FORESTED KARST RESEARCH ACTIVITIES ON QUADRA ISLAND, BRITISH COLUMBIA

– Tim Stokes, Lorill Ireland and Natalie Cielanga*

Quadra Island is one of the larger (20 km by 10 km) islands in the Strait of Georgia - the body of water which separates Vancouver Island from the coast of the British Columbia Mainland. During July and August of 2008 research work was initiated on a forested karst area in the approximate centre of Quadra Island. The initial focus of the research was to investigate the geomorphologic and hydrologic functions of forested karst sinkholes. However, based on the specific concerns of a homesteader whose domestic water was from a karst spring, it became apparent that karst groundwater flow in the area also warranted investigation. (It was suspected that the spring's catchment occurred within an area of ongoing development activity with nearby road side quarrying, forest harvesting and installation of a new transmission line). Hence criteria and methodologies for two small research projects were developed. One project focused on sinkholes and the other on the karst spring. Two students from Vancouver Island University (VIU) – Natalie Cielanga and Lorril Ireland – were directly involved in completing these projects. They have used much of the data as part of GEOL 490 Direct Studies courses which contributed towards their respective degrees with a Minor in Earth Science at VIU. Funding for the project was supplied by an internal research grant from VIU, while logistical support was provided by Paul Griffiths and Carol Ramsey of KarstCare/Cave Management Services. Analytical work and advice for dye tracing procedures was provided by Tom Aley of the Ozark Underground Laboratory (OUL).

Photo 1. Preparing to survey sinkhole and select sites for test pits

The forested karst of Quadra Island is confined to a belt of limestone of the Triassic Quatsono Formation, which extends north-south through the centre of the island. The limestone belt is approximately 15 km long and 1-2 km wide, and varies in elevation from sea level to approximately 100m. Most of the island, including the study area, has been logged in the past and is comprised of second growth forest of various stages. Active logging continues both on and off the karst. The limestone unit is bounded by basaltic volcanic rocks to the west and by granitic rocks to the east, and is steeply to moderately dipping. Much of the limestone is located along a broad topographic low that is mantled by glacial materials. Small (<10 m diameter) sinkholes are common, but variable in their concentration. Large sinkholes (e.g., 40 m in diameter) also occur, but are rarer. Solutional holes and grikes can be found on occasional exposed epikarst zones, which are typically form bedrock highs (or hums). A number of springs occur along lower elevation slopes, while small caves can be found in a number of locations, but are typically not of great length or depth.

Photo 2. One of the smaller sinkholes examined with test pit exposing thick organic soil in centre, along with soil corer.

Forested Sinkhole Project

The objectives for this project were to complete a preliminary investigation into the geomorphologic and hydrologic processes that develop forested karst sinkholes, and in particular examine the aspects of soil movement and accumulation in sinkholes. Some of the initial questions posed were:

- How exactly do sinkhole functions both hydrologically and geomorphologically?
- How does soils move and/or develop in the vicinity of sinkholes?
- How does water move in and around sinkholes?
- Are sinkhole processes on-going and currently active?
- Do sinkholes have discrete and measureable openings beneath them, and are they related to the fracture characteristics of the underlying bedrock?

- When did the sinkholes form and at what rate have these features formed?
- Has later anthropogenic activity altered the function and nature of sinkholes, and the associated karst system?

Photo 3. Digging and logging soil profiles in sinkhole test pits.

The first step in this investigation was to select six sinkholes of differing sizes for detailed examination. Five of the selected sinkholes were in close proximity to each on a gentle sloping bench. Their sizes ranged from 5-12 m in diameter and 1-3 m in depth. The sixth sinkhole was much larger (45 m in diameter and 8 m deep) and was located some distance away at the base of a moderate gradient slope. Each sinkhole and it's surrounding slopes were surveyed in detail using 1 m contour intervals (see Photo 1). To do this a meter staff and a laser distance measuring instrument were use along the four cardinal directions (N, S, E & W) and the four intervening quadrants (NE, SE, NW & SW). Small hand dug test pits were then excavated into the rims, sideslopes and bases (drainage foci) of each sinkhole (see Photos 2 and 3). A soil borer was used to achieve greater depths where the ground was suitable. The soil profiles were recorded, and representative soil materials collected for later examination. Some of the interesting findings resulting from this work include:

- Significant accumulations (up to 80 cm thick) of forest floor organic material at the drainage focii of the five sinkholes, as compared what was present on their rims and sideslopes (5-10 cm thick). Most mineral soils from the five smaller sinkholes appear to be derived from weathered glacial till.
- No significant accumulation of organics at the base of the large (45 m diameter) sinkhole. Most mineral soils likely derived from glacio-fluvial material.
- Visible ash-like layers in the upper soil profiles of at least two of the five smaller sinkholes, with greater thicknesses of ash observed where small draws (linear depressions) enter the sinkholes.
- A large (50 cm) void in glacial material encountered in a test pit on the sideslope of one sinkholes.

The above findings suggest that organic materials have been accumulating for a significant period at the drainage foci of the five sinkholes in the gentle sloping bench area. It is likely that the organic material moved into the base of the sinkholes by a combination of surface water flow and gravity along the sideslopes of the sinkholes. This organic matter may play an important role in the geomorphic (and possibly the biologic) development of these sinkholes.

Based on their size and shape, these five sinkholes have likely formed from on-going solution processes following deglaciation. The lack of organics at the base of the large sinkhole suggests it may have developed differently, and this may in part be related to it shape and slope position. It is also apparent that openings likely occur beneath many of these sinkholes, reinforcing the idea of a close link between the surface and subsurface processes.

