EXPLORATION

EXPEDITION REPORT

Exploration and Biosurvey of the Pearse Resurgence, New Zealand

December 27th 2010 – January 12th 2011

NGS – Waitt Research Grant #W89-10

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ABSTRACT

Six Australian cave divers travelled to the Pearse Resurgence, a vauclusian spring in New Zealand's South Island, to continue exploration of the cave and to sample the invertebrate stygofauna biodiversity of the cave.

The divers were on site for 13 days, performing a total of 74 dives in the 6.5°C water, with one diver suffering a minor episode of decompression sickness that resolved with first aid.

In collaboration with scientists from the National Institute of Water and Atmospheric Research (NIWA), 40 baited invertebrate traps were set and retrieved in the upper 115 m of the cave, and samples were preserved for subsequent analysis by NIWA.

Exploration in the deep main shaft of the cave continued from the previous point of penetration by the team in 2008, using four dry decompression habitats and other technologies to improve the safety of deep diving and prolonged decompression in the cold waters of the cave.

Results

- Analysis of the invertebrate trap fluid demonstrated a new species of amphipod, an oligochaete and a small gastropod.
- Deep exploratory dives revealed a new vertical shaft descending out of sight beyond 194 m in depth.
- Repeated dye tracing from the Ellis Basin did not reconfirm this connection.

INTRODUCTION

The Pearse Resurgence marks the origin of the Pearse Stream located on the eastern side of the Arthur Range, New Zealand. It is a vauclusian spring with an average discharge of approximately 2 m^3 per second. Dye tracing has suggested a connection as far away as the Ellis Basin; a distance of approximately 6 km.[1] The cold (6-8°C) waters of the resurgence were first dived in 1975 but the remote nature of the cave and harsh conditions have precluded extensive exploration over the years.

Several divers have played a major role in the exploration of the Pearse since the earliest dives.

Keith Dekkers from New Zealand was pivotal in the early days, visiting the cave on several occasions and pushing down the start of the main shaft. 1995 saw an ill-fated expedition led by New Zealand caver Kieran McKay during which one of the divers, Dave Weaver, perished during an attempt at a depth record whilst breathing air. From 1997, expeditions by Sydney-based diver David Apperley made the most significant advances in the cave's exploration with the first use of a decompression habitat (2000) and culminating in the exploration of the cave by Apperley and Rick Stanton (UK Cave Divers Group) to 177m in 2007.

The author first dived the cave in 2007 with Apperley and has returned on three further occasions, pushing the cave slightly further in 2008. The lower level at 182 m depth poses serious obstacles to further exploration.

Using open circuit (traditional SCUBA) technology, the amount of gas required to perform a single dive to the bottom of the cave would be prohibitive; requiring vast numbers of helium, oxygen and SCUBA cylinders to be taken into the cave. The helicopter trips required would increase exponentially as would the expense and time required for gas preparation.

The use of closed circuit rebreather technology allows the same dives to be performed with far smaller quantities of gas and also confers other benefits such as better heat retention and greater gas reserves in the event of an emergency.

However, deep cold water diving on rebreathers is not without problems. Carbon dioxide retention is a particular hazard in this setting and a very conservative approach to CO_2 scrubber management is required.

The 2010 expedition saw an increase in the complexity of the diving operations in an attempt to safely dive beyond the current 182 m limit, and then decompress for the expected 8-10 hours in the low temperature water.

A mobile decompression habitat was constructed by the author with the intention of entering the habitat at 40 m and "riding it up" to 14 m before transferring across to a second rigid habitat at 7 m depth.

Unfortunately the plan was overly complex and the mobile habitat concept failed, leaving insufficient time for ongoing exploration.

During one decompression phase, however, a small cave-adapted invertebrate was noted swimming near the wall of the main shaft at approximately 15 m depth. This and another different species (a flatworm) were captured and forwarded to Dr Graham Fenwick, a systematist at the National Institute of Water and Atmospheric Research (NIWA).

The stygofauna samples represented previously undescribed species of amphipod and flatworm.

The importance of such stygofauna is twofold — they contribute to the health of the aquifer by biofiltration and in turn they may represent an important marker of the health of the water.

The discovery of these animals was the main impetus for a further more comprehensive biosurvey of the cave. In parallel, further exploratory dives would be performed.

THE EXPEDITION

Project Goals

- Invertebrate biosurvey of the cave.
- Continued exploration and mapping of the cave.
- Repeat dye tracing to confirm hydrological connection from Ellis Basin to Pearse Resurgence.
- High definition video of surface and diving activities.

