Hydrogeological assessment of Hookina Spring (Pungka Pudanha), Flinders Ranges

DEWNR Technical note 2015/13

Government of South Australia
Department of Environment, Water and Natural Resources

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Summary

Hookina Creek has been identified as an important cultural, archaeological, biological and hydrological site, and is the only registered storyline in South Australia under the *Aboriginal Heritage Act 1988*. Hookina Spring (*Pungka Pudanha*) is an important healing spring and there is strong interest from the local aboriginal community to maintain the sustainability of the spring against threats such as erosion, livestock grazing, water extraction, tourism, weeds and feral animals which could damage the ecological and cultural value of the site.

The objective of this investigation is to provide an understanding of the nature of the spring and creek system, where the source of water flowing from the spring originates from, and the age of the groundwater, and to identify whether the spring is vulnerable to changes in land and/or water management at a local or regional scale. Due to resourcing constraints, the investigation was limited to a desktop study of existing information, and a short field component for water sampling, inspection of the physical characteristics of the spring and Hookina Creek, and engagement with the local indigenous community, the Kuyani people, to document their experiences and understanding of the spring.

The springs were found not to have a readily distinguishable or accessible discrete source which is commonly observed in many other springs elsewhere in South Australia. The occurrence of lush vegetation in the creek bed coincides with two south-west to north-east trending faults that seem to control the direction of Hookina Creek and a tributary. This suggests that faulting may provide a conduit for groundwater discharge from deeper aquifers. The flow appears to progressively increase downstream to the main *Pungka Pudanha* waterhole where the channel is restricted and was gauged by the Department of Environment, Water and Natural Resources (DEWNR) to flow at a reasonably constant 20 L/sec.

An indicator that groundwater discharge has been occurring for a considerable period of time is the presence of a very hard cemented conglomerate in the creek bed which appears just downstream of where the first signs of discharge were observed. The area of exposed conglomerate at the main waterhole exhibits widespread fracturing and local vertical upward displacement, which strongly suggests the area is still seismically and tectonically active. This is supported by anecdotal evidence from traditional owners who have regularly felt earth tremors in the area, and have observed less water in the waterhole, with the deeper pools appearing shallower.

Water samples were collected from an accessible waterhole in Hookina Creek and an equipped stock well (Bobby Creek Bore) located six kilometres south of the spring, and analysed for cations, anions, metals and carbon isotopes. The analyses show that there is a strong similarity between both the waterhole and the stock well water, with salinity values of 2170 and 1945 mg/L respectively, with the dominant ions being sodium, chloride and sulfate ($Na\text{-}Cl\text{-}SO_4$ type water). The likely upper limits to the age of the water are 1700 and 3000 years before present respectively, which indicates a regional source for the spring. It is also highly unlikely that Hookina Spring has a local source because the very low, current rainfall and recharge rates could not maintain the observed discharge flows.

A regional source for *Pungka Pudanha* suggests it is unlikely that the spring flow rate will be affected by local or short term influences such as droughts or changes in land use. Consequently, local changes in land management are not likely to have any impact on spring flow. However, significant increases in groundwater extraction to the east of Hookina Creek (i.e. upgradient of the spring) could reduce the spring flow.

1 Background

This project has been jointly funded by DEWNR and the SA Arid Lands NRM Board and contributes to the Science, Monitoring and Knowledge Branch (SMK) Groundwater Program, the Natural Resources (NR) SA Arid Lands Aboriginal Partnerships Program and the Sustainable Water Use, Planning and Evaluation Program. The SMK Groundwater Program's Non-Prescribed Groundwater Assessments project aims to gain more knowledge of groundwater resources in non-prescribed areas. The NR SA Arid Lands Aboriginal Partnerships Program seeks to support and enable Traditional Owners and Aboriginal people living in the region to maintain their connection with land and protect and maintain culture, cultural sites and natural resources of the lands and water of the SA Arid Lands NRM region, whilst the Sustainable Water Use, Planning and Evaluation Program involves supporting projects that improve our knowledge, understanding and management of water resources to protect and maintain the health, quality and integrity of our water resources, dependent species and communities, including the people that rely on them.

Hookina Creek has been identified as an important cultural, archaeological, biological and hydrological site and is the only registered storyline in South Australia under the *Aboriginal Heritage Act 1988*. The Hookina Creek storyline runs from Hawker through to Lake Torrens and some of the highest densities of archaeological sites (both registered and unregistered) in South Australia are located along the creek banks. Aboriginal accounts that are many thousands of years old refer to the area having environmental conditions that are commensurate with tropical zones as we know them today. Of particular interest for this project is the waterhole known as Hookina Spring (*Pungka Pudanha*) as it is an important healing spring and there is strong interest from the local aboriginal community to maintain the sustainability of the spring. They have raised concerns regarding the noticeable drop in water levels and flow rates in their lifetime and that if unmanaged threats such as erosion, livestock grazing, water extraction, tourism, flooding, weeds and feral animals will continue to damage the ecological and cultural value of the site.

The objective of this investigation is to provide an understanding of the nature of the spring and creek system, where the source of water flowing from the spring originates from, and the age of the groundwater and to identify whether the spring is vulnerable to changes in land and/or water management at a local or regional scale. The investigation will also provide an opportunity for the local community, natural resources staff and other interested stakeholders to participate in field sampling and to gain an understanding of the hydrology.

