Davis on the aircraft.

The GPS station was located approximately 500m east of the campsite on a flat ledge at the northern side of the nunatak. Travel to the GPS site involved riding the quad bike up the snow bank on the southwest side of the nunatak and then walking 400m over uphill terrain strewn with large boulders and loose rocks around the nunatak to the opposite side.

The survey monument (AUS351) is a stainless steel plate with a 5/8" spigot set into a concrete pillar and was established in the summer of 2000/01 by Geoscience Australia surveyors. Adrian Corvino and Henk Brolsma installed the GPS station in late-December 2003. Two Geoscience Australia surveyors re-visited the site in early 2005 to repair the station and install new equipment.

On arrival in 2007, the GPS receiver was still running despite some damage to the site. Damaged equipment was removed and replaced and some modifications to the system design were introduced which included removing the 12V computer and having the GPS receiver communicate directly to the iridium modem.

Assessment of site

On the 29th of January a comprehensive site analysis was undertaken to identify what had been disturbed at the GPS site, that is, what could be repaired and what needed to be replaced. A number of photographs were taken of the site with particular attention paid to the damaged equipment. A detailed list of the state of equipment on arrival is provided below.

Wind turbine:

- Frame not disturbed, rocks in place over supports and still rigid, nuts and bolts still attached and tight;
- Turbine mount still firmly connected to stand;
- Turbine still firmly connected to mount;
- Two turbine blades found several metres from site, nuts and bolts loosened;
- Positive and negative cables still running out of base of turbine stand, along ground and into battery box, earth cable still buried under rocks and earth, alongside wind turbine stand.

Figure 25: *Grove Mountains, damaged wind turbine and stand and met station, view south*

Solar panel frame:

- Frame still upright with receiver and computer box still attached and rocks piled on top;
- One solar panel was found shattered several metres from site with part of the solar panel frame still attached. Cables out of solar panel disconnected but still plugged into the junction box;
- Frame still in relatively good condition, despite base corner of frame being ripped from main frame;
- Three solar panels attached to frame and in good condition, all three reading 20+ volts when tested individually;
- Solar panel cables all operational and in good condition;
- Nuts and bolts connecting solar panels to frame still attached;
- Junction box still in good condition, junction box cable to battery box in good condition and reading 20+ volts when tested.

Figure 26 and 27: *Left: Grove Mountains, damaged solar panel stand, Right: Damaged solar panel*

Receiver / computer pelican case:

- Pelican case still secured to solar panel frame with rope;
- All cables connected within box;
- No snow drift or visible damage;
- Antenna cable still connected to GPS antenna;
- Computer power cable still connected to over/under protection, power light on;
- *Ashtech* Micro-Z receiver still connected to over/under protection, green lights flashing for tracking satellites, red light on for disk full;
- All modem cables connected.

Figure 28: Grove Mountains, inside receiver / computer pelican case.

The 12-Volt computer and *Ashtech* Micro-Z receiver were removed from the station and returned to Australia. The small amount of data on the GPS receiver was downloaded successfully, however, the data could not be downloaded from the computer. All data was downloaded off the computer and backed up at Geoscience Australia when the equipment was returned to Australia.

Survey monument (AUS351) and GPS antenna:

- Survey monument stable, not disturbed;
- Shim flush with survey plate and tight;
- GPS antenna attached to shim tightly and orientated north;
- Snow dome still in good condition, firmly attached to choke ring antenna with all bolts connected tightly.

Figure 29: Grove Mountains, *survey monument (AUS351) and GPS antenna*

Primary battery box:

- Stable with rocks still stacked on top;
- Turbine switch toggled to charge;
- Regulator light flashing green;
- One battery leaked with bulged and busted sides, other two batteries in good condition;
- All batteries tested individually, busted battery found to lose voltage quickly while other two in good condition, holding voltage;
- Connections within box still attached although cables discoloured due to battery leak;
- All cable entries into box in good condition, although solar panel cable connection to batteries of stripped wire rapped around terminals could be improved;
- No signs of snow drift or moisture build up within box;
- Dump box connected with cables in good condition and dump box not disturbed a few metres away from site.

Figure 30: Grove Mountains, i*nside primary battery box.*

Meteorological station:

- Met station and mount still firmly attached to wind turbine stand;
- Nuts and bolts and U-bolt connections all in good condition;
- Plastic wrap around met station cable still in place and cable running into receiver/computer box in good condition.

Secondary battery box:

- Stable with rocks still stacked on top;
- Connections within box attached and in good condition;
- All cable entries into box in good condition;
- All batteries tested individually and found to be in good condition, holding voltage.

Figure 31: Grove Mountains, i*nside secondary battery box.*

Iridium modem:

- Antenna and pole support still firmly attached to solar panel frame with stainless steel cable ties;
- Cables and connection into and within box all in good condition.

Figure 32: Grove Mountains, *GPS station on arrival, view south..*

Upgrade and maintenance of site

Once a detailed analysis of the site condition was complete, broken equipment was set aside as rubbish to be returned to Australia. Damaged equipment was repaired and new equipment and batteries were installed. Tasks performed in the site upgrade on the 29th and 30th of January 2007 are detailed below.

As the wind turbine stand/frame was not disturbed it was decided to leave it in its current position, 5m South of the GPS antenna. The turbine mount was disconnected from the frame with the turbine, and the cables were removed from the frame shaft and disconnected from the battery box. The earth wire was also extracted from the ground.

A new *Air Industrial* wind turbine with blades and cables was then assembled and attached to the turbine mount as previously described. Upon installation, the wind turbine was only seen to spin very slowly over the next two days; however, during windier conditions in the evening the turbine could be heard from the camp to be spinning freely.

Figure 33: *Grove Mountains, new wind turbine and repaired GPS station, view north.*

The solar panel frame was left in the same position, a few metres west of the GPS antenna, flush with the ground and aligned to true north.

The frame is designed to hold four slide-in solar panels. Given that one of the panels was damaged, no spare slide-in panels were available and the corner base of the frame was damaged, the site was left with only three working panels.

The positive and negative ends of the cable from the junction box (left in the original position at the back of the frame) to the primary battery box were stripped back and new battery connections were attached using a crimping tool. This should provide a more robust connection to the battery terminals than the previous stripped wire wrapped around the terminals. Each solar panel cable was tested individually and all displayed strong voltage readings when the sun was visible. The cable running from the solar panel junction box was also tested, showing plenty of voltage from the solar panels.

Figure 34: *Grove Mountains, solar panel frame and profile view of GPS station, view south.*

Two *Gel Tech* batteries were moved from the primary battery box and used to replace two older batteries in the second battery box. The parallel battery connection was maintained. These batteries were connected to the primary battery box batteries via two longer cables. The faulty battery from the primary battery box was removed along with the two old batteries from the second battery box and set aside as RTA rubbish.

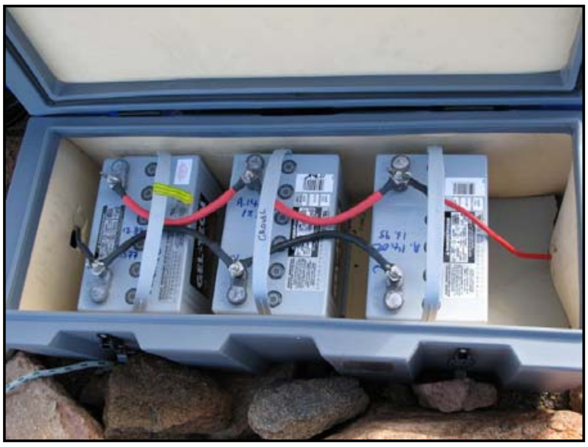


Figure 35*: Grove Mountains, inside second battery box.*

The stainless steel survey plate, concrete pillar, shim and *Thales* antenna (701945-02 Rev E1, s/n: CR6200327018) with SCIGN snow dome were not disturbed and noted to be stable and in good condition.

The 10m long GPS antenna cable attached to the antenna with self-amalgamation tape to form a watertight seal was undisturbed.

Figure 36*: Grove Mountains, survey monument (AUS351) and GPS antenna.*

A new *Ashtech* Micro-Z UZCGRS receiver (s/n: UC2200524009) was installed at the GPS site utilising the existing power, communication and antenna cables. The GPS receiver replaced the previous *Ashtech* Micro-Z receiver and computer and was placed inside the existing receiver/computer pelican case.

The new receiver, powered via a connection into the old over/under voltage monitor, communicates directly with the modem without a computer, thereby reducing the power drawn from the batteries. The drawback of this set-up is that if the communication link to Canberra breaks down, the new receiver will be the only place data can be stored. In order to reduce the daily file size, allowing the receiver to store more data and ensure more efficient download times, the observation interval in the new receiver was set to 90 second epochs, as opposed to the standard 30 second epochs.

Upon installation, the receiver made a successful communication link to the Geoscience Australia office in Canberra. Prior to leaving the site, all appropriate lights were flashing and two days of data were downloaded from the receiver. The box was left in the same position on top of the solar panel frame with rocks piled around and over it.

Figure 37: *Grove Mountains, inside GPS receiver / modem case.*

A new Iridium *NAL* (A3LA-I) (IMEI: 300003000539300) satellite modem was also installed at the site in the same manner as described earlier in the report.

The numbers of the Grove Mountains Iridium are:

Analogue phone number:	0011 8816 214 13964
Data phone number:	0011 8816 931 13964

As was the case at the Bunger Hills and Wilson Bluff, power and GPS receiver communication connections into the modem were extremely loose. Rope was used to secure the connections because the gender changers and cable connections did not have screws to fasten them together.

On arrival it was noted that the space case, which had been on site for a few years, was in relatively good condition.

The old regulator could not be removed as the bolt connections attaching it to the box wall had seized. Therefore, the old regulator was left in place and a new *Xantrex* power regulator was placed at the bottom of the box and connected to the battery bank. Three new 74 Amp hour batteries were placed in the primary battery box and a new dump box was connected to the new regulator and placed in the same location as the previous dump box, a few metres south of the GPS antenna.

For a detailed description of a site wiring, please refer to Appendix A.

All cable connections into the battery box glands were wrapped with generous amounts of self-amalgamation tape. In addition, once the battery box was closed, sealant was applied at screw connections around the box wall in further attempts to avoid moisture seeping into the box. The primary battery box was positioned next to the solar panel frame and large rocks were placed on top. All cables running throughout the site were covered with rocks to secure and protect them.

Figure 38: Grove Mountains, *inside primary battery box.*

Figure 39*: Grove Mountains, battery boxes, solar panel frame and modem, view north.*

Local area reference mark survey

Unfortunately, due to weight restrictions and anticipated time restrictions the equipment to carry out a GPS or total station reference mark survey was not taken to the Grove Mountains this season. Reference marks were inspected on site and showed no visible signs of disturbance.

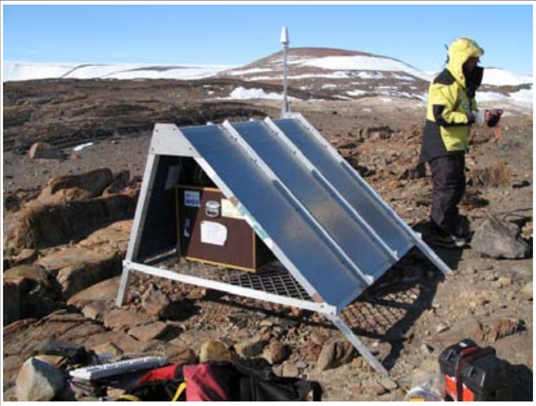
DALTON CORNER

After a 25-minute flight from Wilson Bluff the field party consisting of Alex Woods, Nick Brown and Dan Zwartz arrived at Dalton Corner; another rock outcrop located about 100km north east of Wilson Bluff in the Southern Prince Charles Mountains at the southern end of the Mawson Escarpment.

Nick and Alex assisted Dan to install three new batteries and equipment to the Dalton Corner CGPS station. Upgrades were also made to the software controlling the CGPS site. The campsite was located next to a small outcrop on the western side of Dalton Corner alongside the Lambert Glacier, and the GPS station was *c.* 1.8km east of the campsite.

The walk from the campsite to the GPS station took about half an hour over rough terrain with a change in elevation of over 200m. It had been a couple of years since the previous visit to the site and it was observed to be in good condition. The antenna, solar panels and cables were not disturbed, the batteries were charged and the receiver and computer were all fully operational.

After replacing the three batteries, the modem and upgrading the computer software, communications were established with the RSES data centre in Canberra and data was successfully downloaded. The station was monitored and several tests were performed over two days while the field party awaited transport back to Davis station.



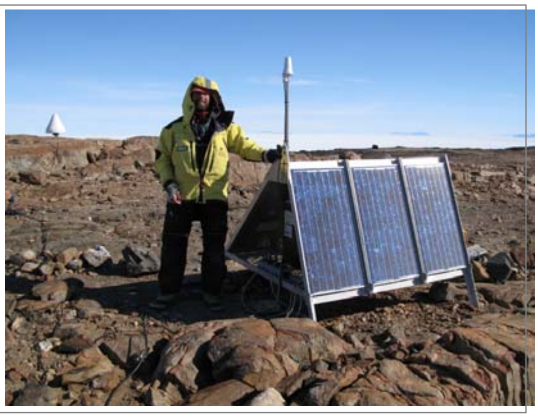


Figure 40 and 41*: Dalton Corner, solar panel frame and box, view northeast (left), view south (right)*

Figure 42: Dalton Corner, c*lose up of survey monument.*

BEAVER LAKE

After repairing the Wilson Bluff continuous GPS tracking station and upgrading the GPS site managed by ANU at Dalton Corner the field party returned to Davis station with a brief visit to Beaver Lake to withdraw equipment from the, ANU managed, GPS station at Beaver Lake. Beaver Lake is located on the eastern side of the northern Prince Charles Mountains; 30km west of the Amery Ice Shelf and the GPS station is *c*. 4km from the Beaver Lake apple huts.

On Saturday the 20th of January the CASA aircraft landed on the lake ice alongside the Beaver lake apple huts and the field party walked directly to the GPS station and withdrew the receiver, computer, power regulators, meteorological and communication equipment and cables. Quad bike tracks from previous expeditions led the majority of the way to the GPS site, which took approximately one hour to walk to. After collecting the equipment, the field party returned to the aircraft and flew back to Davis station.

The GPS site is situated on a sandstone rock outcrop in a valley, above some small lakes. The GPS antenna is nearby a ledge where sandstone appears to be breaking off. The long-term stability of the site is questionable. However, it was difficult to identify a better place to set-up a GPS station in the area.

The GPS site was found to be in good condition, with the antenna, solar panels and battery box undisturbed. Geoscience Australia intends to takeover the operation of the site in the future, thus the antenna was left in its position. In addition, the solar panels, framework, batteries and operations battery box were also left on site. More time on site or the assistance of a helicopter would have been required to remove the batteries and satellite dome.