With the assistance of a grant from the National Geographic Society-Waitt Grants Program, the author assembled a team of Australian cave divers to camp at the cave entrance in early 2011:

- Dr Richard Harris, Adelaide, South Australia
- Mr Ken Smith, Adelaide, South Australia
- Mr John Dalla-Zuanna, Melbourne, Victoria
- Ms Sandy Varin, Melbourne, Victoria
- Mr David Bardi, Melbourne, Victoria
- Dr Craig Challen, Perth, Western Australia.

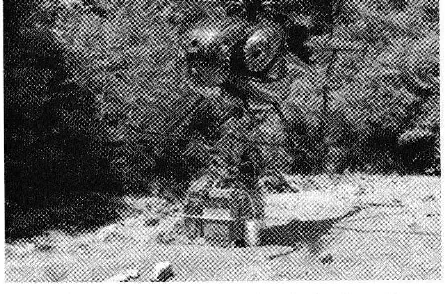
In New Zealand, local cavers John Patterson and Deb Cade handled logistics. Invertebrate sampling was coordinated on site by Ken Smith under the direction of Dr Fenwick in Christchurch.

After shipping 9 m^3 of camping, diving and imaging equipment from Australia to Nelson in New Zealand, the divers departed Australia on December 27th 2010.

Access to the Pearse Resurgence is difficult as it is protected from vehicular access by approximately 5 km of temperate rainforest and a steep-sided valley.

Hence all equipment must be transported to the site from a distant logging clearing by Hughes 500C helicopter, using cargo nets with a 400-500kg capacity.

Ten loads saw all the divers and their equipment inserted into the site late on December 29th.



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The author attaches a load to the hook on the helicopter. The pilot watches through his open door.

The camp was established on the grassed area between Eyles Creek and the Pearse River, with separate areas for tents, mess tent, charging station, compressor and generator. Diving operations commenced on December 30th and were completed on January 9th. After extraction from the site, the team left New Zealand on January 12th.

DIVING OPERATIONS

Diving in the cold and deep waters of the Pearse Resurgence requires a very different approach from ocean diving.

All the divers are highly experienced cave divers, trained in Australia by the Cave Divers Association of Australia to "Full Cave" rating which is the highest qualification available. In addition, deep diving requires the use of mixed gases containing oxygen, helium and nitrogen ("trimix") and hence the team are all trained to the highest level in the use of these gases.

Five of the six divers are also using closed circuit rebreathers, which offer specific advantages for this kind of diving. Unit specific training is also required to operate these machines safely.

Recreational divers are trained to utilise air SCUBA to dive to depths of 40 m. Advanced trimix certifications recommend diving to depths of 100 m. Beyond this, technical divers are beginning to explore the limits of current technology and physiology.

Great depths have implications for issues like gas consumption, thermal protection, prolonged decompression, work of breathing due to high gas density, narcosis, oxygen toxicity and High Pressure Nervous Syndrome (HPNS).

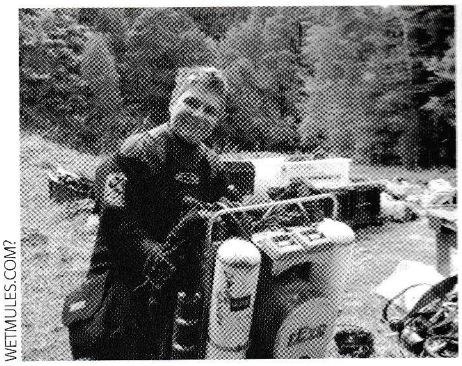
Proven decompression algorithms are not available and the divers must to some degree construct these themselves.

Exploration in the cave reached the depth of 182 m in 2008. With the possibility that the cave would either continue at this depth or go deeper, the team needed to prepare for greatly extended decompression times in the 6.5°C water. An unclad swimmer in this water would be unlikely to survive beyond 30 minutes.

A good drysuit can extend "comfortable" dive times to over an hour. With the high quality thermal protection used by the team (compressed neoprene dry suits with built in boots, Thinsulate® undergarments, 12V heated vest, gloves and boot soles, and dry gloves), we are able to stay immersed comfortably for three hours and safely for five hours.

However, a dive to 185m for 27 minutes would require over 10 hours of decompression, well beyond the safe in-water duration.

Furthermore, a breach or leak in a drysuit early in the decompression phase would be lethal should the diver be unable to exit the water.