The project contributes to the following resource condition targets (RCTs) and management action targets (MATs) from the SAAL Regional NRM Plan:

- RCT 3 – By 2020, the extent and condition of at least 50% of priority aquatic ecosystems is improved and other priority aquatic ecosystems are at least maintained in extent and condition
- RCT 7 – By 2020, the average quality, pressure and level of groundwater are maintained or improved
- MAT 17 – Commence research to improve knowledge regarding ecosystem function and services for priority ecosystems by 2014
- MAT 29 – Implement protection, management and/or rehabilitation measures in at least ten priority aquatic ecosystems (priority at a local/community level) by 2016

Due to resourcing constraints, the investigation was limited to a desktop study of existing information and a short field component for water sampling, inspection of the physical characteristics of the spring and Hookina Creek and engagement with the local indigenous community to document their experiences and understanding of the spring.

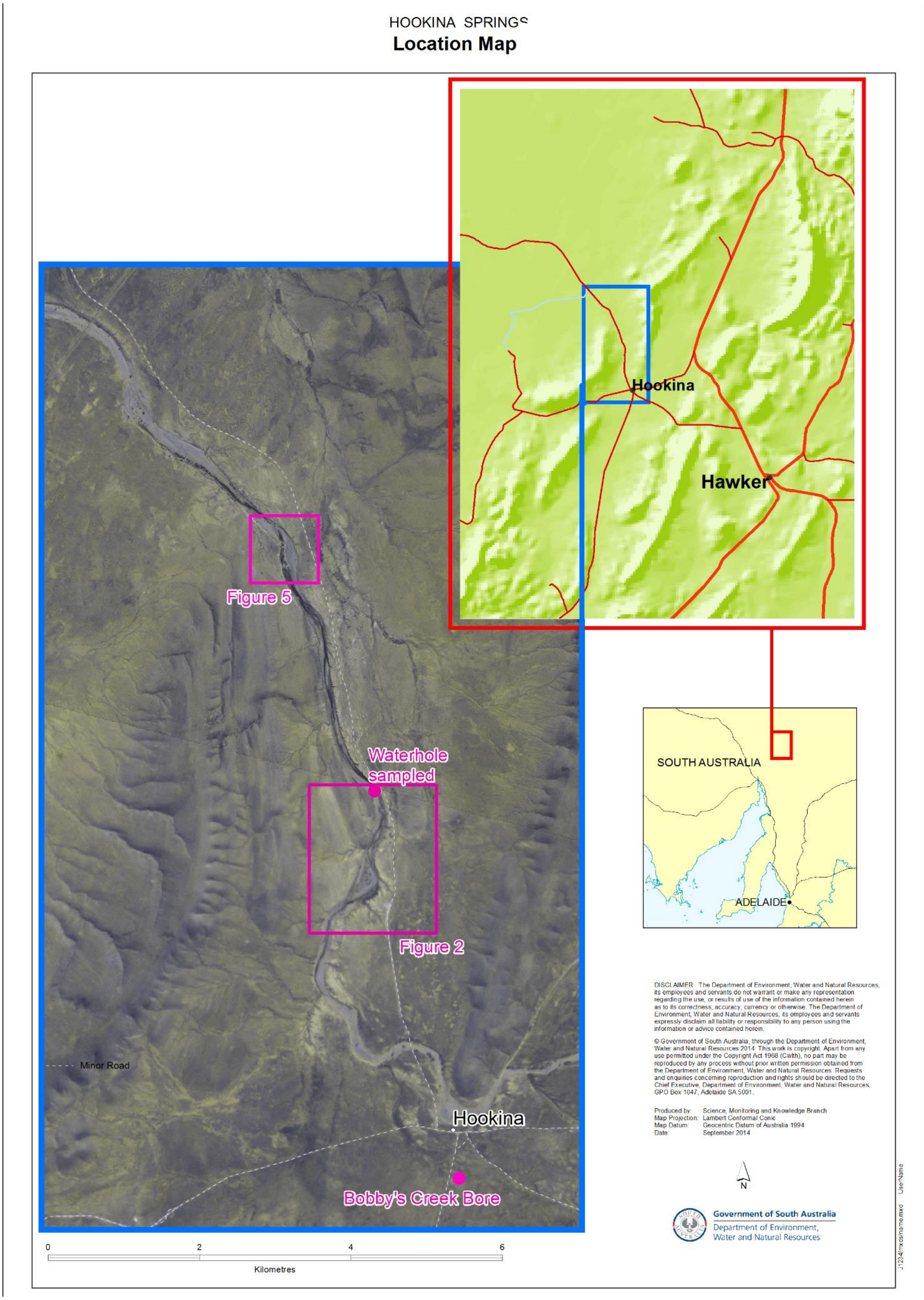

Figure 1. Hookina Spring location map

2 Geomorphology of the site

The spring does not have a readily distinguishable or accessible discrete source, which is commonly observed in many other springs elsewhere in South Australia. The first indication of groundwater discharge is where the creek bed is permanently damp. Further downstream from this point, the creek bed becomes progressively wetter, with small pools of water becoming more frequent, together with thicker vegetation (shrubs, reed beds and larger eucalypts).