Figure 43: *Beaver Lake continuous GPS station.*

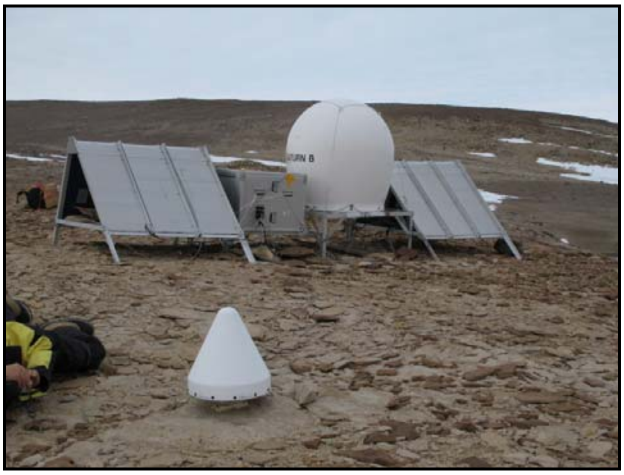


Figure 44: *Beaver Lake continuous GPS station reverse view.*

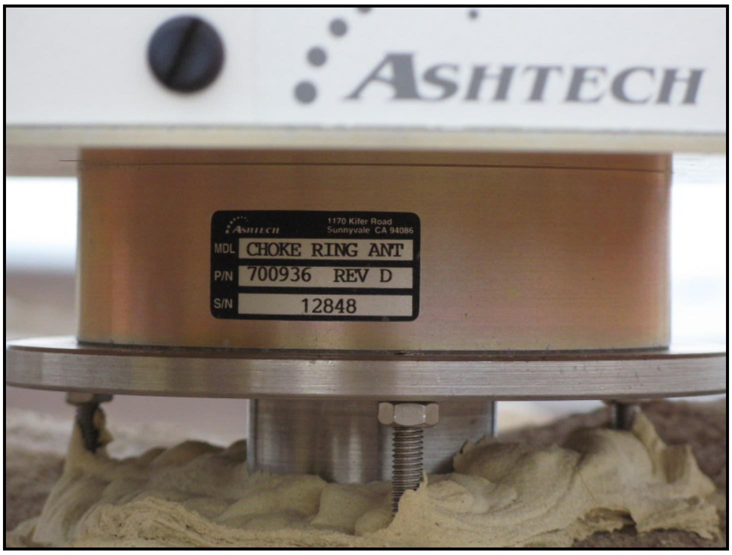


Figure 45: *Beaver Lake GPS antenna left in situ*

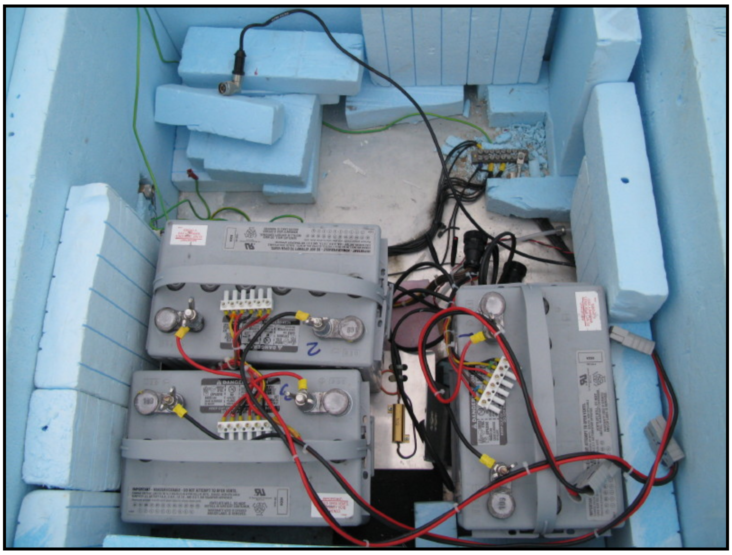


Figure 46: *Inside Beaver Lake battery box before closing*

ARGN Equipment Upgrade

DAVIS

An upgrade of the GPS and communications equipment of the Davis ARGN site was undertaken on the 10th of January 2007. The following is a summary of the upgrade:

- *Ashtech* Z-18 (s/n:ZX00104) was replaced with a new *Trimble* NetR5 GPS receiver (s/n: 4614K01058);
- The *Ashtech* Micro-Z receiver (s/n: UC2200340007) was left in place;
- The three old *Dell* PCs were substituted with two new Dell PCs;
- A new stallion board was added along with a serial port console;
- The old stallion board, MUX and Modem Datalink 14.4k were all withdrawn;
- Additional cables for the new equipment were installed and the old cables no longer required were removed;
- The large *Navstar* GPS Turbo Rogue was also taken out of the system and returned to Australia (RTA) along with the three PCs and Z-18.

<u>New equipment</u>:

Trimble NetR5 GPS receiver	s/n: 4614K01058	AGSO: 0031393
Main *Dell* GRX260 PC	s/n: 00019-107-151-590	AGSO: 0028163
Backup *Dell* GRX260 PC	s/n: 00019-108-567-072	AGSO: 0028180
Stallion board (8 port)		
Black Box Serial Port Console	s/n: 12050018	
Woomera Modem	s/n: 819564	

<u>Equipment left in place</u>:

Computer monitor
Keyboard
Mouse
TrueTime GPS Time and Frequency Receiver Model XL-DC (GEO2/00001)
GPS Power Controller Model CE-0034
GPS Charger Unit – Rubidium 5MHZ Model CE-0034A
GPS Antenna cable Splitter
2 CG12-33 Gel Batteries

<u>Equipment withdrawn</u>:

Main *Dell* PC	s/n: 00019-065-086-460	RTA
Backup *Dell* PC	s/n: 00019-065-086-482	RTA
GLONASS *Dell* PC	s/n: 00019-064-478-589	RTA
Ashtech Z-18 Receiver	s/n: ZX00104	
Navstar GPS AUX Rogue	s/n: C206U	RTA
Stallion board (16 port)		
MUX		
Modem Datalink 14.4k		
2 transformers		

<u>Spare equipment</u>:

Ashtech Choke Ring Antenna (701945-02G)	s/n: CR5200428009
Stallion board	
Various comms and network cables and adaptors	
Antenna splitter	

Equipment and port connections

Main *Dell* PC

Port	Connection
Network	Wall Slot G012B (blue cable)
Power	Wall UPS
Stallion Board	Stallion Board
Mouse	Mouse
Monitor	Monitor
Keyboard	Keyboard

3 Com Ports not connected

Backup *Dell* PC
Not Connected

Monitor

Port	Connection
Main Dell PC	Main *Dell* PC
Power	Wall UPS

Mouse
Connected to Main *Del*l PC

Keyboard
Connected to Main *Dell* PC

Stallion Board (8 ports – 5 used)

Port	Connection
Stallion Board Main	Main *Dell* PC Stallion Board
Port 00	Not Connected
Port 01	Serial Port Console Port 3
Port 02	Not Connected
Port 03	*Ashtech* UZCGRS Port A
Port 04	Not Connected
Port 05	*Ashtech* UZCGRS Port C
Port 06	GPC PC Input
Port 07	Serial Port Console Port 8

Serial Port Console

Port	Connection
Power	Wall UPS
Port 1	Not Connected
Port 2	*Woomera* modem
Port 3	Stallion Board Port 01
Port 4	Not Connected
Port 5	Not Connected
Port 6	GPC MUX Input
Port 7	Not Connected
Port 8	Stallion Board Port 07

GPS Charger Unit – Rubidium 5MHZ

Port	Connection
GPC	GPC
Power	Wall UPS

GPS Power Controller (GPC)

Port	**Connection**
GPS 1 Com	Not Connected
GPS 2 Com	Not Connected
MUX Input	Serial Port Console Port 6
PC Input	Stallion Board Port 06
GPS 1 Power	*Ashtech* UZCGRS Receiver Power
GPS 2 Power	Antenna Splitter
Rb1 Power	Not Connected
Rb2 Power	RB Clock
Battery Charger	GPS Charger Unit
Battery Supply	2 Gel Batteries
Power	Wall UPS

Antenna Splitter and In-Line Amplifier

Connection	**Connection**
Input	GPS Choke Ring Antenna
Output 1	*Ashtech* UZCGRS Receiver Ant Port
Output 2	*Trimble* NetR5 Receiver Ant Port
Output 3	RB Clock Ant Port
Power	GPC GPS 2 Power

***Ashtech* UCGRS Receiver**

Port	**Connection**
Power	GPC GPS 1 Power
ETH	RB Clock 5MHz
Port A	Stallion Board Port 03
Port B	MET Station
Port C	Stallion Board Port 05
Port D	MET Station
Antenna	Antenna Splitter

***Trimble* NetR5 Receiver**

Port	**Connection**
Power	Wall UPS
Network	Wall Slot G012A (grey cable)
Antenna	Antenna Splitter

All other receiver ports are not connected

***Woomera* modem**

Port	**Connection**
Power	Wall UPS
Phone line	Phone slot in wall
Communication to equipment	Serial Port Console Port 2

2 *Gel Tech* Batteries

Connected to GPC Battery Supply

MAWSON

New GPS, communication and power equipment was installed at the Mawson Station ARGN site on the 25th to 26th of December 2006. Below is a summary of the work completed:

- *Ashtech* Z-XII (s/n:04262) was replaced with a new *Leica* GRX1200 Pro receiver (s/n: 462883);
- The old *APC* UPS was replaced with a new *APC* UPS;
- Two batteries were replaced;
- The two old batteries and old UPS were presented to the communications technicians on station;
- The two old *Dell* PCs were substituted with two new *Dell* PCs;
- A new stallion board was also added along with a serial port console;
- The old stallion board, MUX and Modem Datalink 14.4k were all withdrawn;
- Additional cables for the new equipment was installed and the old cables no longer required were removed;
- The large *NavGPS* AUX Rogue was also taken out of the system set-up and returned to Australia.

<u>New equipment</u>:

Leica GRX1200 Pro Receiver	s/n: 462883	AGSO: 0030803
Main *Dell* GRX260 PC	s/n: 00019-108-504-990	AGSO: 0028081
Main *Dell* GRX260 PC	s/n: 00019-108-375-437	AGSO: 0028113
Stallion board		
Black Box Serial Port Console		
APC Smart-UPS 1400XL		
2 new *GelTech* 74AH Batteries		

<u>Equipment left in place</u>:

Choke Ring Antenna (701945-012 Rev G)	s/n: CR5200345019	
Ashtech ICGRS receiver	s/n: IR2200408010	AGSO: 0029452
Ashtech Z-XII receiver (700570-6 C)	s/n: 04262	
Flatron monitor screen		
Keyboard		
GPS Power Controller Model CE-0034		
GPS Charger Unit – Rubidium 5MHZ Model CE-0034A		
Splitter and in-line amplifier		
Blackbox short haul modem	s/n 9711	

<u>Equipment withdrawn</u>:

Main *Dell* PC	s/n: 00019-063-646-915	RTA
Backup *Dell* PC	s/n: 00019-063-646-929	RTA
APC UPS		
Navstar GPS AUX Rogue	s/n: C119.U	RTA
Stallion board		
MUX		
Modem Datalink 14.4k		
2 old batteries		

<u>Spare equipment</u>:

Ashtech Choke Ring Antenna (701945-012G)	s/n: CR5200348019
Stallion board – 16 ports	
Various comms and network cables and adaptors	

Initially, the modem line was not connected. Firstly, there were not enough 9pinF to 25pinM cables available and secondly the modem line is known to interfere with the phone line to the Cosray building (on the same line), with the modem picking up before anyone can answer the phone. Before departure it was decided to connect the *Blackbox* short haul modem. An additional, 9pinF to 25pinM adaptor was supplied by the station communications technicians to allow this connection.

It was originally intended to return the *Ashtech* Z-XII to Australia after replacing it with the new *Leica*. However, problems were encountered when trying to communicate with the *Leica*, thus the *Ashtech* was left with the ARGN equipment as a backup receiver for the *Ashtech* ICGRS until the problem with the *Leica* could be resolved. The *Ashtech* Z-XII receivers will be RTA in a future voyage.

Equipment and port connections

Main *Dell* PC

Port	Connection
COM1	*APC* UPS
Network	Wall Slot G005B (blue cable)
Power	*APC* UPS
Stallion Board	Stallion Board
Monitor	Monitor
Keyboard	Keyboard

Pink and Blue Com Ports not connected

Backup *Dell* PC

Not Connected

Monitor

Port	Connection
Main *Dell* PC	Main *Dell* PC
Power	Wall Power

Keyboard

Connected to Main *Dell* PC

APC UPS

Port	Connection
PC Com (10101)	COM 1 Main *Dell* PC
Power 1	Main *Dell* PC Power
Power 2	GPC
APC Power	Wall Power

Remaining power outlets not connected

Stallion Board (8 ports – 5 used)

Port	Connection
Stallion Board Main	Main *Dell* PC Stallion Board
Port 00	Not Connected
Port 01	Serial Port Console Port 3
Port 02	Not Connected
Port 03	*Ashtech* ICGRS Port A
Port 04	Not Connected
Port 05	*Ashtech* ICGRS Port C
Port 06	GPC PC Input
Port 07	Serial Port Console Port 8

Serial Port Console

Port	**Connection**
Power	*APC* UPS Power 2
Port 1	Cable Not Connected (9F to 9F)
Port 2	*Black box* short haul modem
Port 3	Stallion Board Port 01
Port 4	Not Connected
Port 5	Not Connected
Port 6	GPC MUX Input
Port 7	Not Connected
Port 8	Stallion Board Port 07

GPS Power Controller (GPC)

Port	**Connection**
GPS 1 Com	Not Connected
GPS 2 Com	Not Connected
MUX Input	Serial Port Console Port 6
PC Input	Stallion Board Port 06
GPS 1 Power	*Ashtech* ICGRS Receiver Power
GPS 2 Power	Antenna Splitter
Rb1 Power	*Leica* GRX1200 Receiver Power
Rb2 Power	Not Connected
Battery Charger	GPS Charger Unit
Battery Supply	2 *Gel Tech* Batteries
Power	Wall Power

GPS Charger Unit – Rubidium 5MHZ

Port	**Connection**
GPC	GPC
Power	Wall Power

Antenna Splitter and In-Line Amplifier

Connection	**Connection**
Input	GPS Choke Ring Antenna
Output 1	*Ashtech* ICGRS Receiver Ant Port
Output 2	*Leica* GRX1200 Pro Receive Ant Port
Power	GPC GPS 2 Power

***Ashtech* ICGRS Receiver**

Port	**Connection**
Power	GPC GPS 1 Power
ETH	Cable Not Connected
Port A	Stallion Board Port 03
Port B	Not Connected
Port C	Stallion Board Port 05
Port D	Not Connected
External Frequency	Not Connected
Antenna	Antenna Splitter

***Leica* GRX1200 Pro Receiver**

Port	**Connection**
Power	GPC Rb1 Power
Network	Wall Slot G005A (grey cable)
Antenna	Antenna Splitter

All other receiver ports are not connected

***Ashtech* Z-XII Receiver**
Not connected. Available as a backup receiver.

Blackbox short haul modem

Port	Connection
Power	Wall Power
Phone line	Phone slot in wall
Communication to equipment	Serial Port Console Port 2

2 *Gel Tech* Batteries
Connected to GPC Battery Supply

CGPS Reference Mark Surveys

Reference mark (RM) surveys are routinely carried out at all Australian Regional GPS Network (ARGN) stations in Australia and the Australian Antarctic Territory, the purpose of which is to monitor local deformation at a permanent GPS site. The Antarctic stations make up a network of permanent GPS sites that are used to study Earth processes such as crustal dynamics and sea level rise; the data from which contribute to the International GPS Service (IGS). Reference Mark surveys allow analysts to distinguish between localised site deformation and continental movement.

DAVIS

A reference mark survey was conducted at the Davis ARGN site on the 6th of February 2007 in near nil wind conditions. The survey was performed using a *Leica* TCA2003 total station, a set of three *Leica* precision prims with previously determined prism offsets and three tripods to set-up equipment over the RM's. The total station was used to observe horizontal and vertical angles as well as slope distances between each of the survey marks.