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Sandy Varin wearing a heavy-duty neoprene drysuit, checking her closed circuit rebreather.

Hence, a major challenge facing the team has been the implementation of dry diving "habitats" or havens within the cave, where a decompressing diver can get out of the water during the dive. The advantages of dry-decompression are many but include:

Maintaining core temperature: Heat loss in water is many times higher than that in air. Maintaining core temperature bolsters musculo-skeletal circulation and so improves the efficiency of off-gassing critical to effective decompression. Hypothermia is dangerous in and of itself, with the decreased mental acuity contributing to mistakes and accidents.

The dry environment of the habitat alters cardiorespiratory physiology in a favourable way. CNS oxygen toxicity is less likely (a major concern with the high oxygen exposures seen in these dives) and in the event a seizure does occur, drowning is less likely. Respiratory mechanics are improved and elimination of CO_2 is more efficient.

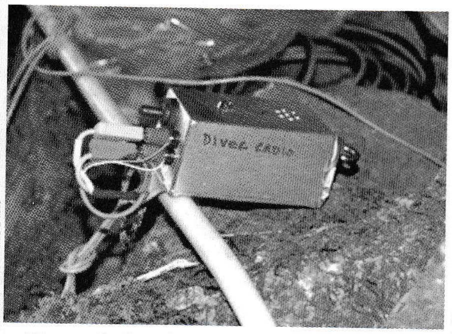
Warm food and fluids may be imbibed by the diver, which contributes to warmth, energy levels and morale.

The 7 m habitat can be used for treatment of acute decompression sickness when medical evacuation may not be feasible.

The diver is more comfortable, less bored (thanks to submersible MP3 players!) and can communicate with the surface and support divers more readily.

However, the installation of habitats is time consuming, requires practice and new skills, and carries its own risks including minor environmental impact to the cave. Each of the "IBC" containers used has a volume of 1 m^3 and hence has a lifting force of 1000kg. Unexpected movement or release of such a habitat presents great physical danger to nearby divers, especially one decompressing inside.

Entry and exit from habitats is a time of significant risk, when the diver may easily become separated from their gas supply or flood a rebreather. Finally, decompression planning is complicated by the use of prolonged stops at habitat depths. We would only recommend their use when possible benefits outweigh the risks and effort required.



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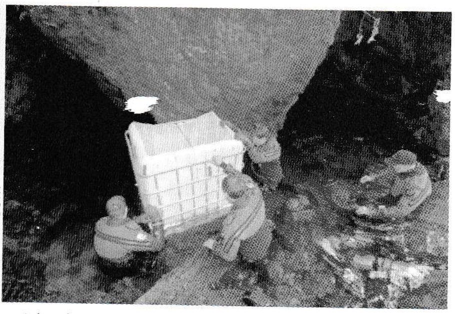
Diver radio based on dry caving "Michie phone" which can communicate between surface and habitats.



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The divers manoeuvre one of the bulk containers (IBC) into the cave entrance. The IBC will be inverted in the cave, secured and then filled with air to create a habitat for the divers to get out of the water for decompression.

The use of rebreathers in the cave offers considerable benefit. Closed circuit rebreathers (CCRs) use only small amounts of gas regardless of depth, compared with "open circuit" traditional SCUBA whose consumption increases dramatically with depth.

This means that less gas needs to be transported to the site by helicopter, each diver must carry less gas, dive durations can be prolonged, and more time is available to the diver to resolve problems that can develop underwater.

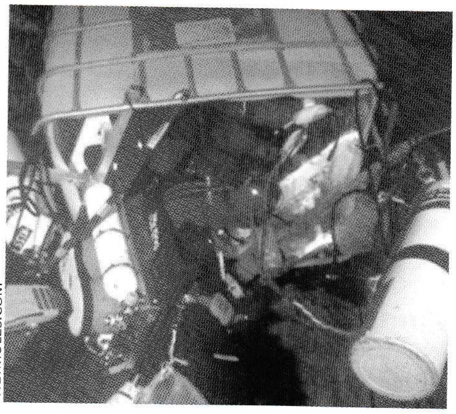
CCRs also keep the diver warmer and allow for more efficient decompression. It would be very difficult to do these exploration dives without CCRs.

Four separate habitats were installed into the cave during the first three days of diving. They resided at the following depths: 40 m, 28 m, 16 m and 7 m. Bailout (safety) gas was staged in the cave to a depth of 125 m.

Two spare small rebreathers were placed in the 40 m and 7 m habitats for use during decompression, so the diver could doff his larger main unit.