Photo 4. Stramberg Farm Homestead With karst spring located 100 m upslope in forest area behind house.

Photo 5. The Stramberg Spring and water storage set up for micro-hydro power generation.

Photo 6. Sink Point and injection site that links by subsurface flow to Stramberg Spring

Photo 7. Measuring water conductivity at a road side spring/seepage

Karst Spring Evaluation

The objectives of the second project were to determine the characteristics and likely catchment of a karst spring (known as the Stramberg Spring) that was being used as a domestic water source and a site for micro-hydro power generation by a local homesteader (see Photos 4 and 5). A number of land use activities are ongoing in the likely catchment of the Stramberg Spring including: forest road construction, timber harvesting, an existing operational gravel road corridor linking the south and north parts of the island, a small road-side quarry development, and construction of a hydro-electric transmission line. The primary concerns for the Stramberg Spring are whether, and to what extent, these ongoing activities might affect water quality and quantity. The first goal of the project was to complete a small dye tracing exercise (during the low flow conditions of the summer) to study subsurface flow paths and determine the characteristics and likely limits of the spring catchment. A secondary goal was to initiate longer term monitoring of the spring using continuous temperature loggers and spot checks of pH and conductivity. Some of the research questions this project sought to address were:

- What is the likely extent of the catchment area that contributes to the Stramberg Spring?
- What are the primary insurgence points that contribute to the Stramberg Spring?
- What are the main subsurface flow paths?
- Are there significant areas of non-karst that are part of the catchment?
- Are there any obvious impacts or sensitive areas within the catchment?
- Is the karst spring associated with a near surface or deeper aquifer?
- How successful will the dyes be for groundwater tracing in this type of forested environment?

Reconnaissance field work was carried out upslope and around the Stramberg Spring to identify: the karst boundary, sink point sites, other springs and outflow sites along creeks. Three sink point sites upslope from the Stramberg Spring were selected for dye injection (see Photo 6).

Approximately fifteen sample sites for dye detectors were chosen including the Stramberg Spring itself, another large spring nearby (the Corner Spring), small seepages/springs and other flowing creeks.

Following collection of background samples, two charcoal detector packets were placed at each sample site, and measurements of water pH and conductivity taken along estimates of flow rate (see Photo 7).

Photo 8. Fluroescein dye appearing at Corner Spring one week after dye injection.

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Photo 9. Some of the 2008 Karst Research Field Crew: Ivanna, Natalie, Lorill and Allen.

Three non-toxic dyes (fluorescein, eosine and rhodamine WT) were chosen for the dye tracing tracing. A different type of dye was introduced into the each of the three sink points. The charcoal packets were left in place for one week after the dye was introduced at the sink points.

After a week the charcoal packets were collected and new ones were deployed. The second set of charcoal packets was collected approximately one week later. Four remaining packets were placed at key sites (including the Stramberg Spring and Corner Spring) and were picked up ten weeks after the initial dye injection.

Results from the dye tracing showed that, at low flow conditions, the subsurface flow path of the Stramberg Spring connected with one sink point, while the Corner Spring was connected to the other two sink points.

In both cases these sink points were located directly 500-700 m upslope of the springs with the subsurface flow paths approximately following the slope of the land. Dyes reached both springs within the first week of sampling and were apparent in both springs after the second week (see Photo 8).

Dye was also found in the Stramberg Spring ten weeks following dye injection. For the most part precipitation rates were minor following dye injection. Flow rates at most of the sample sites gradually decreased over the sampling period, while those at the Stramberg Spring were more constant.

Data from continuous temperate loggers placed in the Stramberg Spring site showed a good correlation between slight increases in the spring water temperature and increases in the ambient air temperature.

From the dye trace results to date it is apparent that the Stramberg Spring is connected directly to one of the three sink points injected during low flow periods. This sink point is adjacent to a recently constructed forest road and a harvested cut block. The stream contributing to this sink point extends 200-300 m upslope toward the karst unit boundary and appears to include a small non-karst catchment. Simple comparison of the flow rates at the sink point and the Stramberg Spring indicate that other sources contribute water to this spring, some of which is likely autogenic.

The relatively slow movement of dye through the groundwater system suggests some level of aquifer storage and likelihood of a reasonably deep groundwater system. The correlation between spring water temperature and ambient air temperature are likely explained by reappearance/disappearance of water flow in a creek section immediately upslope of Stramberg Spring.

Further Research Activities

It is anticipated that further work will be carried out on both projects during 2009. Further sinkholes in different settings (e.g., upper elevation) could be investigated using similar techniques of detailed mapping of their morphology and examination of soil profiles. Methodologies could also be developed to try and trace the surface and subsurface water flow characteristics in and around sinkholes (e.g, by techniques such as dye tracing, salt, or resistivity).

A selected area of sinkholes may also be chosen for a ground penetrating radar survey. Techniques to measure CO2 gas exchange around sinkholes could also be tried in order to identify or confirm sites of biological activity (e.g., at the drainage foci of sinkholes with organic accumulations).

For the Stramberg Spring Project, the next logical step would be to replicate the dye trace during the high water flows of the wet winter season. Of particular interest would be determining whether there are any cross-over or connections of the subsurface flow paths between the various sink points and springs.

Continuous temperature loggers (and possibly pressure/water level loggers to help determine flow rates) could also be placed in the three sink points and at both the Stramberg and Corner Springs to better understand aquifer characteristics.

A preliminary grab sample has been collected for water chemistry analysis during low flow. Others could be collected at different flow regimens throughout the year to see whether and how water chemistry varies.

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* Earth Science Department, Vancouver Island University, Canada.