In addition, precise Electronic Distance Measurement (EDM) heighting was undertaken to obtain reduced levels for each of the RM's and the ARGN survey monument. This was performed using the total station, a fixed-height stainless steel rod with bi-pole supports and a *Leica* precision prism. For observations to the pillar monument the prism was fitted to a fixed height stub.

To set the instruments up over the AUS099 survey monument, the GPS antenna and dome had to be removed. This involved unscrewing the snow dome and GPS antenna from the survey plate and removing two shims (3mm and 0.5mm). Upon completion of the survey, the shims, antenna and dome were re-fitted and an adhesive gel was applied to the contact point around the survey plate to ensure a watertight seal.

Before moving the antenna, its alignment was marked on the pillar and observed to be at approximately 152 degrees (magnetic bearing). This equates to approximately 73 degrees (true bearing). At the end of the survey the antenna was returned to the same alignment. The orientation away from true north was noted for the GPS log file.

A collimation test was conducted at the beginning of the survey. The horizontal index error was negligible; however, the vertical index error in the instrument was minus 16". It is thought that perhaps the instrument was poorly handled during transit to Antarctica and that the instrument should be serviced when returned to Australia.

In conducting the observations, the total station was set up over each of the survey marks (AUS099, RM1, RM2, RM3) and five rounds of FL/FR observations were taken to each of the other three survey marks. Each round of FL/FR observations involved recording horizontal and vertical angles as well as slope distances. Survey tripods were levelled and centred over the RM's using a ZNL *Wild* optical plummet.

An EDM heighting levelling survey was also conducted between the AUS099 pillar and the three RM's. The level run went from AUS099 to RM1 to RM2 to RM3 to AUS099. For each instrument set-up five rounds of FL/FR observations were made to the back sight (BS) and fore sight (FS), with readings of zenith angles and slope distances recorded. A misclosure of 0.1mm was obtained for the level survey, well within zero-order specifications. This indicated that the height difference observations were very precise and that no gross errors were made during the survey. Orthometric heights (MSL reduced levels) were derived for each of the survey marks relative to the 1983 MSL of NMV/S/4 (2.179m) and are shown in the survey results below.

All observed distances were corrected for the atmospheric effects by entering temperature, pressure and humidity readings (made using a Kestrel weather watch) into the total station (done during levelling) or by applying these atmospheric readings to the observations in data processing (done for the horizontal survey). Temperature and pressure readings made by the local Bureau of Metrology observers were also utilised and compared against the weather watch readings.

All observations were pre-processed using in-house software developed by Geoscience Australia and then processed using the least squares survey network adjustment program (SNAP) to determine the final coordinates of survey marks, with estimates of their precision, and a comprehensive evaluation of the quality of the observations. The network was fixed using the known ITRF2000@2000.00 coordinates of AUS099 from the Antarctic Geodesy 2000/01 report (Johnston & Digney, 2001) and was aligned with an azimuth from AUS099 to RM1 (derived using coordinates supplied in the 2000/01 report). These coordinates were based on the GRS80 reference ellipsoid.

All observations were entered into the SNAP data file and processed. Initially, a vertical and horizontal angle precision of 1 second, slope distance precision of 1mm + 1ppm, levelling precision of 0.3mm and azimuth error of 0.1 seconds were adopted. However, the data did not adjust well, quoting a large standard error of unit weight (2.4), large sum of squared residuals (+155), relative to the 27 degrees of freedom, and large adjustments applied to horizontal angle observations. The large standard error of unit weight indicated that the residuals in the data were greater than expected and that the observation error estimates were underestimated. Therefore, the horizontal angle precision was changed to 3". This significantly reduced the standard error of unit weight (1.0), the sum of squared residuals (27) and produced a more realistic precision estimates.

The need for this larger horizontal angle precision is not perfectly clear. Possible reasons include instrument-pointing errors either through technical pointing difficulties as the instrument is in need of calibration or due to multiple instrument operators during the survey, introducing observation bias. The latter possibility is unlikely due to the automatic target recognition (ATR) feature in the instrument. This provides further evidence that the instrument should be calibrated/serviced upon return to Australia.

Survey results

Table 3: 2007 Davis RM Survey. Latitude, longitude and ellipsoidal height and associated one sigma uncertainty (mm) for the RM stations. GRS80 ellipsoid and ITRF2000@2000.00 co-ordinates adopted at AUS099 (DAV1)

SITE	LATITUDE (DMS)	σ (MM)	LONGITUDE (DMS)	σ (MM)	ELLIPSOIDAL HT (M)	σ (MM)
AUS099	-68 34' 38.36207"	0.0	77 58' 21.40903"	0.0	44.4160	0.0
RM1	-68 34' 36.94417"	0.4	77 58' 21.69996"	0.0	42.0895	0.1
RM2	-68 34' 38.69745"	0.4	77 58' 22.27439"	0.2	43.9723	0.0
RM3	-68 34' 38.63385"	0.3	77 58' 21.17207"	0.1	43.4687	0.0

Table 4: 2000/01 Davis RM Survey. Latitude, longitude and ellipsoidal height and associated one sigma uncertainty (mm) for the RM stations. GRS80 ellipsoid and ITRF2000@2000.00 co-ordinates adopted at AUS099 (DAV1)

SITE	LATITUDE (DMS)	σ (MM)	LONGITUDE (DMS)	σ (MM)	ELLIPSOIDAL HT (M)	σ (MM)
AUS099	-68 34' 38.36207"	0.0	77 58' 21.40903"	0.0	44.4160	0.0
RM1	-68 34' 36.94416"	0.4	77 58' 21.69996"	0.5	42.0894	0.2
RM2	-68 34' 38.69741"	0.3	77 58' 22.27440"	0.3	43.9718	0.1
RM3	-68 34' 38.63380"	0.3	77 58' 21.17200"	0.1	43.4684	0.1

Please note that the 2006/07 results were processed using SNAP, whereas the 2000/01 results were processed using *GEOLAB*. The programs utilise height observations differently. See Table 5 for a better understanding of the changes in height differences between the surveys. Table 5 shows orthometric height differences computed from the levelling survey between the ARGN pillar and RM's.

Table 5: Comparison of height differences between ARGN pillar and RMs for each survey from 1996 to 2007. Surveys performed by contracted Antarctic Division surveyors (1996), AUSLIG surveyors (2001) and Geoscience Australia surveyors (2005, 2007). All units are in metres.

AUS099 TO	1996	2001	2005	2007
RM1	-2.3270	-2.3271	-2.3266	-2.3265
RM2	-0.4440	-0.4440	-0.4435	-0.4437
RM3	-0.9480	-0.9485	-0.9474	-0.9473

The results show very good agreement between the 2000/01 and 2006/07 surveys. Height differences agree at the 1mm level and horizontal positions are also similar. This indicates that there has been no significant local vertical or horizontal deformation of the AUS099 station. Although the results are markedly similar, care should always be taken when comparing the results between different years because of the different adjustment software packages and survey techniques employed.

Figure 47: *Davis Station ARGN monument AUS099 with GPS antenna attached*

MAWSON

The Mawson reference mark survey was conducted on the 28th of December 2006 in near nil wind conditions using the equipment and observation procedures described earlier in this report.

To set the instruments up over the AUS064 survey monument, the GPS antenna and dome had to be removed. This involved unscrewing the snow dome and GPS antenna from the survey plate and removing two shims (3mm and 0.5mm). Upon completion of the survey, the shims, antenna and dome were re-fitted and an adhesive gel was applied to the contact point around the survey plate to ensure a watertight seal.

Before moving the antenna, its alignment was marked on the pillar and observed to be at approximately 60 degrees (magnetic bearing). This equates to approximately 353 degrees (true bearing). At the end of the survey the antenna was returned to the same alignment.

A collimation test was also conducted prior to the start of the Mawson RM survey. In this case the horizontal index error was also negligible; however, the vertical index error in the instrument was minus 17". This provides further confirmation of the collimation error of the total station and the need for it to be serviced.

The total station was set up over each of the survey marks (AUS064, RM1, RM2, RM3) and five rounds of FL/FR observations were taken to each of the other three survey marks. Each round of FL/FR observations involved recording horizontal and vertical angles as well as slope distances. Survey tripods were levelled and centred over the RM's using a ZNL Wild optical plummet. Additional horizontal angle observations were taken to the Bechervaise Island Trig Station when the instrument was set-up over AUS064, however, these measurements were not used in the data processing because accurate coordinates were not available for the monument and therefore, the azimuth was unknown.

An EDM heighting levelling survey was conducted between the ARGN pillar monument and RM's. The level run went from AUS064 to RM1 to RM2 to RM3 to AUS064 and back again. For each instrument set-up five rounds of FL/FR observations were made to each of the BS and FS, with readings of zenith angles and slope distances recorded. A misclosure of 0.3mm was obtained for the level survey, well within zero-order specifications. Orthometric heights (MSL reduced levels) were derived for each of the survey marks relative to the MSL of ISTS051 (9.792m) which was obtained by T. W. Gordon (1995/96).

All observations were pre-processed using in-house software developed by Geoscience Australia and then processed using the least squares survey network adjustment program (SNAP) to determine the final coordinates of survey marks, with estimates of their precision, and an evaluation of the quality of the observations. The network was fixed using the known ITRF2000@2000.00 coordinates of AUS064 from the Antarctic Geodesy 2000/01 report (Johnston & Digney, 2001) and was aligned with an azimuth from AUS064 to RM3 (derived using coordinates supplied in the 2000/01 report). These coordinates were based on the GRS80 reference ellipsoid.

All observations were entered into the SNAP data file and processed. Statistically reliable results were obtained with the vertical and horizontal angle error estimates set to 1 second, slope distance precision set to 1mm + 1ppm, levelling precision specified as 0.3mm and the azimuth error set to 0.1 seconds. The final adjustment stated a standard error of unit weight of 0.67, which indicates that the precision of the observations was better than expected. The original observation error estimates provided were unchanged, as the results were deemed satisfactory.

Survey results

Table 6: 2006 Mawson RM Survey. Latitude, longitude and ellipsoidal height and associated one sigma uncertainty (mm) for the RM stations. GRS80 ellipsoid and ITRF2000@2000.00 co-ordinates adopted at AUS064 (MAW1)

SITE	LATITUDE (DMS)	σ (MM)	LONGITUDE (DMS)	σ (MM)	ELLIPSOIDAL HT (M)	σ (MM)
AUS064	-67 36' 17.15923"	0.0	62 52' 14.57667"	0.0	59.1460	0.0
RM1	-67 36' 17.95014"	0.3	62 52' 14.07892"	0.1	56.7805	0.1
RM2	-67 36' 17.53840"	0.1	62 52' 16.45655	0.3	58.6566	0.1
RM3	-67 36' 16.53206"	0.3	62 52' 13.27324"	0.0	55.6916	0.1

Table 7: 2000/01 Mawson RM Survey. Latitude, longitude and ellipsoidal height and associated one sigma uncertainty (mm) for the RM stations. GRS80 ellipsoid and ITRF2000@2000.00 co-ordinates adopted at AUS064 (MAW1)

SITE	LATITUDE (DMS)	σ (MM)	LONGITUDE (DMS)	σ (MM)	ELLIPSOIDAL HT (M)	σ (MM)
AUS099	-67 36' 17.15923"	0.0	62 52' 14.57667"	0.0	59.1460	0.0
RM1	-67 36' 17.95014"	0.4	62 52' 14.07901"	0.4	56.7786	0.2
RM2	-67 36' 17.53840"	0.4	62 52' 16.45657"	0.4	58.6551	0.2
RM3	-67 36' 16.53205"	0.5	62 52' 13.27321"	0.5	55.6890	0.2

Please note that the 2006/07 results were processed using SNAP, whereas the 2000/01 results were processed using GEOLAB. The programs utilise height observations differently. See Table 8 for a better understanding of the changes in height differences between the surveys. Table 8 shows orthometric height differences computed from the levelling survey between the ARGN pillar and RM's.

Table 8: Comparison of height differences between ARGN pillar and RMs for each survey from 1996 to 2006. Surveys performed by contracted Antarctic Division surveyors (1996), AUSLIG surveyors (2000) and Geoscience Australia surveyors (2006). All units are in metres.

AUS064 TO	1996	2000	2007
RM1	-2.3654	-2.3662	-2.3655
RM2	-0.4890	-0.4898	-0.4895
RM3	-3.4538	-3.4553	-3.4544

The results show very good agreement between the 2000/01 and 2006/07 surveys. Height differences agree at the 1mm level and horizontal positions are also similar. This indicates that there has been no significant vertical or horizontal deformation of the AUS064 station. It also highlights the need to take care when comparing the results between different surveys as different adjustment software packages have been utilised. For example, SNAP applies more weight to levelled height differences than GEOLAB does, thus the discrepancy in the ellipsoidal heights.

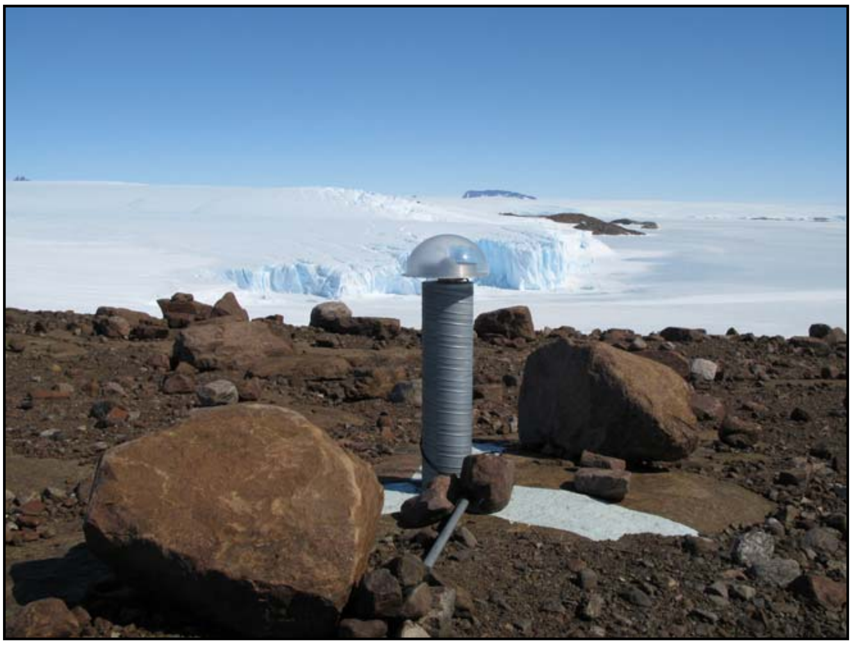


Figure 48: *Mawson Station ARGN monument AUS064 with GPS antenna attached*

Tide Gauge Levelling

Orthometric levelling is routinely carried out at each of the Australian Antarctic bases to determine the orthometric height of the tide gauge benchmarks, the ARGN station and its reference marks, and monitor any changes in height between these points.

Utilising the "leap frog" EDM heighting technique, differences in height between change points were determined from zenith angle and slope distance observations. This precise levelling method is similar to the common technique of precise spirit levelling; however, it allows longer sighting lengths, of as much as 50m, over steep terrain.

The equipment used for the levelling survey included a *Leica* TCA2003 total station on *Leica* tripod and a single fixed height stainless steel survey rod with bi-pole supports and a *Leica* precision prism. This prism pole was held over particular change points throughout the survey for back sight (BS) and fore sight (FS) observations. Efforts were made to pick up as many permanent survey marks during the survey run to check against previous survey results and update coordinate records for these points. At each instrument set-up, 5 rounds of face left (FL), face right (FR) observations were taken to the BS and FS.