Figure 2 shows the area where the spring commences together with the mapped 1:100 000 geology. The geological outcrops appear to be much more complex than the published geology suggests. The occurrence of lush vegetation coincides with two south-west to north-east trending faults that seem to control the direction of Hookina Creek and a tributary. This suggests that faulting may provide a conduit for groundwater discharge from deeper aquifers, which appear from Figure 2 to be the Wonoka Formation or possibly the Bonney Sandstone.

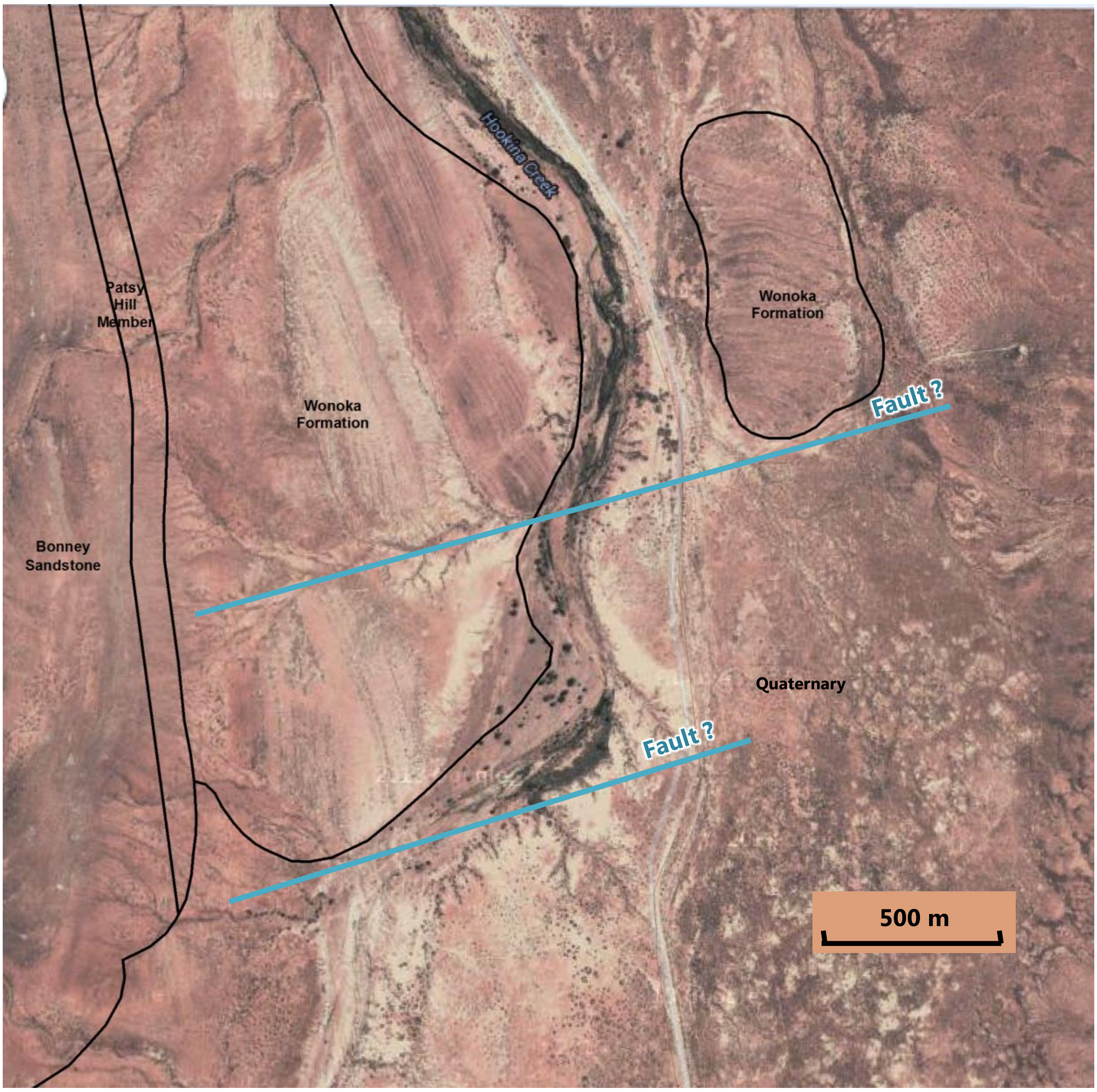

Figure 2. Geology and source of springs

An indicator that this groundwater discharge has been occurring for a considerable period of time is the presence of a very hard, cemented conglomerate in the creek bed, which appears just downstream of where the first signs of discharge were observed (Fig. 3). The conglomerate consists of rounded cobbles (of various rock types) in an off-white calcareous cement, which was probably formed by the evaporation of groundwater discharged from the spring in the creek bed.

For most of the eight kilometre length of creek where permanent flow occurs, the creek bed is mostly covered by reeds (Fig. 4). About 1.8 km from the spring source, some large waterholes have formed probably as a result of scouring of the creek bed during rare flood events that occur every 10–15 years or so. The largest of these is about 3 m deep, with an observed estimated discharge from the downstream end of 1–2 L/sec. Figure 4 also shows how the creek has been incised about 10–15 m into the generally fine grained Quaternary outwash sediments.