Surface supplied heating cables reached the 40m habitat so the decompressing diver could plug into the drysuit bulkhead, and activate the 12V heating undergarments.

Communications intercoms were placed in the 16 m and 7 m habitats enabling the diver to maintain contact with the surface. Support divers made regular visits to decompressing divers to check on them and give them food or drink.



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A support diver under the 28m habitat helps get the push diver settled in. Surface supplied heating cable can in seen in the right-foreground.

Once all habitats, heating cables, comms and bailout cylinders were installed in the cave, exploration dives could begin in earnest. The primary objective was to push the cave from the author's previous limit of exploration at 182 m.

Dave Bardi and Sandy Varin performed a video dive to the main deep passage, reaching a depth of 156 m. Craig Challen managed to extend the cave about 15 m horizontally and 12 m down to a new depth of 194 m.

At this point he developed some early respiratory difficulties due to the high work of breathing at depth. Rather than push on to the tempting target of 200 m, he wisely turned the dive and returned to the surface after 9½ hours of decompression. At 194 m, Craig found himself above a steeply sloping circular "well shaft" which disappeared down out of sight. Small HD cameras on his scooter and helmet recorded the record dive.

A further day of diving was required to remove the habitats and ancillary equipment from the cave, before the team was extracted by helicopter and could return to Nelson, then Australia.

DECOMPRESSION PLANNING

Diving beyond the recreational limits of 40m requires the use of decompression planning software that most would still regarded as unproven.

Dives performed beyond 100 m depths may carry a Decompression Illness (DCI) rate of over 20%[2], hence in a remote environment where medevac may take many hours, significant conservatism must be built into any dive planning.

A second difficulty arises when planning to prolong decompression stops in the dry habitats.

A "normal" decompression strategy would be to follow the decompression "ceiling" all the way to the surface, in other words to constantly remain at the shallowest depth allowable by the algorithm.

This maximises the gradient for off gassing and makes decompression more efficient.

Other ways to maximise the efficiency of decompression are by maximising the "oxygen window" (breathe the highest safe PO_2 possible to increase the gradient for off gassing inert gases), and to stay as warm as possible and gently exercise during decompression.

Our strategy diverges from this ideal slightly. When a diver reaches a decompression habitat they enter it and stay there for a period, despite the fact that the decompression ceiling is continuing to rise above them.

The longer they stay, the less efficient decompression may theoretically become. On the other hand, the improvement in core temperature is beneficial and so a trade-off is reached.

When the "virtual ceiling" reaches the next habitat, the diver exits and moves up to the next one at approximately 5 m/min. This continues over the four habitats staged throughout the cave until finally the diver may leave the 7 m habitat and return to the surface.

The author has coined the term "segmented staged decompression" to describe this technique.

Over the course of a 10-hour decompression, approximately one extra hour is added to the total run time due to the inefficiencies described.

However. the benefits to diver warmth, comfort, safety and morale more than justify this extra time in our opinion.

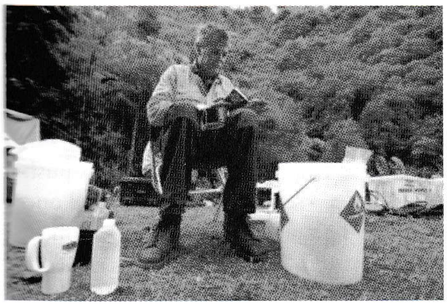
INVERTEBRATE BIOSURVEY

During the period on site, a stygofauna biosurvey was performed in the cave, with one reference sample also collected 50m downstream from the Eyles Creek junction near the southern bank.

With appropriate permission from the Department of Conservation, two techniques were utilised to sample the stygofauna.

Firstly, any invertebrates observed free swimming in the cave were captured by hand using a turkey baster (the "Stygo-slurper").

This was very effective for any animals seen with the naked eye, and several specimens were captured by this technique. Macroscopically these appeared to be identical to the previously undescribed amphipod captured on the January 2010 expedition.



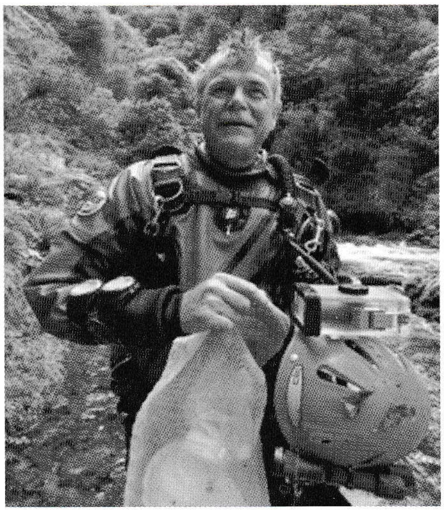
Ken Smith processes and sorts samples from the baited traps.