The intention for the levelling surveys was to be within zero-order specifications. To ensure this was achieved, several criteria were followed, namely:

- Misclosure to comply with allowable maximum of $2\sqrt{d}$ (where d is the distance in kilometres between bench marks)
- Sighting lengths kept to a maximum of approximately 60m and BS/FS sights kept to approximately equal lengths;
- Temperature, pressure and humidity measurements were taken using a Kestrel weather watch throughout the level run at 30min intervals. These values were entered into the total station to apply corrections to the slope distances;
- Work conducted in calm weather conditions.

DAVIS

Alex Woods and Nick Brown of Geoscience Australia conducted the Davis station tide gauge levelling survey on the 6th of February 2007. Orthometric heights were derived with respect to NMV/S/4, which has a mean sea level (MSL) height of 2.179m. In accordance with good survey practice each survey mark was observed twice as the level run went from AUS099 down to the tide gauge benchmarks (AUS186 and NMV/S/4) and then back up to AUS099 to close the level loop. Survey marks along the route, namely D3 and D5, AUS303, the Met benchmark and additional stainless steel pin change points (SSPIN1, SSPIN2, SSPIN3), previously drilled into rock along the survey route (Figure 49), were also observed. After completing the level run in both directions, the final level misclosure was calculated as 0.00055m, well within zero-order specifications.

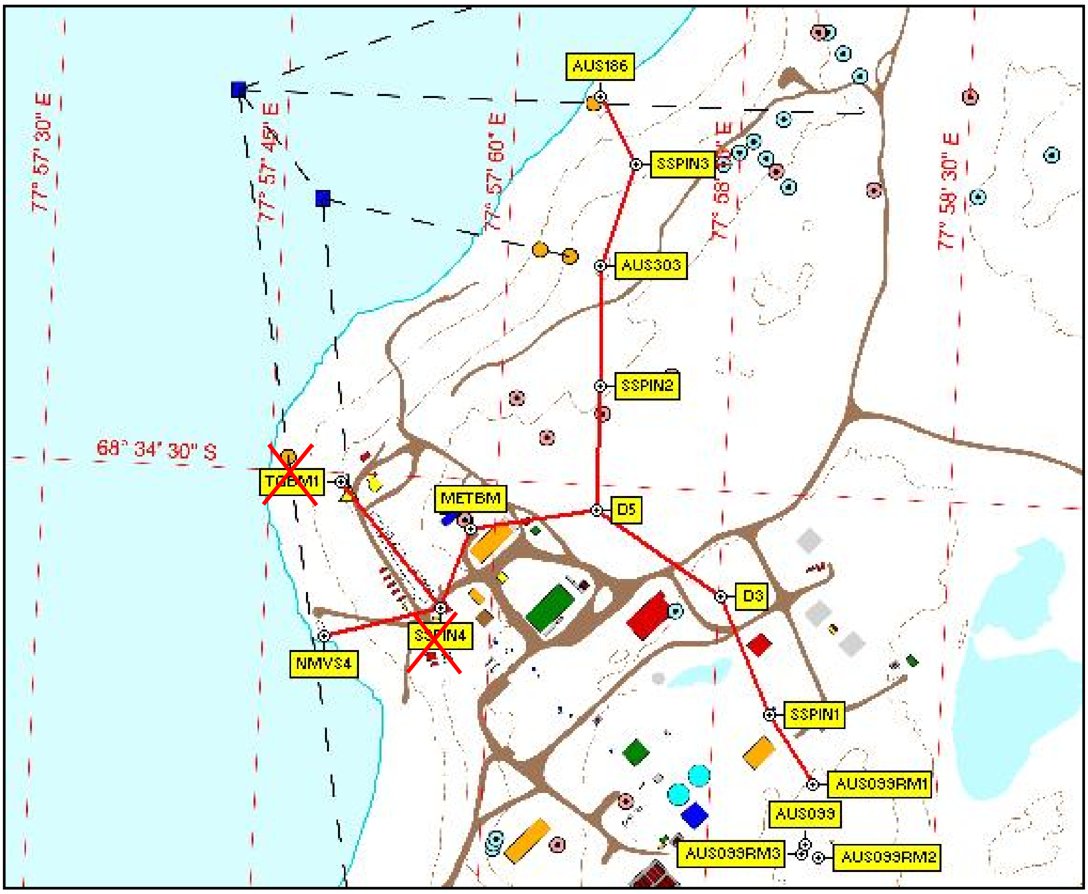


Figure 49: *Davis Station levelling route and location of survey marks observed*

The reduced levels obtained for the survey marks are shown in Table 9 along with a description of the location and approximate WGS84 latitude and longitude coordinates (obtained from a handheld GPS receiver). These coordinates are simply to assist with locating survey marks on plans and in the field.

Table 10 provides a comparison of the 2007 level survey results with levels obtained in past surveys. It should be noted that all heights shown in Table 9 and Table 10 are based on the 1983 MSL value of 2.179m for NMV/S/4 (Johnston, G. & Digney, P., 2001 AUSLIG Technical Report 5).

Table 9: Summary of survey marks connected to in 2007 levelling survey with a short location description, approximate WGS84 Latitude and Longitude coordinates (units are in DMS) and derived final Reduced Level (RL) with respect to NMV/S/4.

STATION	LOCATION DESCRIPTION	LATITUDE	LONGITUDE	RL (M)
AUS099	ARGN pillar	-68° 34' 38.3"	77° 58' 21.4"	27.8628
AUS099 RM1	Inside magnetic quiet zone	-68° 34' 36.9"	77° 58' 21.7"	25.5363
AUS099 RM2	Inside magnetic quiet zone	-68° 34' 38.7"	77° 58' 22.3"	27.4191
AUS099 RM3	Inside magnetic quiet zone	-68° 34' 38.6"	77° 58' 21.2"	26.9155
SSPIN1	Survey pin in rock b/w RM1 & D3	-68° 34' 35.3"	77° 58' 18.8"	22.4396
SSPIN2	Survey pin in rock b/w D5 & A303	-68° 34' 27.6"	77° 58' 07.1"	15.0104
SSPIN3	Survey pin in rock b/w A303 & A186	-68° 34' 22.3"	77° 58' 08.3"	8.4064
D3	40m NE of Workshop	-68° 34' 32.5"	77° 58' 14.8"	23.0803
D5	50m NE of Science Building	-68° 34' 30.5"	77° 58' 06.9"	19.9161
AUS186	TGBM	-68° 34' 20.7"	77° 58' 05.5"	4.7155
AUS303	On top of rise near shore	-68° 34' 24.6"	77° 58' 06.1"	15.4952
METBM	On slab of tower at Met building	-68° 34' 31.1"	77° 57' 58.4"	18.3956
NMV/S4	Next to Beach House	-68° 34' 34.0"	77° 57' 49.6"	2.1790

Note: Misclosure of 0.00055m from AUS099 to the tide gauge benchmarks and back.

Table 10: Comparison of Reduced Levels obtained for survey marks at Davis Station in 2007 with previous survey results. All heights in metres and relative to NMV/S/4

SURVEY MARK	1994/95	1996/97	1998/99	1999/2000	2000/01	2004/05	2006/07
AUS099	27.8659	27.8690		27.8680	27.8686	27.8637	27.8628
AUS099 RM1		25.5420			25.5415	25.5370	25.5363
AUS099 RM2		27.4250			27.4245	27.4202	27.4191
AUS099 RM3		26.9210			26.9206	26.9163	26.9155
SSPIN1							22.4396
SSPIN2							15.0104
SSPIN3							8.4064
D3		23.0880	23.1010	23.0870	23.0843	23.0810	23.0803
D5		19.9220			19.9195	19.9161	19.9161
AUS186	4.7140	4.7320	4.7200	4.7202	4.7202	4.7151	4.7155
AUS303			15.5080	15.5000	15.4995	15.4953	15.4952
METBM	18.4000	18.3994			18.4013	18.3957	18.3956
NMV/S4	2.1790	2.1790	2.1790		2.1790	2.1790	2.1790

Note: 2000/01, 2004/05 and 2006/07 results obtained using EDM heighting technique while all previous years results obtained using precise spirit levelling.

There is very little difference between the 2004/05 and 2006/07 surveys, with the largest discrepancy being no more than 1.1mm. Nevertheless, the consistent 5mm offset between the 2000/01 and 2004/05, 2006/07 results indicates that there may be an error in the 2000/01 data reductions or that NMV/S/4 has been disturbed. There were no visible signs of disturbance to NMV/S/4 at the time of survey.

Furthermore, two survey marks observed in previous year surveys (SSPIN4 and TGBM1) were not measured in the 2006/07 level survey as they could not be located. It is believed that these points have been disturbed by recent construction work on station or simply lack of appropriate position information prevented them from being located.

MAWSON

Alex Woods of Geoscience Australia conducted the Mawson station tide gauge levelling survey on 29 – 30th of December with the assistance of Jo Melick, the station doctor, following the route shown in Figure 50.

Orthometric heights were derived with respect to ISTS051, which has a MSL height of 9.792m. In accordance with good survey practice, each survey mark was observed twice as the level run went from the GPS station (AUS064) down to the tide gauge benchmarks (AUS258, AUS300, AUS301, AUS267 and AUS268) and back to AUS064 to close the level loop. Reduced levels were also obtained for Pageos mark (ISTS051 and ISTS051 RM2), NMV/S/1, AUS251 and a survey mark nail found in the concrete bridge opposite the green store. After completing the level run in both directions, the final misclosure calculated as 0.00135m, was well within zero-order specifications. The levels determined for these survey marks are shown in Table 11 along with a description of the location and approximate WGS84 latitude and longitude coordinates (obtained from a handheld GPS receiver). These coordinates are provided to assist with locating survey marks on plans and in the field.

Table 12 provides a comparison of the 2006 level survey results with levels obtained in past surveys. It should be noted that all heights shown in Table 11 and Table 12 are based on the MSL value of 9.792m for ISTS051 derived from levelling completed in 1996 by T. W. Gordon "Antarctic Mapping Program Field Work report 1995-96 Summer Season" (AUSLIG report for Antarctic Division).

Table 11: Summary of survey marks connected to in 2006 levelling survey with a short location description, approximate WGS84 Latitude and Longitude coordinates (units are in DMS) and derived final Reduced Level (RL) with respect to ISTS051 (9.792m)

STATION	LOCATION DESCRIPTION	LATITUDE	LONGITUDE	RL (M)
AUS064	ARGN pillar	-67° 36' 17.2"	62° 52' 14.6"	32.4441
RM1	Near Cosray Building	-67° 36' 18.0"	62° 52' 14.1"	30.0786
RM2	Near Cosray Building	-67° 36' 17.5"	62° 52' 16.5"	31.9547
RM3	Near Cosray Building	-67° 36' 16.5"	62° 52' 13.3"	28.9897
NMV/S/1	Near ANARESAT radome	-67° 36' 14.0"	62° 52' 19.2"	15.5673
AUS251	Next to Smokers hut	-67° 36' 11.1"	62° 52' 29.5"	18.1385
AUS267	Alongside tide gauge box	-67° 36' 08.9"	62° 52' 50.3"	2.8755
AUS268	Alongside tide gauge box	-67° 36' 10.2"	62° 52' 51.0"	3.5365
NAIL	Opposite green store	-67° 36' 08.4"	62° 52' 22.6"	13.4230
ISTS051	Near balloon building	-67° 36' 04.8"	62° 52' 24.1"	9.7920
051 RM2	Near balloon building	-67° 36' 05.0"	62° 52' 25.6"	11.6833
AUS300	Near incinerator	-67° 36' 01.7"	62° 52' 20.6"	2.1312
AUS258	Next to Hangar	-67° 36' 00.6"	62° 52' 22.8"	1.4098
AUS301	60m North of Hangar	-67° 35' 57.6"	62° 52' 21.0"	1.8342

Note: Misclosure of 0.0014m from AUS064 to the tide gauge benchmarks and back.

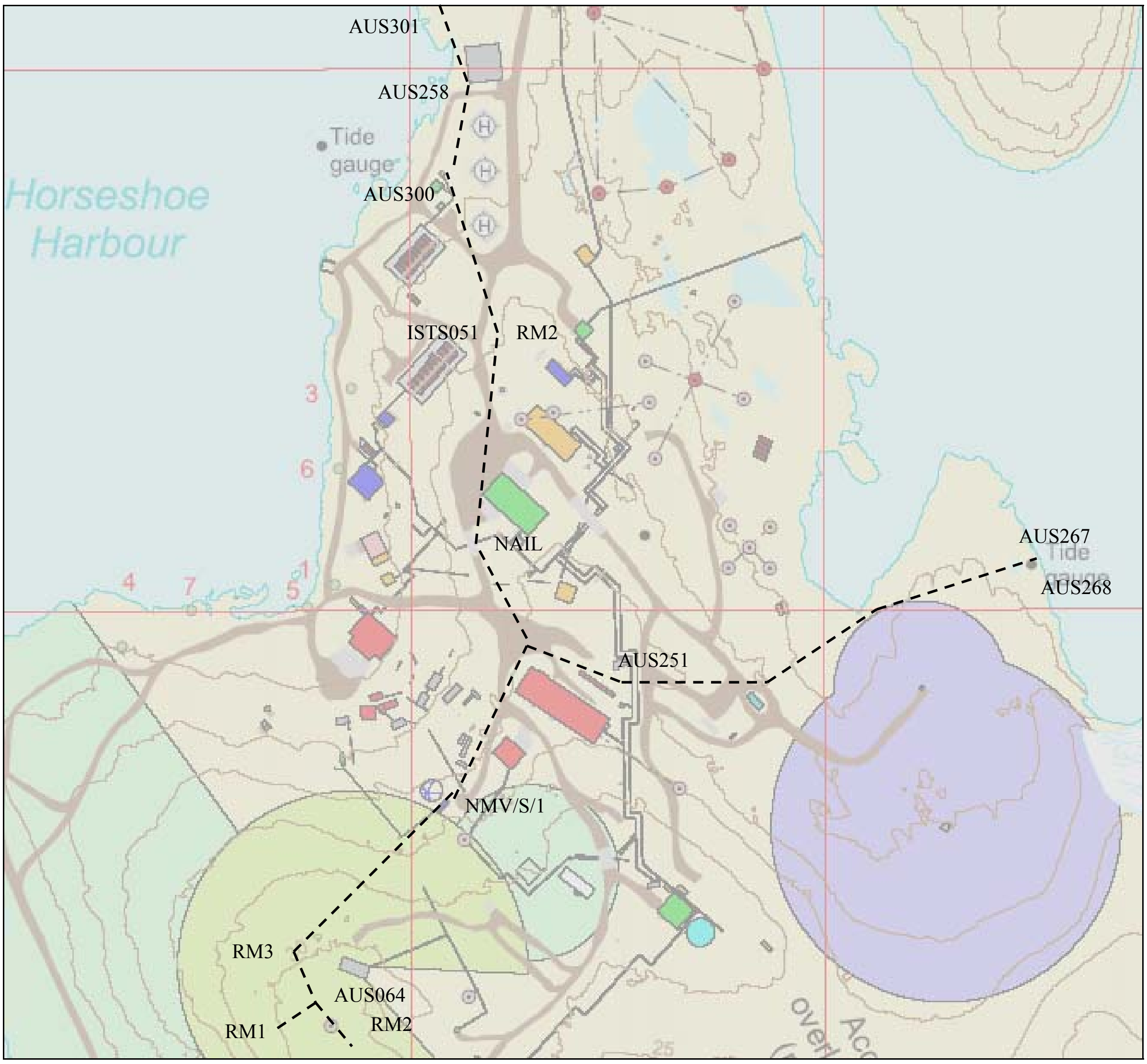


Figure 50: *Mawson Station levelling route and location of survey marks observed*

Table 12: Comparison of Reduced Levels obtained for survey marks at Mawson Station in 2006 with previous survey results. All heights are in metres and relative to ISTS051

SURVEY MARK	1995/96	1996/97	1997/98	1998/99	2000/01	2006/07
ISTS051	9.792	9.792	-	-	9.792	9.7920
ISTS051 RM2	11.686	11.684	-	11.677	-	11.6833
AUS064	32.449	32.449	32.449	-	32.4458	32.4441
AUS064 RM1	-	30.084	-	30.058	30.0792	30.0786
AUS064 RM2	31.959	31.960	31.956	31.956	31.9557	31.9547
AUS064 RM3	-	28.995	28.993	28.990	28.9905	28.9897
AUS300	-	-	2.148	2.122	2.1328	2.1312
AUS301	-	-	1.850	-	1.8351	1.8342
AUS258	1.413	1.414	1.427	1.400	1.4108	1.4098
NMV/S/1	-	-	-	-	-	15.5673
AUS251	-	-	-	-	-	18.1385
AUS267	-	-	-	-	-	2.8755
AUS268	-	-	-	-	-	3.5365

Note: 2000/01 and 2006/07 results obtained using EDM heighting technique while all previous years results obtained using precise spirit levelling.