The main access to the spring occurs about five kilometres downstream from the source (Fig. 5). Here, the reed beds have been removed, exposing a significant area of the cemented conglomerate over which the creek flows. This is also the location of an offtake for stock supplies. The flow appears to have progressively increased downstream and has been recently gauged by DEWNR to flow at 20 L/sec at this location, with no obvious point source providing the additional flow.

The creek bed conglomerate terminates about one kilometre downstream of the Pungka Pudanha waterhole at a location which corresponds to the western faulted margin of the Flinders Ranges, which is unlikely to be a coincidence. The permanent flows in the creek continue for about another 600 m past this point. In areas where the unconsolidated creek bed gravels were absent, it was observed that the creek bed consisted of a reddish brown low permeability clay. The flow terminated in a deep hole in the creek bed which probably penetrated through the clay layer, allowing infiltration into the underlying more permeable sediments. Just before the creek 'disappears', the flow rate had decreased to an estimated 5–10 L/sec.

Figure 3. Cemented conglomerate deposited in the creek bed

Figure 4. Creek bed covered in reeds

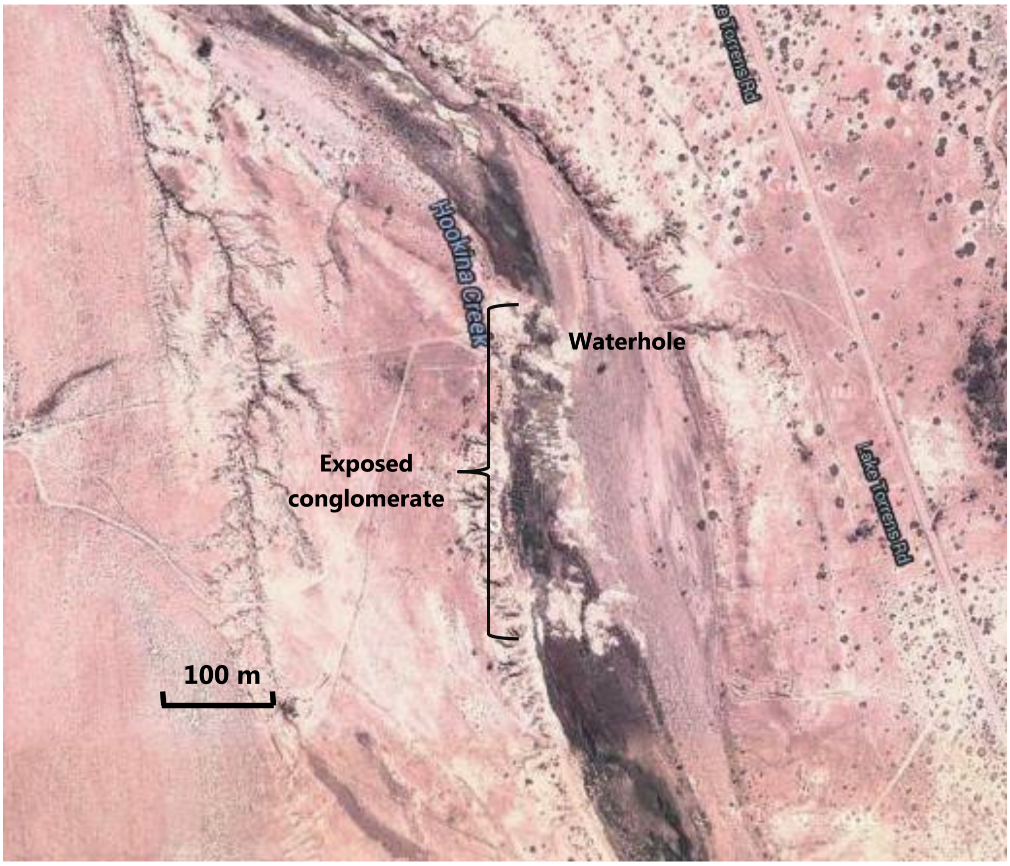

Figure 5. Hookina Spring and area of exposed conglomerate

3 Water sampling

Water samples were collected in the field to help determine the source of the spring water. The absence of a discrete source and poor accessibility along Hookina Creek complicated the process. The first sizeable and accessible waterhole was selected for sampling (Fig. 6). An equipped stock well (Bobby Creek Bore, well 6534-110) located 6 km south of the springs was also sampled. Figure 1 shows the location of the sampling sites. These were collected for laboratory analysis of cations, anions, metals and carbon isotopes. The carbon-14 activity of dissolved inorganic carbon (DIC) in groundwater, expressed as percent modern carbon (pMC), can be a very useful tool for estimating groundwater residence times in the range 500–25 000 years.

Samples were collected and filtered onsite. Filtering samples prevents possible impurities which may be present in the water from influencing concentrations of major ions. General water quality parameters such as salinity, pH and water temperature were also collected at each sample site using an YSI water quality device. Samples for the analysis of carbon isotopes (radioactive carbon-14 and stable carbon-13/ carbon-12) were collected in 1 litre rinsed plastic bottles directly from the pump outlet. The samples were preserved with 3–5 mL of Sodium hydroxide (NaOH 50%) to help to ensure that any dissolved CO2 is fixed and not lost.