The second technique involved the deployment of baited fauna traps in the cave at depths from 5 m-115 m below the surface. Small plastic jars baited with a small shrimp were filled with nylon gauze and secured in various places in the cave, amongst a variety of habitats and substrates.

Before deployment, the jars were filled with filtered water and the lids attached. Once deployed, the lids were removed and the trap left in situ for 2-4 days.

On retrieval, the lids were replaced and the traps brought to the surface. The water in the trap was filtered and the filtered material placed in a plastic bag with ethanol preservative. The nylon gauze was also placed in the bag with more ethanol.

The bags' contents were then sent to NIWA with data regarding trap locations, and habitat descriptions as well as substrate samples for analysis by Dr Graham Fenwick and his team.



Ken Smith with sampling equipment. Note the housed Contour camera on the side of his helmet which successfully captured dives down to 194m depth.

ANALYSIS OF SAMPLES

(Graham Fenwick)

A total of 40 collections were made by the expedition, one from the epigean reaches of the Pearse River, the other 39 from various points within the hypogean karst system.

Of these collections, 15 contained invertebrates. Two invertebrate collections comprised solely terrestrial insects (one collembolan/spring-tail; one with beetle fragments), almost certainly inadvertent contaminants during sample processing. Another pair of samples contained only epigean stream insects (bodies pigmented and eyes well developed). Thus, 11 (28 %) of the total 40 collections contained true stygofaunal invertebrates.

One undescribed (new) species of amphipod dominated the stygofauna collected from the Pearse Resurgence. This species, completely colourless in life and with colourless eyes, belongs to the poorly known genus *Paraleptamphopidae,* one of two genera within the New Zealand endemic Family *Paraleptamphopidae.*

Originally described from Canterbury's deep alluvial aquifers, this family is represented by species (mostly new to science) inhabiting groundwater and marginally subterranean habitats throughout New Zealand.

Within the Pearse karst system, this amphipod was found most commonly within the main shaft, where the expedition's divers stalked it on rock faces or caught it in small traps baited with shrimp. It appears to live on the water-worn rock surfaces from within 2 m of the surface of the main shaft's airbell, to more than 40 m depth where they were taken amongst gravel and finer sediments.

The two other stygofaunal invertebrates discovered in the system were a minute gastropod snail (c. 1.5 mm diameter) and an oligochaete worm (c. 8 mm long). Both were taken from rare deposits of fine sandy sediments within the main shaft at depths of 15-34 m. Further identification of these await specialist study.

The apparent overall low abundance and diversity of invertebrates within the Pearse system is not unexpected.

Water entering the system appears low in both dissolved and fine particulate organic matter, so that, in the absence of light and plant or algal growth, food is scarce for invertebrates. Also, finer sediments, which often entrap fine particulate organic matter and support greater abundances and diversities of invertebrates than rock surfaces, are rare in parts of the system accessed, apparently because of low inputs of finer sediments and moderate to higher water velocities within the system at times.

Conceivably, invertebrates are more abundant and diverse in less accessible crevices closer to points of water entry and containing more sediments and organic matter. More intensive collecting, especially using airlifts or other suction devices to extract material from smaller, quieter passages and crevices seem certain to yield more abundant and richer collections of taxonomically valuable stygofauna.

DYE TRACING EXPERIMENT

The dye tracing study described by Wright[1] observed that dye placed in the small inlet known as Grange Slocker later appeared in the Pearse Resurgence.

This trip presented an opportunity to repeat this study with the assistance of dry cavers from the Nelson Speleological Group.

Two cavers flew by helicopter up to the Ellis Basin and deposited 1000 ml of Rhodamine WT ($C_{29}H_{29}N_2O_5ClNa_2$) into the water at exactly 1200hrs on December 29th, 2010.

Oz Patterson pours rhodamine dye into Grange Slocker, several kilometres from the Pearse Resurgence

The cave divers were camped by the cave for the next 12 days and during that time, no visible colour change was observed. It is possible that the amount of dye instilled at Grange Slocker was insufficient for a visual colour change, and unfortunately sensitive fluorometry detecting hardware was not available for use. However, this negative result was somewhat puzzling.