The misclosure of 0.0014m is very good. This is most likely due to an accumulation of random errors and indicates that no gross errors were made during the survey. It should be noted that there is consistent difference of approximately 1mm between the 2000/01 and 2006/07 results.

Tide Gauge Benchmark GPS Survey

GPS data was collected over the tide gauge bench marks (TGBM) at Davis station, Mawson station and Law base in the Larsemann Hills.

Tide gauge benchmarks (TGBM) are used to assist in the monitoring of changes in sea level with respect to the land. Observations from a tide gauge provide evidence of relative sea level changes. However, tide gauge observations alone do not distinguish whether the sea level is rising or the surrounding land is subsiding / rebounding.

Absolute changes in sea level rise can be estimated with the assistance of GPS data collected over a TGBM. By monitoring the changes in absolute position, most importantly, height of the TGBM, it is possible to distinguish between land movement and sea level rise.

For example, if a tide gauge shows that the sea level is rising by 1cm every ten years, a survey can be performed on the TGBM to see if it is experiencing the same change. If the TGBM indicates no change, then the rising sea level is confirmed. However, if the land is found to be subsiding, this may suggest no change in the sea level.

DAVIS

GPS antenna and receiver units were set-up over tide gauge benchmarks (TGBM) NMV/S/4 and AUS186 at Davis station from the 9th to 12th of February 2007. Tripods were levelled over the survey marks using a *Leica* precision level mount with optical plummet. An adjustable *Ashtech* turning mount was then inserted into the tribrach and used to orientate the antenna to true North (79 degrees magnetic). Slant heights were measured from the benchmark to the bottom of the choke ring antenna (three observations were taken around each antenna). The vertical offset of the TGBM was initially set to zero in the receiver metadata file and it was updated with the slant height before data processing.

Each GPS receiver was set-up to record 24-hour sessions with 30-second epochs and an elevation mask of zero degrees. Throughout the length of the survey, the equipment was checked daily to ensure there was no change in level or the antenna height and that the batteries were holding their charge from the solar panels. At the end of the survey the data was downloaded from the GPS receiver and processed through AUSPOS.

Data from these tide gauge benchmarks have been collected for a number of years now and in the near future these data will be processed using *BERNESE* to determine a more accurate position and the site velocity.

Site: NMV/S/4 (next to beach house)
Slant height: 1.286m
Receiver: *Ashtech* UZCGRS (s/n: UC2200302005)
Antenna: *Leica* AT504 (art no: 667132) (s/n: 103316)
Start time: 05.05 UTC, Day 040 (Local 12.05pm, 09/02/2007)
End Time: 04.05 UTC, Day 043 (Local 11.05am, 12/02/2007)

Table 13: AUSPOS results for NMV4. From AUSPOS Jobs #50802

SITE	LATITUDE (DMS)	LONGITUDE (DMS)	ELLIPSOIDAL HT (M)	ABOVE GEOID HT (M)
NMV4	-68°34’33.9234” (0.001m)	77°57’48.9686” (0.002m)	18.703 (0.006m)	1.049

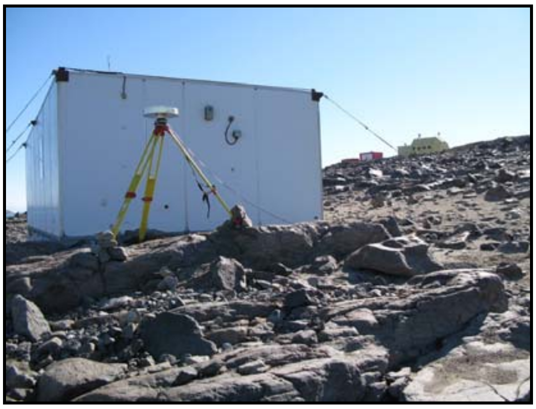


Figure 51*: Davis, GPS unit over NMV/S/4 alongside beach house, view North*

Site: AUS186 (Northern TGBM)
Slant height: 1.400m
Receiver: *Ashtech* Z-Ref Station (s/n: ZR520013902)
Antenna: *Leica* AT504 (art no: 667132) (s/n: 103318)
Start time: 04.18 UTC, Day 040 (Local 11.18am, 09/02/2007)
End Time: 03.30 UTC, Day 043 (Local 10.30am, 12/02/2007)

Table 14: AUSPOS results for AUS186. From AUSPOS Jobs #50801

SITE	LATITUDE (DMS)	LONGITUDE (DMS)	ELLIPSOIDAL HT (M)	ABOVE GEOID HT (M)
A186	-68°34’20.6002” (0.001m)	77°58’05.6297” (0.001m)	21.254 (0.004m)	3.591

Figure 52*: Davis, GPS unit over AUS186, view North*

MAWSON

From the 22nd to 25th of December 2006 a GPS survey of TGBM AUS258 and the water level adjacent to a tide gauge was conducted using *Trimble* 5700 GPS receivers available at the station. *Trimble* GPS ground plane antennas (*Trimbl*e model 41249-00) mounted on tripods were set-up over the TGBM (AUS258) and on the sea ice directly over a hole next to the tide gauge (Figure 53). Note: To access the water level at the tide gauge a hole was drilled through the sea-ice, using a Jiffy ice drill.

To capture a full tidal cycle the sea-ice station was intended to record for 36 hours at a rate of 1 second, however, it was noticed that the receiver at the tide gauge water level shut down for a few hours sometime during the survey, thus the survey was restarted, resulting in the collection of more data.

To prevent the hole from freezing over it was monitored at regular intervals and cleared of newly formed slush ice. The height of the antenna above water level was measured every 6-8 hours using a measuring rod. A large degree of variation in antenna height above water level was noticed during the survey. In addition, the tribrach on the tripod progressively moved out of level as the tripod legs sunk during the survey. Although every effort was made to ensure the stability of the tripod (tripod legs were buried into the ice), the deteriorating nature of the ice, as the sea ice was melting, meant that the tripod and thus antenna definitely moved during the survey. Thus, this survey was deemed insufficient for the intended purpose. However, the data collected over TGBM AUS258 during this survey was considered fine and was used to determine the position and ellipsoidal height of TGBM AUS258.

Site: TGWL (Tide gauge water level through sea ice), adjacent to tide gauge
Slant height: 1.048m – 0.986m (LARGE VARIATION)
Receiver: *Trimble* 5700 (s/n: 0220340467)
Antenna: *Trimble* Ground Plane (p/n: 41249-00) (s/n: 12572753)
Survey aborted

Figure 53: Mawson, *the sea-ice GPS station at the Mawson tide gauge, December 2006. Photo looking north.*

Site: AUS258 (TGBM, between helipad and old hangar)
Slant height: 1.416m
Orientation: True North (66 degrees magnetic)
Levelled over punch mark in bolt using tribrach and optical sight
Receiver: *Trimble* 5700 (s/n: 0220324679)
Antenna: *Trimble* Ground Plane (p/n: 41249-00) (s/n: 12612090)
File Name: 46793562.t01
Start time: 04.05 UTC, Day 356 (Local 10.05am, 22/12/2006)
End Time: 06.00 UTC, Day 359 (Local 12.00, 25/12/2006)

Table 15: AUSPOS results for AUS258. From AUSPOS Jobs #50805

SITE	LATITUDE (DMS)	LONGITUDE (DMS)	ELLIPSOIDAL HT (M)	ABOVE GEOID HT (M)
A258	-67°36'00.5468" (0.170m)	62°52'22.7085" (1.019m)	28.350 (0.478m)	-0.889

Note the large uncertainties in these results. Given that poor results were also obtained from the survey performed by Kym Newbery on the 19 – 21 Nov 2006 (Table 16), the error may be caused by the antenna.


Figure 54 and 55: *Left: Mawson, antenna close up, Right: View south*

Although the above-mentioned GPS survey was unsatisfactory due to the sinking of the tripod during the survey, Kym Newbery, in the exact same fashion conducted a survey in November 2006 when the sea ice was more stable and this data could be used to calibrate the tide gauge. During the survey, survey control was provided by the GPS base station setup over the TGBM (AUS258). The reduced level of AUS258 was determined in a high-precision levelling survey conducted from the permanent Mawson ARGN GPS station (AUS064) to AUS258 in late December 2006. Additional survey control can be derived from the permanent ARGN GPS station (AUS064).

Data Files Supplied by Kym Newbery

04673232.dat – data collected over tide gauge benchmark AUS258
46793231.dat – data collected over hole in sea ice

Kym observed the slant heights during the survey and noted them in an Excel spreadsheet. The antenna set-up over AUS258 (Figure 54) (Table 15) had the same slant height at the beginning and end of the survey (1.534m). For the antenna set-up over the sea ice (Figure 57), a rise and fall of the water level relative to the antenna was seen throughout the survey (Table 16).

Table 16: Slant heights measured at the GPS antenna set-up over the sea ice (units in m)

DATE/TIME (UTC)	SLANT HEIGHT 1	SLANT HEIGHT 2	SLANT HEIGHT 3
19/11/2006 9:30	1.166	1.180	1.176
19/11/2006 12:00	1.178	1.184	1.188
19/11/2006 18:00	1.186	1.187	1.193
20/11/2006 2:00	1.178	1.178	1.176
20/11/2006 7:00	1.158	1.158	1.164
20/11/2006 12:00	1.168	1.168	1.169
20/11/2006 17:00	1.182	1.180	1.184
21/11/2006 2:00	1.170	1.170	1.168
21/11/2006 8:30	1.148	1.150	1.152

Figure 56 and 57: *Left: Mawson, GPS over AUS258, view west, Right: GPS over sea ice, view east*

Kym found that the antenna / tribrach connection was loose when setting up the GPS antenna over the sea ice, therefore, he attempted to hold the antenna in place by securing it to the tribrach and tripod with a pink band (shown in Figure 57).

All available data will be supplied to the AAD mapping group, including GPS log sheets which have been prepared to accompany the *Trimble* .dat files, pictures from the survey and the Excel spreadsheet of variation in antenna height above water level.

Table 17: AUSPOS results for AUS258. From AUSPOS Jobs #50806

SITE	LATITUDE (DMS)	LONGITUDE (DMS)	ELLIPSOIDAL HEIGHT (M)	ABOVE-GEOID HIGHT (M)
A258	-67°36’00.5431” (0.746m)	62°52’22.6766” (1.796m)	27.433 (0.936m)	-1.806

Obviously, there was a significant problem with the Mawson GPS surveys over the sea ice, with the tripods sinking, and over the TGBM (AUS258). The repeated problems in the two surveys indicate that an alternative water level determination technique over the tide gauge be adopted. Perhaps, simple levelling between the TGBM and a hole in the ice could be undertaken over a 24 hour to 36 hour period, with observations taken every hour and at 15min intervals around high and low tide times. This would be more laborious, but would ensure accurate results. The large standard errors noted in the derived coordinate position estimates for AUS258 are hard to explain. There were no signs of disturbance to the equipment during the surveys, with antenna heights and level remaining constant throughout. It is possible that the antenna has been damaged or that the wrong settings were entered into the GPS receiver.

LARSEMANN HILLS

GPS antenna and receiver units were set-up over the GPS survey mark and tide gauge bench mark (TGBM) at Law Base in the Larsemann Hills from the 17th to 24th of February 2007. NMV/S/278 is a survey plate with 5/8" spigot mounted in concrete about 100m south of Reid Hut at Law Base (Figures 58 and 59) and TGBM AUS334 is a bolt in rock, with a centre punch mark, located adjacent to the tide gauge in Nella Fjord, about 1km north of Law Base (Figures 60, 61 and 62).

Note AUS334 is next to another survey plaque named GPS1011.

A GPS antenna was screwed directly onto the survey plate at NMV/S/278. It was noted that the antenna orientation was 65 degrees (magnetic bearing), which equates to a true bearing of 348 degrees when the magnetic declination quoted for the area of 77 degrees is applied.

TGBM AUS334 was observed using a *Leica* antenna on a tripod levelled and directed over the TGBM using a *Leica* precision level mount with optical plummet. An adjustable *Ashtech* turning mount was inserted into the tribrach and used to orientate the antenna to 65 degrees magnetic (the same orientation as the other antenna on NMV/S/278). The slant height of the antenna was measured from the benchmark pin to the base of the choke ring antenna (three observations were taken around the antenna).

For each GPS set-up the vertical offset was initially set to zero in the receiver and will be updated for AUS334 with the corrected slant height before data processing. Each GPS receiver was set-up to record 24-hour sessions at 30-second epochs and an elevation mask of zero degrees.

The GPS equipment was left at Law base to record data for a full week. Solar panels were connected to the batteries to ensure the batteries remained charged throughout the survey. At the end of the survey the antenna heights were remeasured to ensure they were undisturbed and the data was downloaded from the GPS receivers.