The analysis results are presented in Table 1.

Figure 6. Hookina Spring waterhole chosen for sampling

Table 1. Analysis results

MAJOR ION ANALYSIS

Location	Field assessed			Lab assessed										
	pH	*EC (dS/m)*	*Total Alkalinity (meq/L)*	*F^- (mg/L)*	*Cl^- (mg/L)*	*Br^- (mg/L)*	*NO_3^- (mg/L)*	*SO_4^- (mg/L)*	*Ca (mg/L)*	*K (mg/L)*	*Mg (mg/L)*	*Na (mg/L)*	*S (mg/L)*	*Si (mg/L)*
Waterhole	8.1	3.9	5.9	0.5	848	1.4	1.6	546	114	11	104	545	168	5.1
Bobby Creek bore	7.9	3.5	6.8	0.7	666	1.3	9.9	603	116	8.9	107	474	185	8.9

METALS

Location	*As (mg/L)*	*B (mg/L)*	*Al (mg/L)*	*Cd (mg/L)*	*Co (mg/L)*	*Cr (mg/L)*	*Cu (mg/L)*	*Fe (mg/L)*	*Mn (mg/L)*	*Mo (mg/L)*	*Ni (mg/L)*	*P (mg/L)*	*Pb (mg/L)*	*Sb (mg/L)*	*Se (mg/L)*	*Sr (mg/L)*	*Zn (mg/L)*
Waterhole	<0.05	0.49	<0.1	<0.05	<0.05	<0.05	<0.05	<0.1	<0.1	<0.05	<0.05	<0.2	<0.05	<0.1	<0.05	2.5	0.08
Bobby Creek bore	<0.05	0.56	<0.1	<0.05	<0.05	<0.05	<0.05	<0.1	<0.1	<0.05	<0.05	<0.2	<0.05	<0.1	<0.05	2.6	0.10

ISOTOPES

Location	*$\delta^{13}C$ [‰]*	*$\Delta^{14}C$ [‰]*	*pMC [‰]*	*Calibrated age (yBP)*
Waterhole	-10.55	-350.3	64.97	1700
Bobby Creek bore	-10.6	-426.89	57.31	3000

The analyses show that there is a strong similarity between both the spring water and the stock well water, which is pumped from alluvial gravels at a depth of 18 m. The salinity values are 2170 and 1945 mg/L respectively. Although these salinities are theoretically above the World Health Organisation recommended limit for human consumption (1500 mg/L), the spring would have been a valuable drinking supply for short periods if no other source was available. The spring also supplies good stock quality water.

The dominant ions are sodium, chloride and sulfate (Na-Cl-SO_4). The high SO_4 content could be due to the dissolution of gypsum which may be associated with the Wonoka Formation which was deposited in a marine environment. Table 1 also shows that there are no abnormal levels of heavy metals in the water.

In its simplest form, carbon-14 activities of 100 pMC or more represent modern groundwater that has been recharged within the last 50 years, while carbon-14 activities of 50 pMC and 25 pMC indicate that the groundwater has been isolated from the atmosphere for one half-life (5730 years) and two half-lives (11 460 years) respectively. These carbon-14 activities have to be corrected to take into account processes that absorb or release carbon in the subsurface. The University of Oxford has developed a program (OxCal) that provides radiocarbon calibration and a probable range for the initial carbon-14 activity and subsequently probable age range for the sample. The likely upper limit to the age of the water are recorded in Table 1 are 1700 years before present (yBP) for the waterhole and 3000 yBP for Bobby Creek bore.

The elevated age of the groundwater suggests that local modern recharge is not a major contributor to the aquifer beneath the plains or the springs. Discharge from the regional fractured rock aquifers could be occurring at both the spring and Bobby Creek bore which could be mixing with smaller volumes of modern groundwater. The older water at the bore could be the result of diffuse upward leakage from the fractured rock aquifers which would occur at a slower rate than flow through fractures and faults which appear to contribute flow to the spring.

It is important to note that the age of the spring water bears no relationship to the period of time that the spring has been flowing, or the period of occupation by Aboriginal people. If a major earthquake today triggered movement on a major fault resulting in a new spring discharge point nearby, the age of the water would probably still be over 1000 years old.

4 Seismicity

The Flinders Ranges were formed by substantial uplift, both by faulting and broad up-doming during the Cainozoic period, and strong differential weathering and erosion of the folded Neoproterozoic and Cambrian sedimentary rock layers of varying resistance and thickness (Preiss, 1999). Harder rocks such as sandstone and quartzite typically form the high ridges and hogbacks, while softer rocks which are more easily eroded such as shale, siltstone and calcareous siltstone commonly underlie the valleys.