CAVE VIDEO AND MAPPING

Most of the deep dives, and many of the shallow ones, were videoed using the small Contour® point of view HD cameras in underwater housings. These were mounted on the divers' helmets and on the front of the dive propulsion vehicles.

Review of the footage generated from these video cameras was used to aid in the construction of maps of the cave and eventually a computer generated 3D model of the cave. This was particularly useful where the depths were too great to allow traditional cave mapping techniques (such as line distance, compass bearings and tape measurements) to be used.

Together with data collected on previous expeditions by the author, a good quality map of the system is gradually being developed.

SUMMARY

- The six Australian cave divers safely achieved all the goals of the expedition to the Pearse Resurgence in New Zealand. In what appears currently to be the deepest cold–water flooded cave in the world* seventy-five dives were performed to a maximum of 194 m with one minor case of decompression sickness being the only adverse outcome.

- The team further refined cold-water diving techniques to allow prolonged decompression in the 6.5°C water. "Segmented staged decompression" was utilised for the first time by this team with great success.
- A repeat of the dye tracing experiment from Grange Slocker in the Ellis basin did not confirm a connection to this area.
- A stygofauna biosurvey of the cave revealed only three species of invertebrate present in low density.
- Further HD video of the cave was obtained and the map of the cave grew in detail and accuracy as a result of this and further surveying.

* There are currently 16 diveable caves in the world deeper than the Pearse Resurgence. Of these, only 10 have been dived to depths greater than the current depth (194m) in the Pearse.

REFERENCES

1. Wright AC. 2004 'Aspects of the geology and hydrology of Nettlebed Cave, Nelson, New Zealand.' *Journal of the Royal Society of New Zealand*, Vol 12, Number 2, pp143-157.

2. Doolette DJ. 'Decompression practice and health outcome during a technical diving project.' *SPUMS J.*2004; 34:189-195.

ACKNOWLEDGEMENTS

The divers would like to thank local cavers "Oz" Patterson and Deb Cade in Nelson, Dr Graham Fenwick (NIWA), BOC Nelson,

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The team from L-R: Richard Harris, John Dalla-Zuanna, Sandy Varin, Oz Patterson, Dave Bardi, Craig Challen and Ken Smith. Absent Deb Cade.

Syd and Dick Deaker and Action Helicopters, Chris Holman from SCUBA Imports and Liquivision Computers, Grant Pearce and AquiferTec, GMS Concepts, Sue Crowe (Tabata Australia) and Waterproof Gloves, rEVO Rebreathers, Sea Optics Adelaide, Damien Griggs (DKG Drysuits) and Weezle Skins, and O'Three Dry Suits for their very generous support and assistance.

POSTSCRIPT

The team have just completed the 2012 expedition to the Pearse River Resurgence near Mt Arthur in the South Island of New Zealand. The six Mules (David Bardi, Craig Challen, John Dalla-Zuanna, Richard "Harry" Harris, Ken Smith and Sandy Varin), were accompanied by diving physician and support Dr Karen Richardson for the 17 day trip.

Both primary objectives of the trip were accomplished. With the assistance of Nelson Speleological Group's Andrew Smith and Dawn Wood, dye tracing from the Spillway in Nettlebed Cave again confirmed the connection between the two sites. Unfortunately, the dye appeared to be coming from the main passage deeper than 120m, so any hopes of making a shallow connection were lost.

Hence attention shifted back to pushing the deep section of the cave, and once the four habitats were installed at 7 m, 16 m, 28 m and 38 m, and gas was staged in the cave, build-up dives commenced.

On Thursday 12th January Dave and Sandy dived to 180 m and completed an extraordinary seven-hour all in-water decompression.

The following day Richard Harris pushed past the end of Craig's 2011 line at 194 m, and laid 70 m of line in large passage to a maximum depth of 207 m. A total run time of 10½ hours was spent in comfort thanks to the habitats and the surface supplied suit-heating systems.

After two days of rain the resurgence flooded, delaying diving for a day. The final push dive by Craig Challen began on Sunday 15th January as the water levels subsided.

Tying off to the end of Harry's line, he scootered on a short distance only to meet another steep descent.

Craig made a final tie off at 221 m and returned to the surface after a total dive time of 17 hours. The passage continues beyond, heading deeper.

Ken, JDZ and Craig made tape measure surveys of several areas including the Nightmare Crescent and Big Room area at 120 m.

More information and images can be found at www.wetmules.com