Site: NMV/S/278 (100m South of Reid Hut, Law Base)
Name entered in receiver: LAW1
Vertical offset: 0.000m (antenna screwed directly onto survey plate)
Receiver: *Ashtech* Z-Ref Station (s/n: ZR520012902)
Antenna: *Leica* AT504 (art no: 667132) (s/n: 103318)
Start time: 04.02 UTC, Day 048 (Local 11.02am, 17/02/2007)
End Time: 03.40 UTC, Day 055 (Local 10.40am, 24/02/2007)

Table 18: AUSPOS results for NMV278. From AUSPOS Jobs #50804

SITE	LATITUDE (DMS)	LONGITUDE (DMS)	ELLIPSOIDAL HEIGHT (M)	ABOVE-GEOID HIGHT (M)
NMV278	-69°23'21.1799" (0.002m)	76°22'50.7602" (0.002m)	80.064 (0.005m)	63.819

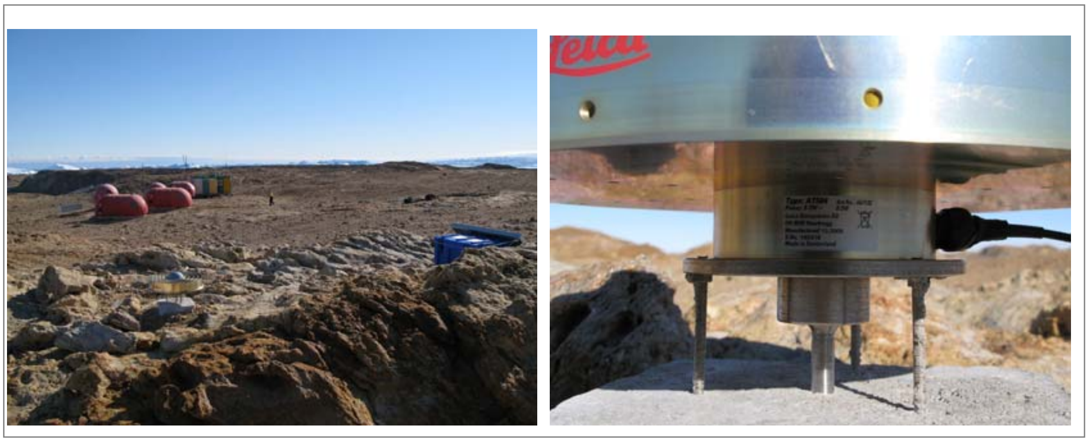


Figure 58 and 59: *Left: Larsemann Hills, NMV/S/278, view north, Right: NMV/S/278 Survey plate*

Site: AUS334 (TGBM located adjacent to tide gauge at Nella Fjord, 800m North of Law Base)
Name entered in receiver: LAW2
Slant height: 1.027m
Receiver: *Ashtech* UZ CGRS (s/n: UC2200302005)
Antenna: *Leica* AT504 (art no: 667132) (s/n: 103316)
Start time: 05.52 UTC, Day 048 (Local 12.52pm, 17/02/2007)
End Time: 03.15 UTC, Day 055 (Local 10.15am, 24/02/2007)

Table 19: AUSPOS results for AUS334. From AUSPOS Jobs #50803

SITE	LATITUDE (DMS)	LONGITUDE (DMS)	ELLIPSOIDAL HEIGHT (M)	ABOVE-GEOID HIGHT (M)
AUS334	-69°23'01.1698" (0.002m)	76°22'20.6097" (0.003m)	17.140 (0.005m)	0.902

Figure 60 and 61: *Left: Larsemann Hills, AUS334, view north, Right: Tripod mount*

Figure 62: *AUS334 survey mark*

Syowa Local Tie Survey Reconnaissance and Proposed Local Tie Survey Methodology

Personnel

Dr Sawagaki - VLBI Operator from Hokkaido University (JARE-47)
Mr Ishii – Antenna Technician from NEC (JARE-47)
Mr Sugawara – Antenna Technician from NEC (JARE-48)
Prof. Kamiyama – Station Leader (JARE-47)
Dr H. Miyaoka – Station Leader (JARE-48)
Dr Hirasawa – S-17 Station Leader

Location

Syowa Station is located just off the coast of the Antarctic mainland on East Ongul Island in Lutzow-Holm Bay, Ongul Straight. The Japanese travel to Antarctica in a ship operated by the Japanese navy to resupply the station and change over expeditioners for the season. The ship normally waits in harbour for a month or so during the resupply operations. There is also a landing strip on the mainland ice sheet, 30km away from Syowa, with an air camp called S-17. A team of four operate this small station undertaking meteorological observation work and air support. The Japanese are considering closing down S-17 next year as they do not expect to use the runway once they finish their work with the Germans. This may cause a problem for Australians wishing to travel to Syowa.

Introduction

There is a need to precisely measure and express the local terrestrial connection between the complimentary space geodetic observation systems, that is, GPS, GLONASS, SLR, VLBI and DORIS, at co-located geodetic observatories. On the 5th and 6th of January 2007 Alex Woods, a geodetic surveyor from Geoscience Australia, visited Syowa station, to undertake a reconnaissance survey of the Syowa VLBI antenna. The primary focus of the survey was to determine whether, or not, the local tie survey technique adopted in Australia could be applied to the VLBI antenna housed within a protective dome, at Syowa station.

The distinguishing feature of the Australian technique is that the invariant reference point (IVP) of large space observing instruments, such as VLBI antennas or SLR telescopes, is observed indirectly. Indirect IVP determination involves classical geodetic observations to prisms placed on the structure as the structure is moved through several rotational sequences. The targets scribe a number of perfect circular arcs as target rotating on a rigid body; rotating about one independent axis can be fully expressed as a circle in three-dimensional space. A method based on three-dimensional circle fitting is applied as the basis for the IVP determination. All target coordinates and their variance-covariance information are passed through a rigorous, geodetic, least squares (minimum constraint) adjustment and then an IVP modelling and estimation procedure is performed, in which a number of geometrical constraints are applied. This process allows the characteristics of the rotational axes, which importantly include their position and orientation in an arbitrary local geodetic datum, and the position of the invariant reference point to be estimated. The adjusted terrestrial network, computer IVP coordinates and variance-covariance matrix are then transformed into a global reference frame before the final solution, for points of interest, is output in SINEX file format. This approach has routinely produced local terrestrial connections between co-located geodetic observing systems to an accuracy of 1mm. It is not intended that this report detail the methodology for indirectly observing the IVP of large space observing systems. For more information on the invariant reference point determination technique adopted in Australia please refer to the report prepared by the geodesy group at Geoscience Australia *The Determination of Telescope and Antenna Invariant Point* (Dawson et al, 2004). This report will outline the findings from the 2007 reconnaissance survey at Syowa station and describe the proposed methodology for a local tie survey of the Syowa VLBI antenna.

Syowa VLBI Antenna

The Syowa Station VLBI antenna was built in 1989 and is approximately 12-13m in height, with an 11m-diameter dish (Figure 63). The antenna operates as an azimuth/elevation system housed within a dome structure (Figure 64). The approximate distance from the centre of the antenna support to the edge of the dome is 7.5m and the moving structural aspects of the antenna are approximately 6.6m from the dome wall. This would allow an approximate set back distance of 6m to observe targets on the structure as it is moved through several rotational sequences. In addition, the approximate height of the base of the moving structural components of the antenna is 4m above the ground. This would lead to quite steep vertical angle observations to targets on the antenna. The antenna can move through 360 degrees in azimuth, fixed in an elevation setting from zero to 90 degrees. However, the antenna can only rotate from zero to 90 degrees in elevation. This will impede the IVP determination technique, as only quarter arcs will be observed for elevation rotations, reducing the reliability of axis determination.

Figure 63 and 64: *Left: Syowa VLBI antenna, Right: Syowa VLBI dome*

An important aspect of the IVP determination technique is that while the antenna is being moved through a particular axis rotational sequence it must remain fixed in the opposing axis orientation setting. This ensures that targets scribe a circular arc, which is assumed in the software developed for the IVP derivation process. The antenna technicians at Syowa believe that the antenna would stay fixed in one axis orientation setting (say 90 degrees elevation) while being rotated through the full degree of movement in the opposing axis (say 360 degrees of azimuth). However, they were not certain of the stability of the antenna and, that it would not change its orientation slightly. The stability of the antenna, in this regard, will need to be clarified.

A geodetic survey station (No. 30-24 JARE 1989) was identified 21m from the only dome entrance on the north west side of the dome. This survey mark supports a direct line of sight into the dome as well as to each of the two GPS antennae located approximately 120m from the dome to the south west (Figure 65). It is anticipated that orientation for the survey will be provided from observations between these two GPS monuments. Connection to an appropriate vertical datum at Syowa can be made by precise levelling observations from a well-defined survey benchmark specified by the Japanese National Institute of Polar Research (NIPR).

Figure 65: *Syowa VLBI dome and GPS antennae, view north east*

GPS

The two GPS geodetic survey antennas located at Syowa station were identified and observed to be approximately 20m apart. The primary GPS is positioned on a specially designed antenna mount approximately 1.5m in height with a snow dome cover (Figure 66). There is a geodetic station survey plate along side the GPS antenna/monument named No. 46-01 JARE 2004. The other GPS antenna belongs to the Japanese NIPR and has been at Syowa for approximately 6 – 7 years. The antenna is labelled JNS RegAnt (s/n: 00124). This antenna is mounted on a tribrach connected to the ground and is housed within a snow dome (Figure 67). Further investigations will need to be made to find out more about the GPS antennas. The secondary GPS antenna is permitted to be removed. It is uncertain whether the primary GPS antenna may be removed to allow survey equipment to be setup over the pillar. The degree of disturbance permitted at these GPS monuments needs to be clarified.

Figure 66: *Primary GPS antenna, monument and survey bench mark on ground*

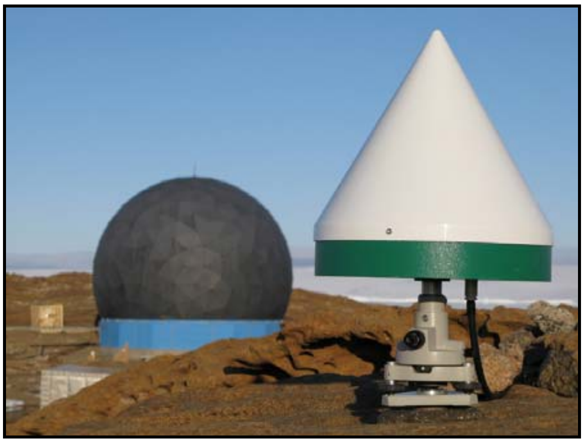


Figure 67: *Secondary GPS antenna on tribrach connected to ground monument*

Past VLBI Local Tie Survey

It seems the Japanese have attempted to survey the VLBI reference point directly by making observations to a target on a specially made rod which is fitted onto the VLBI at the approximate location of the mechanical centre of the telescope. They were not confident of the accuracy of this survey method. Diagrams were provided showing the positioning of the target and rod mount.

Proposed VLBI Local Tie Survey Methodology

The first stage in undertaking a local tie survey of the Syowa VLBI antenna will involve the establishment of a terrestrial network from which to make observations to targets on the VLBI structure. A connection will need to be made to the GPS antenna survey marks approximately 120m from the VLBI dome and the geodetic survey mark (No. 30-24 JARE 1989) located 21m from the dome entrance (Figure 68 and Figure 69). A connection can be made either through direct observation of the survey monuments at the GPS stations, by removing the GPS antennas and placing survey equipment (total station, prisms on tribrachs) over the marks or by making observations to the GPS antennae and determining the position of the survey mark through an indirect approach. This will require the removal of the GPS snow domes at a minimum. Alternatively a GPS baseline could be established between survey mark No.30-24 and one of the permanent GPS stations by collecting GPS observations over the survey mark during the local tie survey. Any of these methods will introduce the horizontal orientation for the survey.

Figure 68: *Entry in VLBI dome and geodetic survey mark (No. 30-24), view South East*

Figure 69: *Geodetic survey mark (No. 30-24)*

Connection to an appropriate vertical datum at Syowa can be established by precise levelling using an EDM-heighting technique, commonly used by Geoscience Australia, from either the GPS antenna monuments or from observations to a well defined survey benchmark specified by the Japanese NIPR. For Example, the survey bench mark at the base of the primary antenna (No. 46-01 JARE 2004), or by levelling from the tide gauge bench mark. Specific positions on the survey marks where heights relate to will need to be clarified by the Japanese as survey marks were noted to have a depression at the centre of the plate which made the reference height slightly ambiguous (top of plate or bottom of depression).

Once an orientation datum has been established and height has been transferred to survey mark No.30-24 a survey mark should be established inside the VLBI dome by direct observation through the entrance. The survey mark will need to be approximately 3m inside the entry way as there is a 2.5m long step inside the dome from the entrance, which is unstable. A survey pin can be driven into the concrete slab floor of the dome. From this instrument station four additional survey marks can be established around the antenna, approximately 1m from the edge of the dome wall, allowing space for the tripod, instruments and operator while also providing the longest possible set back distance (approximately 6m) between the survey instrument and targets. These four survey marks will serve as the instrument stations from which to make observations to targets on the antenna. The four instrument stations should overcome the restricted visibility onto the structure caused by the enclosed conditions of the dome and will support observation to targets as they move through the azimuth rotational sequence. The instrument stations will also be used to observe targets during the elevation rotational sequences. A number of observations will need to be made between these survey marks to establish a strong network and provide accurate position and height information for these points. A rudimentary diagram of the proposed survey mark network and the connections required between survey marks is provided in Figure 70.

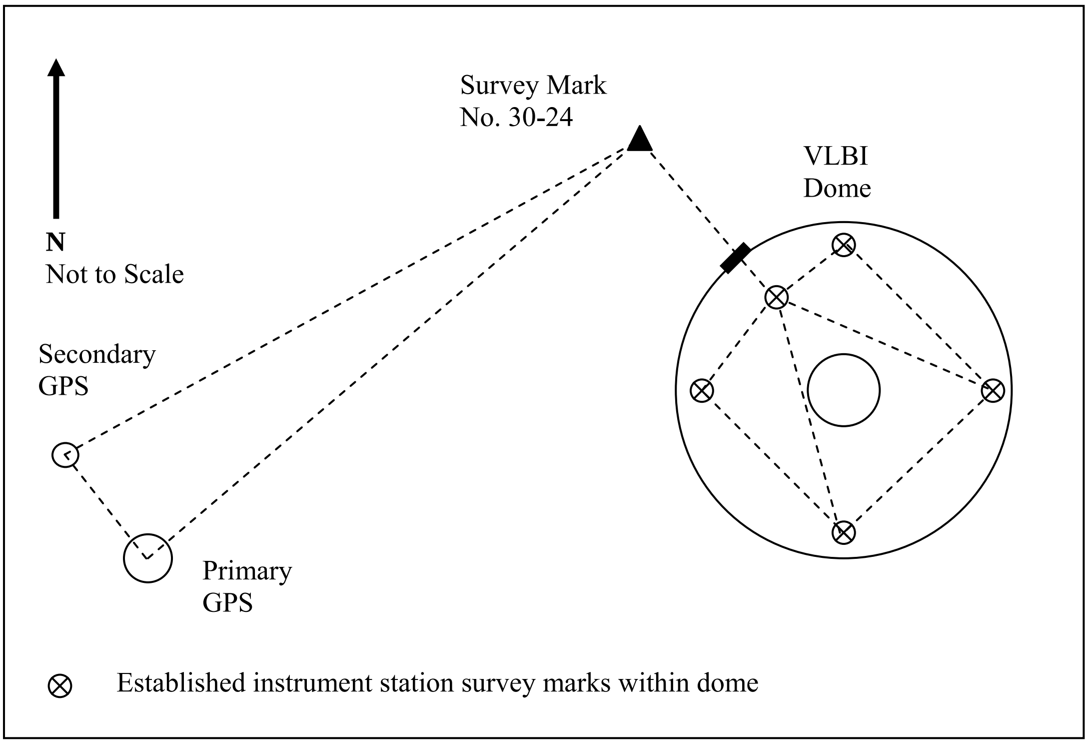


Figure 70: *Intended survey mark network for local tie survey (crude illustration)*

The next stage will involve observations to a minimum of four targets positioned on the antenna structure. Micro-prism targets will be attached using magnetic target mounts and placed on parts of the structure, which move with the antenna (antenna structural supports, etc, as shown in Figure 71). When making observations to targets a survey assistant will be required to rotate targets so they point directly at the total station operator, for each change in antenna orientation. A ladder or scaffold support could be used to access targets without the need to climb onto the structure. Effort will be made to keep the targets at a low height to reduce the severity of the vertical angles and make it easier for an assistant to redirect the targets toward the instrument operator.