Hookina Spring lies on the western margin of the Flinders Ranges where some of most significant faults, although not exposed, have caused very major displacements of various rock units (Preiss, 1999). Figure 7 shows some of the major faults that have been interpreted from aeromagnetic survey data. Uplift is likely to have continued over the past 40 million years and there is much evidence to suggest that this process in continuing in the present day as outlined below:

- Earth tremors are felt regularly, with anecdotal evidence from a traditional landowner reporting a large bubble emerging from the waterhole during one such tremor. A map of epicentres recorded by the network of seismographs maintained by the Geological Survey (Department of State Development) in Figure 7 shows that a number of smaller earthquakes have occurred in the area.
- The area of exposed conglomerate at the Pungka Pudanha waterhole (Fig. 8) has resulted from local vertical displacement or uplift. The conglomerate exhibits fracturing with some vegetation growing within the fractures (Fig. 9). There are also more recent fresh fractures infilled with splinters of conglomerate.
- Anecdotal evidence from traditional landowners indicates there is less water in the waterhole and that the deep pools seem shallower. This is consistent with the floor of the waterhole being uplifted while the water level in the waterhole remains constant..
- Downcutting of the creek bed into the Quaternary sediments (visible in Figs 4 and 6) also suggests local uplift.

Figure 10 presents a south to north schematic section along Hookina Creek which displays these features and the postulated flow processes.