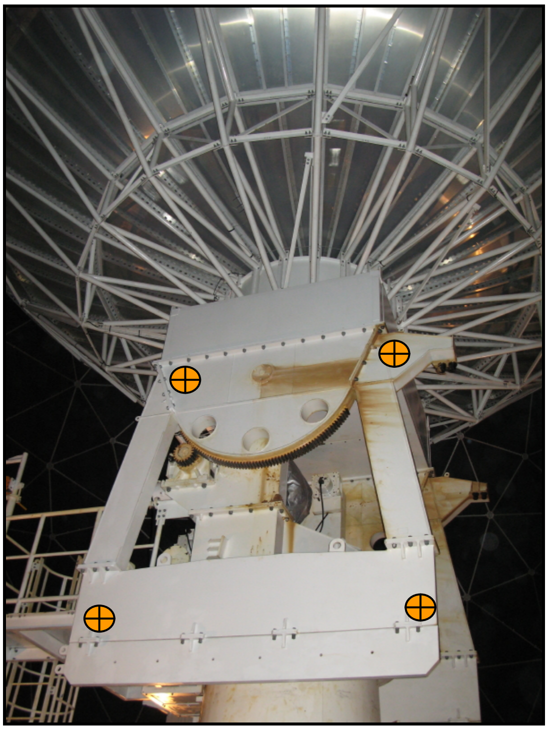


Figure 71: *Potential locations for prism targets on structure*

During rotational sequences the antenna orientation will need to be moved in small incremental steps of 10-20 degrees. Incremental shifts or antenna movement operations will be conducted from the VLBI control room located in a nearby science building. Direct communication to the control room will need to be maintained throughout the survey.

Observations will be made to the targets as the VLBI antenna is moved through vertical orientations and while it is fixed in specific azimuth orientation settings, namely an azimuth orientation orthogonal to the instrument operator's direct line of sight (Figure 72). Observations will be made to the targets from one instrument station at a time and it would be preferable to have observation sets, of changes in vertical orientation, from three positions. During an observation procedure the VLBI antenna will be fixed in an azimuth setting and initially set at an elevation orientation of zero degrees (Figure 73). The general observation procedure will involve the survey total station being setup over one of the established instrument station survey marks, a single round of face left, face right observations will then be made to each of the targets on the antenna structure with additional backsight observations made to two of the other survey marks around the antenna. The antenna will then be moved to an elevation orientation of ten degrees and the observation procedure will be repeated. The antenna will progressively be moved through ten degree increments with observations taken at each setting (Figure 74) until the antenna is pointing at the maximum elevation setting of 90 degrees. This entire measurement procedure should then be repeated from at least two more observation stations.

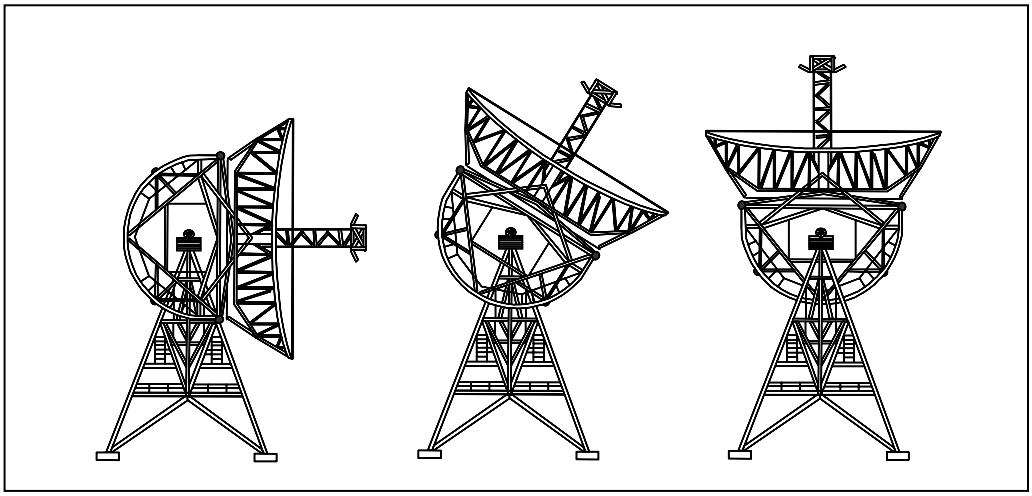


Figure 72: *Changes in vertical orientation of the VLBI antenna*

Figure 73 and 74: *Changes in antenna vertical orientation while fixed in azimuth*

Observations will then be made to targets on the VLBI antenna as it is moved through azimuth orientations and while it is fixed in a vertical orientation (90 degrees). Observations will be made to at least four targets from each of the four instrument stations around the antenna. The VLBI will be fixed in a vertical orientation setting and set at an azimuth orientation of zero degrees. The total station will be setup over one of the instrument station survey marks and a round of face left, face right observations will be made to each of the targets on the structure with additional backsight observations made to two of the other visible surveys marks around the antenna. The antenna will then be moved to an azimuth orientation of 20 degrees (while staying fixed at the same elevation) and the measurement procedure will be repeated. The antenna will progressively move through 20 degree increments until the targets cannot be seen from that instrument station. The total station will then be moved to the next survey mark and observations will be made from there. The antenna may need to be rotated backwards to previous azimuth orientations so that the full viewable arc of target movement can be observed from the next instrument station. The antenna will be moved through the full 360 degrees of azimuth rotation at 20 degree increments.

After the local tie survey, observations will be reduced and put through a classical, geodetic, least squares (minimum constraint) adjustment. The resulting coordinate estimates and their associated variance-covariance matrix will then be processed through an IVP modelling and estimation procedure in which a number of geometric constraints will be applied (Figure 75). The output terrestrial network and computed IVP coordinates and variance-covariance matrix will be transformed to a global reference frame defined by GPS observations made between the permanent GPS antennae on station. The final coordinates will then be output in SINEX file format to support the analysis of the VLBI local tie connection to the other space geodetic techniques at Syowa station.

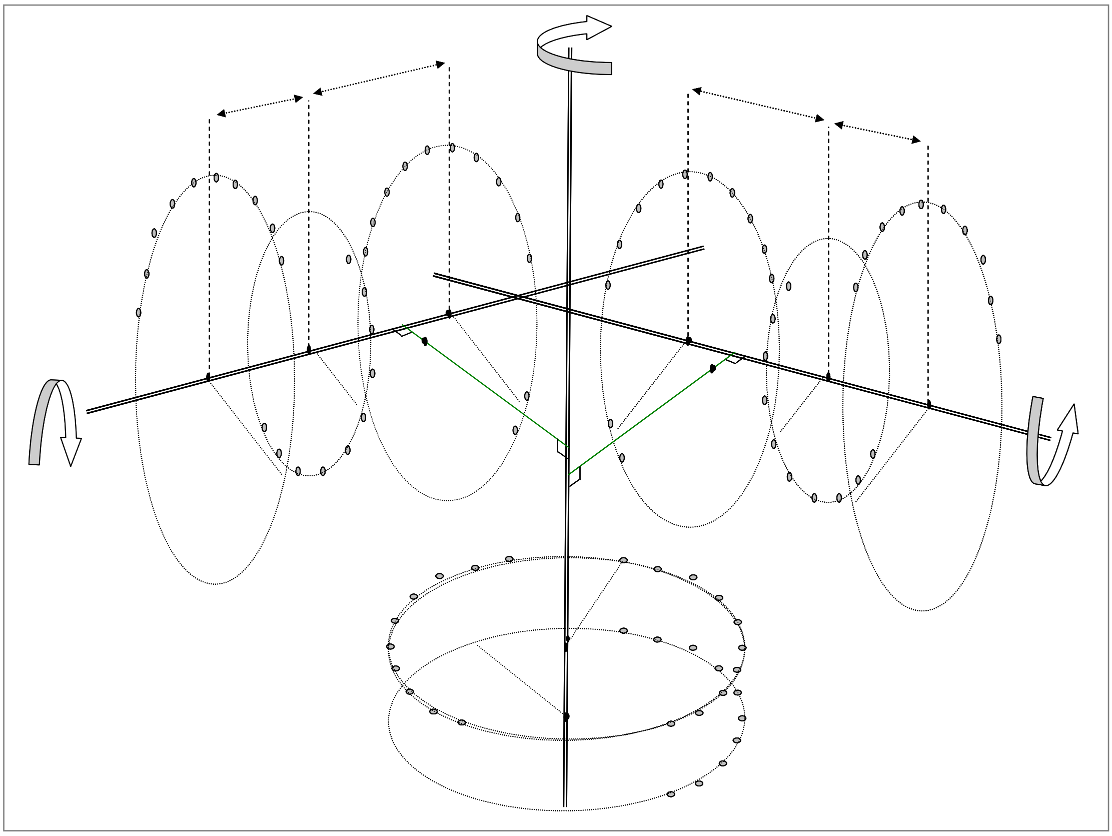


Figure 75: *IVP model. Targets scribe perfect circular arcs which, after a number of geometric constraints are applied, are used to determine the IVP of the observing system*

Conclusion

Based on the findings from the reconnaissance survey at Syowa station in January 2007 and prior experience in conducting local tie surveys on SLR telescopes and VLBI antennas in Australia, a precise local tie connection can be attained at Syowa station between the VLBI and GPS antennae. Additional information regarding the removal of primary GPS antenna from the antenna survey monuments and the stability of the VLBI antenna when fixed in one orientation axis during rotation changes in the other orientation axis will need to be pursued. Agreement on the placement of survey marks within the VLBI dome and the type of survey marks to place in the concrete floor will need to be organised between Geoscience Australia and the Japanese. An initial estimate of three to four days will be required to complete the survey, including the establishment of the local terrestrial network within the dome and the observation of targets on the VLBI antenna during specific rotational sequences of the structure. Logistics planning for a return visit to Syowa will need to be organised between Geoscience Australia, the AGAD and JARE.

Additional Geodetic Infrastructure on station

DORIS beacon

The DORIS beacon is located a relatively long distance from the VLBI dome (+500m). The DORIS is positioned North West of the VLBI, on the opposite side of the main wintering living quarters next to the geoscience building. The reference line for the DORIS is faint but still visible to support observations (Figure 76).

Figure 76: *DORIS beacon, view south east, towards VLBI dome*

Superconducting Gravity Meter

There is a superconducting gravity meter located in close proximity to the VLBI dome in a small building (Figure 77). This building also contains the GPS receivers (*Trimble* units) and computers for the primary GPS antenna, or Syowa GPS station (Figure 78).

Figure 77: *Super conducting gravity meter*

Figure 78: *Primary GPS computer and Trimble receiver equipment indoors*

Tide Gauge

There is a Tide Gauge located on the western side of East Ongul Island, approximately 1km from the VLBI dome. The tide gauge is connected via cable to the geoscience building where the data is constantly collected. There is a tide gauge bench mark (No. 1040) located along side the shore near the tide gauge. Apparently**,** surveys are conducted between the tide gauge and the bench mark every year. In addition, there is a floating GPS buoy for tide surveys which is deployed for three days of data collection each month.

Hydrogen Maser

A hydrogen maser is located in a small building next to the VLBI dome. Time for VLBI observations is kept by the hydrogen maser (Figure 79). The time supplied by the secondary GPS antenna is compared against the hydrogen maser time.

Figure 79: *Hydrogen Maser*

Support to Australian Antarctic Division Mapping Group

Prior to departure, Nick Brown and Alex Woods met with Henk Brolsma from the Mapping Group at the Australian Government Antarctic Division (AAD), who listed several survey tasks to be undertaken, on behalf of the mapping group, while in Antarctica. Most of the work was completed, including lake level surveys in the Vestfold Hills, determination of the height of a new barometer at the Davis skyway for the bureau of meteorology and surveys of the infrastructure developments at Davis and Mawson station.

A number of the requested survey tasks were not performed for a variety of reasons. The tide gauge at Davis was not calibrated as the sea ice was gone on arrival to station. In addition, the tide gauges at Davis and Mawson were not downloaded as the Mawson tide gauge was already downloaded by a scientist named Kym Newbery and the wintering scientist at Davis, David Correll, intended on downloading the Davis tide gauge when the sea ice had reformed. Observation of ground control features, using GPS, at deep field location was not performed due to time constraints and weight limits on aircraft preventing the transport of personnel and equipment. Further, technical difficulties were encountered with the *Thales* kinematic GPS unit which prevented its operation in the cold. The malfunctions noticed with the kinematic GPS unit will be reported to *Thales* and investigated further.

VESTFOLD HILLS LAKE LEVELLING

Over three days, toward the end of the season, relative height differences between the lakes and lake level bench marks were measured using an EDM heighting technique. Although the achievable precision with this technique was greater than required for the survey, the technique did allow long (40-50m) sighting lengths across steep terrain ensuring quick observation of changes in height. In addition, the instrumentation used for the survey was all that was available and included a *Leica* TCA2003 total station and *Leica* precision prism on fixed height stainless steel survey rod with bi-pole. Helicopter support was provided to access all the different lakes. This proved to be an extremely efficient way to visit all the lakes and locate survey bench marks (generally large, white painted crosses visible from the air), with the pilot standing by for 15 - 20 minutes as observations were recorded. All reduced levels were determined with respect to the quoted MSL of bench marks, provided by the AGAD mapping group. During the survey additional observations were made to permanent water level staffs in lakes. These observations are documented in Table 20 along with the observed change in height between survey bench marks and lake water levels and the reduced level determined for each of the lakes water level.

The lakes selected to be observed were specified by the AGAD Mapping Group. The derived reduced levels will be compared against lake levels surveyed in previous years, dating back to 1980s. In addition, Antarctic Division scientists collected water samples from the lakes this season and plan to study the correlation between changes in lake water salinity and the changing lake water levels over time.

Table 20: Vestfold Hills lake levelling results. All reduced levels are relative to the Davis MSL. All times of observations noted are with respect to local Davis time. All unit are in metres.

BM NUMBER	LAKE NAME	RL	ΔH	DATE OF SURVEY	TIME OF OBSERVATION	STAFF LEVEL READING
AUS/V/4	Lake Pauk	Unknown	-3.746	03/03/07	09.30am	
NMV/S/06	Lake Dingle	-9.328	-13.093	01/03/07	10.00am	
NMV/S/08	Deep Lake (NW end)	-50.581	-0.925	01/03/07	12.00pm	0.730
NMV/S/15	Lake Stinear (SW end)	-14.051	-16.705	01/03/07	11.00am	
NMV/S/20	Club Lake	-37.964	-3.659	01/03/07	14.00pm	0.310
NMV/S/21	Oval Lake	-28.862	-2.756	01/03/07	14.30pm	
NMV/S/22	Lake Shield	-7.239	-2.865	01/03/07	15.00pm	
NMV/S/24	Ekho Lake	-1.612	-2.035	01/03/07	15.30pm	
NMV/S/35	Watts Lake	-6.152	-10.547	02/03/07	13.30pm	
NMV/S/36	Lake Lebed	13.272	-3.519	02/03/07	14.00pm	
NMV/S/40	Lake Abraxos	12.688	-4.282	02/03/07	10.30am	
NMV/S/43	Pendant Lake	3.103	-2.689	02/03/07	10.00am	
NMV/S/53	Organic Lake	1.833	-3.928	02/03/07	09.30am	
NMV/S/58	Clear Lake	-8.498	-3.660	02/03/07	12.30pm	
NMV/S/59	Lake McCallum	-1.982	-3.646	02/03/07	11.00am	
NMV/S/63	Lake Zvezda	15.880	-1.270	03/03/07	10.00am	
NMV/S/66	Lake McNeill	26.537	-3.546	01/03/07	16.00pm	
NMV/S/67	Lake Braunsteffer	34.366	-2.229	03/03/07	11.00am	
NMV/S/69	Lake Jabs	-37.174	-3.087	01/03/07	13.00pm	
NMV/S/72	Lake Druzhby	7.941	-1.814	03/03/07	11.30am	
NMV/S/74	Oblong Lake	-3.509	-2.313	02/03/07	14.30pm	
NMV/S/75	Ace Lake (East side)	9.098	-1.719	02/03/07	09.00am	
NMV/S/78	Anderson Lake	3.399	-2.679	02/03/07	13.00pm	

Note: The height of the AUS/V/4 reference mark was not contained within the book provided by A*GAD. Field book reference: Antarctica 2006/07 Field Book pg48-50.*

The reduced levels of previous campaigns can be found in Appendix C.

DAVIS STATION INFRASTRUCTURE CHANGES

There have been several changes to the permanent infrastructure at Davis station in the last few years. Several new structures, not shown on the most up-to-date maps of the station, are now constructed or under construction while others shown on the maps have been removed. A detail survey was undertaken on the 13th February 2007 to determine the positions of the new buildings and allow the AGAD Mapping Group to update the station maps.

New structures**:**

- Field Store and U/G services;
- Met Dome and cable tray from Met Building to Met equipment outside;
- Pillars and supports for new Living Quarters (LQ) and connection to Sleeping and Medical Quarters (SMQ);
- Summer Accommodation Module (SAM) and service tray connecting into pre-existing services;
- Temporary Accommodation Dwelling (TAD), alongside SAM;
- Several temporary accommodation dongas South of old station have been moved, not surveyed as non-permanent features.

Removed features**:**

- Northwest half of old station;
- Temporary accommodation to southwest of old station;
- Waste treatment plant.

To measure the corners of buildings and other key features of new structures on station a small traverse and detail survey was performed. The survey started at survey mark D3, 40m northeast of the workshop, with the initial orientation for the survey obtained by setting azimuth on D2 (alongside the paint testing panels). The coordinates for these points were available in the WGS84 (UTM43) coordinate system, which is the horizontal datum quoted on the station maps. Thus, the coordinates provided are easting and northings in WGS84, UTM Zone 43. The heights are reduced levels determined with respect to the MSL of tide gauge bench mark NMV/S/4 (2.179m).

In observing the new buildings, only three corner points were measured. The missing corner points can be derived at a later stage by the AAD Mapping Group. The new LQ and connection to the SMQ, and new TAD were in the initial stages of construction at the time of survey. The concrete pillars and supports were already in place so these were measured as part of the survey.

The new Met Dome is supported on a near-circular shaped concrete slab that is flush with the ground level. Observations were taken to three points at the edge of the slab to allow the shape to be calculated at a later stage.

Figure 80: *New field store. View 20m west from western corner*

Figure 81: *U/G Services from Green Store to new field store. View from north corner of Green Store.*

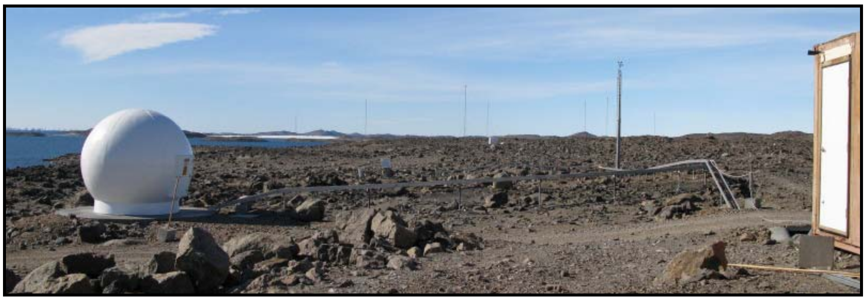


Figure 82: *New Met Dome, cable trays and other Met equipment. View east from north corner of Met building*

Figure 83: *New Met Dome and cable tray. View NW from north corner of Science building*

Figure 84: *New LQ and LQ connection to SMQ construction area. View NW from road intersection (Eastern most flag on old station map)*

Figure 85: *New SAM. View East from road bridge over service tray leading to Operations building*

Figure 86: *Services tray leading into SAM. View NW from 5m SW of west corner of SAM*

Figure 87: *TAD concrete supports. View North from 5m south of southern corner of TAD*

Survey Results

Note all units are in metres. Easting and Northing are with respect to WGS84 coordinates supplied by the AAD mapping group. Heights are relative to Davis MSL. Several heights are supplied for the same position. Although coordinates are quoted at the mm level, precision is more likely 5-10mm.

Survey Control

	E	N	H
D2	621014.098	2389934.520	23.808
D3	621063.959	2390025.891	23.080

New structures

Field Store

	E	N	GROUND LEVEL	SLAB LEVEL	TOP OF BUILDING
South Cnr	621002.998	2390067.089	18.455	18.755	24.300
West Cnr	620994.297	2390076.263	18.456	18.756	24.300
North Cnr	621001.723	2390083.299	18.452	18.752	24.300

U/G Services to Field Store

	E	N	GROUND LEVEL
Entry to Field Store	620996.797	2390073.381	18.479
Change in direction of trench	620957.700	2390049.116	16.937
Trench at cnr of Green Store	620943.521	2390035.639	16.198

Met Dome

	E	N	SLAB LEVEL
SE edge of slab	620883.422	2390123.506	16.643
NE edge of slab	620882.885	2390127.054	16.632
SW edge of slab	620879.793	2390123.041	16.639

Cable Tray from Met Building

	E	N	GROUND LEVEL
At Met build East Cnr	620874.179	2390092.469	17.615
At road intersection1	620890.080	2390106.526	17.402
At road intersection2	620893.679	2390109.824	17.380
Tray end NE of Met build	620937.482	2390149.014	15.893
Off shoot to Met Dome - at main tray	620899.562	2390114.876	17.705
Off shoot to Met Dome - at Met Dome	620883.793	2390124.128	16.637
Off shoot to Met Box - at main tray	620934.962	2390146.752	16.023
Off shoot to Met Box - towards Met Box	620924.072	2390157.557	15.062

Met Box

	E	N	GROUND LEVEL
Met Box	620920.950	2390160.584	15.270

Met Instrument

	E	N	GROUND LEVEL
Met Instrument	620934.915	2390157.273	16.399

Wind Sensor Tower

	E	N	GROUND LEVEL	SLAB LEVEL	TOP OF TOWER
Slab base East Cnr	620935.472	2390144.746	16.079	16.579	26.400
Slab base South Cnr	620934.384	2390143.789	16.081	16.581	
Slab base West Cnr	620933.413	2390144.863	16.174	16.574	

New LQ Construction

	E	N	GROUND LEVEL	TOP OF PILLAR
North Cnr	620916.074	2389897.289	15.292	17.662
East Cnr	620926.289	2389886.386	16.074	17.664
South Cnr	620910.889	2389871.836	15.162	17.662

New LQ Connection to SMQ Concrete base supports

	E	N	GROUND LEVEL	SLAB LEVEL
East Cnr	620921.418	2389897.339	16.705	17.160
South Cnr	620919.994	2389896.014	16.579	17.159
West Cnr	620906.467	2389910.341	15.269	15.569
North Cnr	620907.846	2389911.695	15.268	15.568

Services Cable Tray extension to SAM

	E	N	GROUND LEVEL
South Cnr	620984.106	2389859.777	23.020
East Cnr	620985.779	2389861.303	23.141
West Cnr	620966.305	2389878.701	20.559
North Cnr	620967.924	2389880.285	20.706

SAM

	E	N	GROUND LEVEL	SLAB LEVEL	TOP OF BUILDING
North Corner	621000.009	2389879.281	23.558	23.558	30.214
West Corner	620983.735	2389863.825	23.154	23.549	30.206
South Corner	620992.414	2389854.693	23.158	23.553	30.209
Top of Building Peak SW side	620987.365	2389860.235			31.869

TAD

	E	N	GROUND LEVEL	TOP OF SLAB
South Cnr	620978.272	2389869.643	22.560	23.550
West Cnr	620973.941	2389874.203	22.522	23.552
North Cnr	620987.314	2389886.914	23.154	23.549
East Cnr	620991.625	2389882.336	23.152	23.547

Removed structures

Only a few structures shown on the current maps are no longer at Davis Station. Several temporary accommodation dongas have been positioned opposite the ablutions block; however, these features were not surveyed, as they are not permanent structures. The NW half of the old station has been removed as has the line of temporary accommodation dongas opposite the old station. The waste treatment plant has also been removed with the new SAM built in its place.

Figure 88: *Ablutions block. View east from old station*

Figure 89: *Old Station. View east from 30m west of building corner*

Please refer to Appendix D: Davis Station Infrastructure 2007 for a listing of the structure coordinates.

Upon the request of the summer buildings manager, Douglas Galbraith, an additional survey of the new LQ pillars, supports for the connection to the SMQ and surrounding groundwork was undertaken on the 25th February 2007. In this survey the ground level and top of pillar level was observed for each pillar, with observations taken at the eastern most corner of each pillar. The pillar dimensions are 500mm x 500mm. The other three pillar corners can be derived at a later stage.

Observations were also taken to the corners of the concrete supports for the connection between the new LQ and SMQ, the south and east corners of the SMQ building and at the edge of vehicle tracks surrounding the new LQ building. This should provide enough information for the engineers to develop a model of the groundwork around the new LQ. The results of this survey are contained in Appendix E: New Living Quarter Pillars and Groundwork Survey, which will also be provided to the AGAD Mapping Group.

MAWSON STATION INFRASTRUCTURE CHANGES

There have been several changes to the permanent infrastructure at Mawson station in the last few years. Several new structures, not shown on the most up-to-date maps of the station are now constructed and several features shown on the maps have been removed. A detail survey was undertaken on the 31st December 2006 to measure the new buildings, the results of which will be provided to the AGAD Mapping Group to update the station maps.

New structures:

- Wind Turbine 1;
- Wind Turbine 2;
- Yellow box extension, north of Water supply building (Southern part of map);
- Hydrogen generator next to Balloon building (SW side);
- Field store, under construction. NW of wind turbine 2.

Removed features:

- Fuel tanks, 40m NE of gas storage platform;
- Fuel tank, 20m SW of Met hut. Non-permanent structure. Now at NE corner, of upper fuel farm. Not a permanent feature so not surveyed;
- Container Accommodation, between domestic accommodation and hydroponics; containers removed, except for smokers hut container on SE end. Smokers hut surveyed.

To measure the corners of buildings and other key features of new structures on station a small traverse and detail survey was performed. The survey started at AUS064 RM2 near the Cosray building, with the initial orientation for the survey obtained by setting azimuth on AUS064 RM3. The coordinates for these points were available in the ITRF2000 coordinate system and were transformed to WGS84 (UTM41) coordinates as this was the horizontal datum quoted on the station maps. Thus, the coordinates provided are eastings and northings in WGS84, UTM Zone 41. The heights are reduced levels determined with respect to the MSL of ISTS051 (9.792m).

In observing the new buildings, only three corner points were measured. The AGAD Mapping Group can derive the missing corner points at a later stage.

The new field store was still under construction at the time of survey with the footing in place, thus the footings were surveyed. Tape measurements were made to the side of the shipping containers destined to be the field store building, which provided the height of the building.

Figure 90: *New field store. Observations taken to top of footings. View SE from operations building.*

Figure 91: *New yellow building alongside green water supply building. View SW from road.*

Figure 92: *Smokers hut. At end of where old container accommodation once stood. View south from near hydroponics.*

Figure 93: *Hydrogen generators next to balloon building. View north.*

To determine the centre point of the wind turbines stands observations were taken to either side of the turbine stand at the base. The centre point was then derived as the mid point between these two sides. The height of these points is at the base of the turbine stand, where the turbine is bolted into the concrete foundation support.

Figure 94 and 95: *Left: Wind Turbine 1, view south, Right: Wind Turbine 2, view north.*

Survey Results

Note all units are in metres. Several heights are supplied for the same position. Although coordinates are quotes at the mm level, precision is more likely 5-10mm.

Survey Control

	E	N	H
AUS064 RM2	494525.096	2501182.940	31.955
AUS064 RM3	494487.435	2501214.027	28.990
AUS064 RM1	494497.043	2501170.131	30.079

New Structures

Wind Turbine 1

	E	N	BASE OF STAND	TOP OF PROPELLER HUB
Centre	494575.323	2501126.602	28.652	62.197
East side	494576.293	2501127.718	28.652	
West side	494574.353	2501125.485	28.651	

Wind Turbine 2

	E	N	BASE OF STAND	TOP OF PROPELLER HUB
Centre	494697.654	2501455.882	11.933	45.924
East side	494699.131	2501456.069	11.933	
West side	494696.176	2501455.696	11.932	

Note: Approximate radius of wind turbine stands at base is 0.74m
Top of propeller hub height is only approximate

Yellow building next to water supply building

	E	N	GROUND LEVEL	TOP OF FOOTING	TOP OF BUILDING
NE Cnr	494608.980	2501144.718	28.859	29.289	31.729
NW Cnr	494607.372	2501142.899	28.965	29.295	31.735
SW Cnr	494611.845	2501138.788	28.389	29.269	31.749

Smokers hut

	E	N	GROUND LEVEL	TOP OF FOOTING	TOP OF BUILDING
SW Cnr	494677.885	2501369.256	18.890	18.890	21.440
SE Cnr	494679.219	2501371.347	18.565	18.915	21.465
NE Cnr	494674.291	2501374.798	18.533	18.923	21.473

Field store

	E	N	GROUND LEVEL	TOP OF FOOTING	TOP OF BUILDING
SW Cnr	494705.133	2501463.568	10.089	10.549	13.439
SE Cnr	494709.308	2501466.971	9.646	10.546	13.436
NW Cnr	494689.633	2501482.857	9.614	10.544	13.434

Hydrogen generator slab

	E	N	GROUND LEVEL	TOP OF SLAB
SE Cnr	494644.870	2501548.765	11.473	11.553
SW Cnr	494641.395	2501545.426	11.238	11.568
NW Cnr	494639.202	2501547.404	11.346	11.546

Removed structures

Only a few structures shown on the current maps are no longer at Mawson Station. The fuel tank shown as 20m SW of the Met theodolite hut has been moved to the eastern corner of the upper fuel farm. This feature was not surveyed as it is not a permanent structure. The container accommodation opposite the red domestic building has been reduced to just the smokers hut and the fuel tanks located approximately 40m NE of the gas storage platform have been removed.

Figure 96: *Removed fuel tanks. View NE from road*

Figure 97: *New location of fuel tank, moved from opposite Met hut.*

Please refer to Appendix F: Mawson Station Infrastructure 2006 for a listing of the structure coordinates.

References

Corvino, A. F., 2004. Installation of remote continuous GPS (CGPS) stations for long-term tectonic monitoring in East Antarctica, *Field Report to Geoscience Australia,* 1 -21.

Dawson, J., 2004. The Determination of Telescope and Antenna Invariant Point. *Geoscience Australia*.

Gordon, T. W., 1996. Antarctic Mapping Program Field Work report 1995-96 Summer Season. *AUSLIG report for Antarctic Division*.

Johnston, G. and Digney, P., 2001. Antarctic Geodesy 2000/01 Report. *Geoscience Australia*