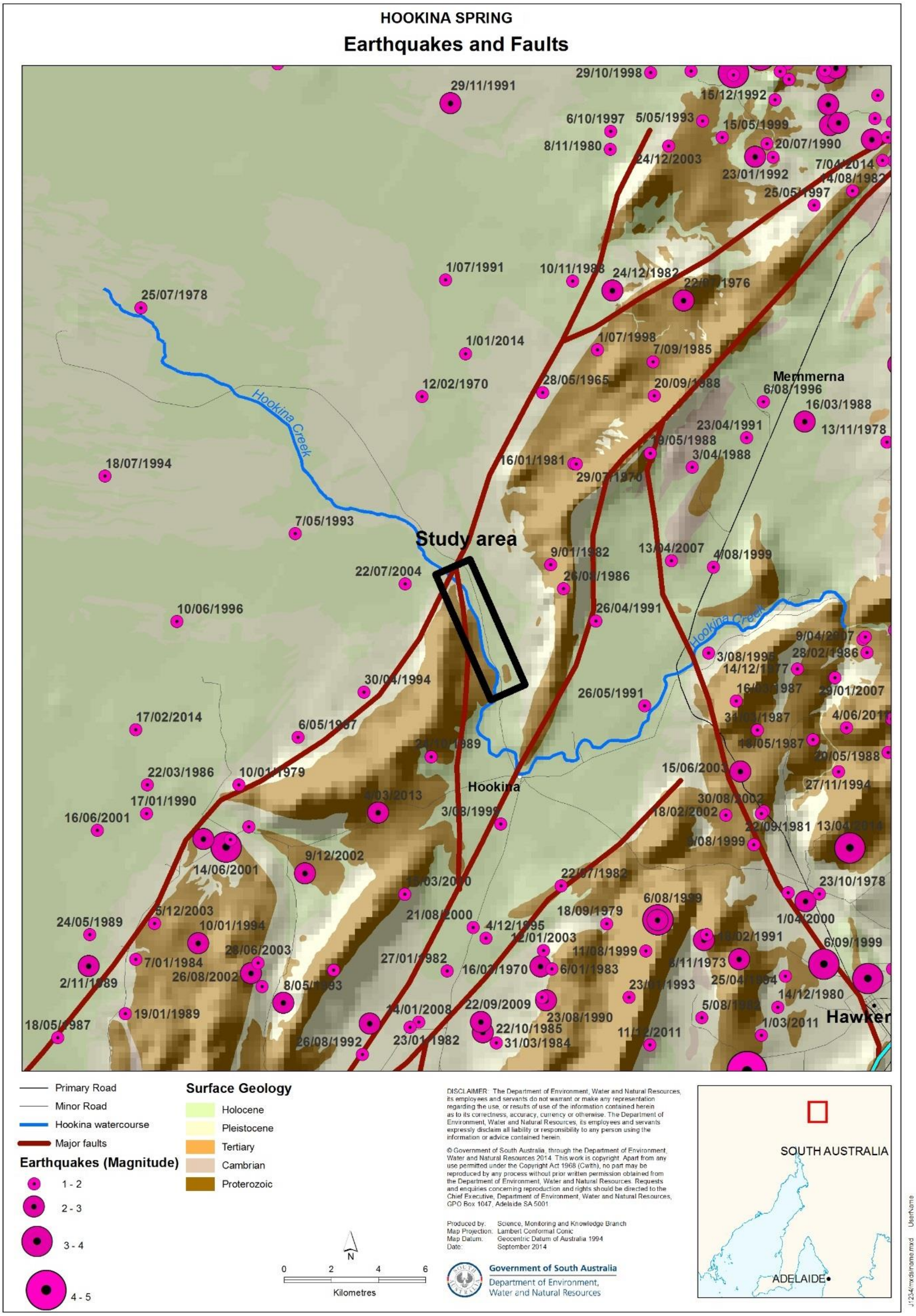

Figure 7. Seismic activity and major faults in the Hookina Spring area

Figure 8. Upward displacement of the creek bed conglomerate

Figure 9. Fractured creek bed conglomerate

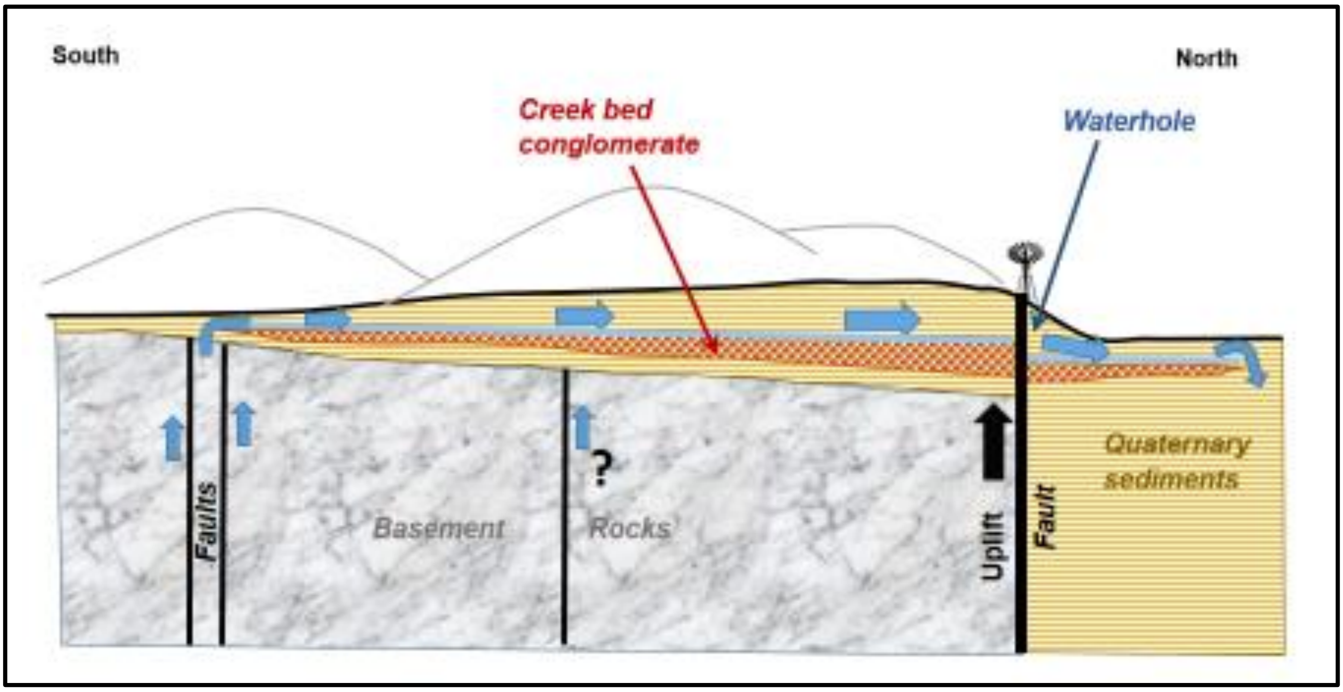

Figure 10. Schematic section along Hookina Creek

5 Source of spring

There are several different types of springs or waterholes in the Far North, each with different sources and flow characteristics.

Fractured rock type springs in the Flinders Ranges are probably sourced from a more localised surface aquifer. Due to the fractured rock environment, groundwater is expressed at the surface at the lowest point in the surrounding terrain, which are usually ephemeral streambeds (White and Scholz, 2008). These streams may flow episodically (after heavy rainfall events) or seasonally. Spring discharge occurs after the stream flow subsides, and will continue to flow in response to the groundwater being recharged from the rain event. Salinities in the more permanent pools are generally low, often below 2000 mg/L (McNeil et al, 2011).

Permanent flowing springs have a reliable source of groundwater that is able to withstand dry seasons and droughts. The groundwater source for these permanent springs is probably supplied through larger regional groundwater aquifers, rather than local sources. To the north in the Great Artesian Basin, most springs are fed by a deep artesian aquifer and form mounds due to precipitation of dissolved minerals and the sediment accumulation around the discharge vent (National Water Commission, 2013). The age of the groundwater in this aquifer is up to several million years old because it has travelled hundreds or thousands of kilometres from the distant recharge areas in Queensland and the Northern Territory.

The Hookina Spring is unique in that it shares none of the characteristics of the above examples. There are no regional artesian aquifers like those that occur in the Great Artesian Basin. It is also highly unlikely that Hookina Spring has a local source because of the elevated age of the groundwater, and the fact that the very low, current recharge rates could not sustain the observed discharge flows of about 20 L/sec for any length of time.

The evidence strongly suggests that “mountain block recharge” may be the source of water for Hookina Spring. Rainfall falling on the Yappala and Elder Ranges to the east has slowly infiltrated down into the fractured rock aquifers (Fig. 11). The lack of vegetation and soil cover on the ranges would enhance such recharge. Groundwater within these aquifers flows under gravity toward the lowest point in the landscape which happens to be Hookina Creek at ~140 m AHD. The extensive faulting in the area as shown in Figure 7 has most likely facilitated regional groundwater flow toward the discharge area, as well as providing the mechanism for discharge in the creek bed as discussed earlier.

Mountain block recharge has been investigated in the Peake and Denison Ranges much further to the north as a source for springs on the margin of the Great Artesian Basin (National Water Commission, 2013).

6 Conclusions and recommendations

As the evidence overwhelmingly suggests a regional source for *Pungka Pudanha*, it is unlikely that the spring flow rate is affected by local or short term influences such as droughts or changes in land use. Consequently, local changes in land management are likely to have no impact on spring flow. However, significant increases in groundwater extraction on the plains to the east of Hookina Creek (i.e. upgradient of the spring) could reduce the spring flow by interrupting the flow from the ranges.

A flow meter should be installed on the offtake which provides stock water for the surrounding rangelands, to ascertain the proportion of spring flow that is diverted for this purpose.

If uplift of the creek bed conglomerate were to continue at the waterhole site, it is unlikely that the creek flow would be permanently dammed, but the flow paths of the creek may move laterally in order to maintain the westerly flow downstream.

More detailed geological mapping is recommended in the vicinity of Hookina Creek to gain a better understanding of the geological structure and faulting patterns that not only control the location of the source of the spring, but also may give an indication of where ground displacement has occurred as a result of recent seismic activity.

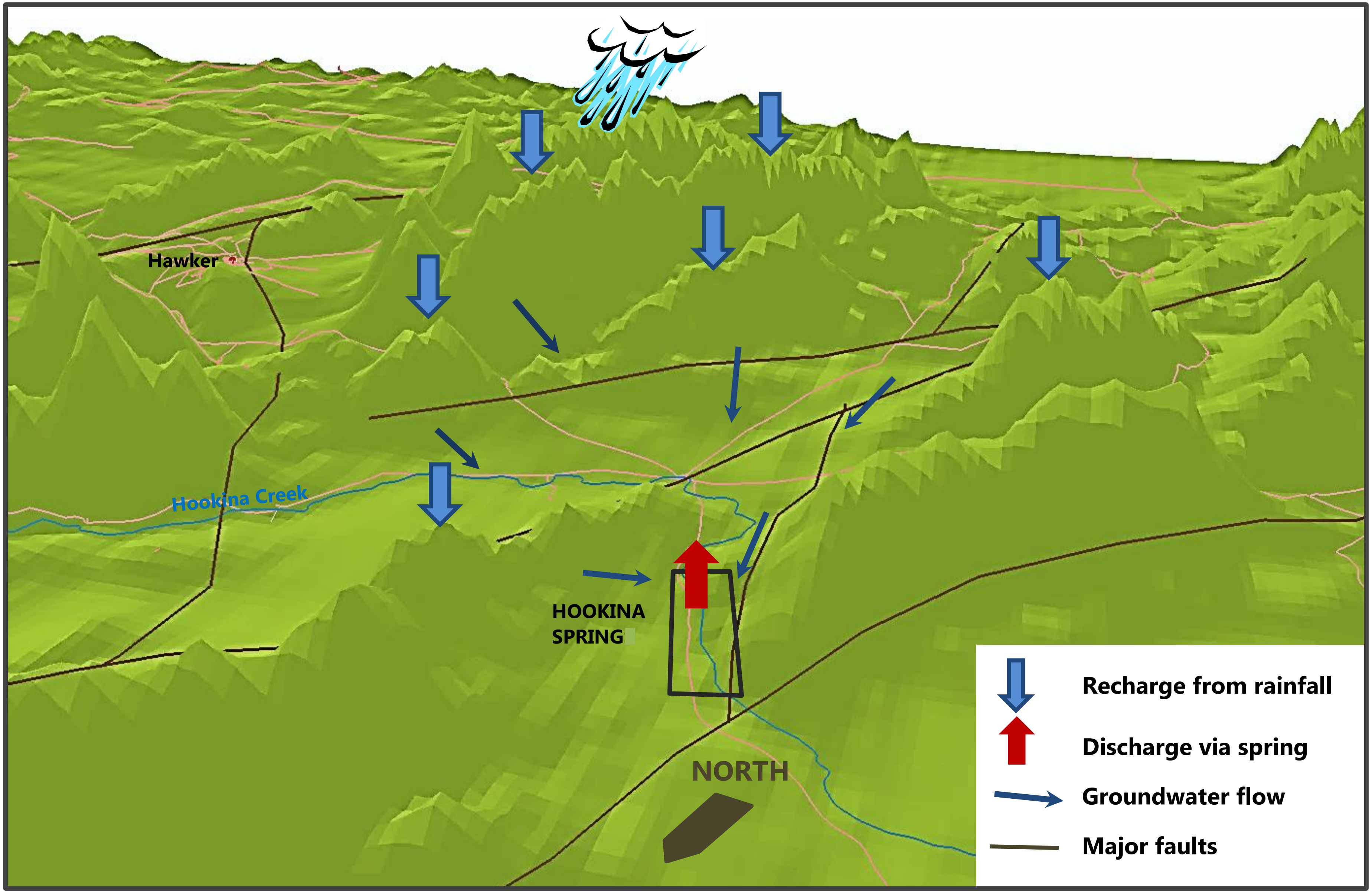

Figure 11. Visualisation of groundwater flow processes

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