Estimated Accuracy of Distribution of Route of Water Path on Mountainous Slopes Using Groundwater Aeration Sounds

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1. Overview

In the past, it has been pointed out that subsurface water paths have been involved in collapses, and a simple way of identifying water paths which can be carried out on steep slopes has been long awaited. Tada et al. (2006) proposed a way to identify the location of water paths by using the sounds produced by groundwater flow. However, it is not clear if this method can estimate areawide distribution of routes of water paths on actual slopes. In order to examine the accuracy of the groundwater aeration sound survey method in identifying areawide routes of water paths, this study estimates dimensional routes of water paths on mountainous slopes using groundwater aeration sound surveys and aligns those with the results of hydrological observations carried out in the past, the routes of water paths estimated from surveys of underground temperature at 1m depth, as well as electric surveys.

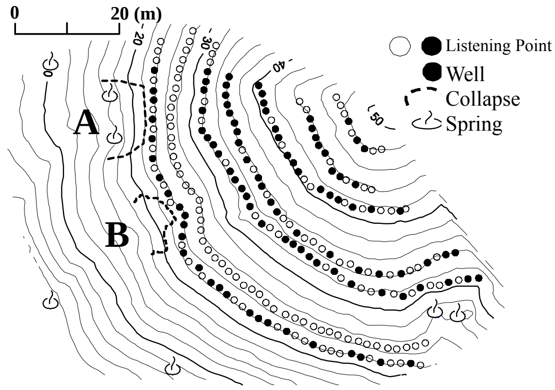

Figure 1 Studied Slope and Various Points of Measurements

2. Investigation Site and Method

An investigation was carried out in a forested area of Japanese cypress in Kagamino-cho, Okayama prefecture. Figure 1 shows the topography of the studied slope. The slope studied has a ridge type slope of an average gradient of approximately 30°. The geological features are granite and 1m of volcanic ash has accumulated on the surface soil. There is a knick line around a relative height of 15m and there are two collapses below the knick line. The slope legs show multiple spring points, which can be seen in the collapse legs and valleys, etc.

We set up measurement lines in the direction of contour lines on this slope and carried out a groundwater aeration sound survey and conventional multiple water path survey methods.

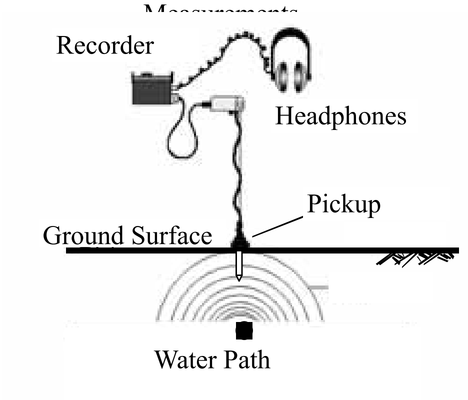

Figure 2 Schematic Depiction of Groundwater Aeration Sound Measurements

(1) **The groundwater aeration sound survey** (Figure 2): We estimate water path locations by utilizing the strength of sounds produced by groundwater flow. Groundwater aeration sounds were measured twice in November, 2004 and July, 2005 and measurements were at 2 m intervals (○, ● shown in Figure 1) in the direction of contour lines.

(2) **Groundwater level observation**: We placed maximum water level gauges at points where the strength of groundwater aeration sounds can be heard (● shown in Figure 1). The depth of wells were discovered to be a bedrock of Nc＝40 according to the penetration test. A total of 12 rainfall events were measured from November, 2004 to December, 2005.

(3) **Survey of underground temperature at 1m depth**: With reference to Takeuchi (1978), we measured the underground temperature at 1 m depth twice on July and November, 2005 (● shown in Figure 1).

(4) **Electric survey (two-dimensional IP image method)**: We surveyed the distribution of resistivity of the bedrock using SYSCAL Kid Switch 24 (Oyo Corporation). Measurements were carried out from October to November, 2005 on each measurement line. The electrode configuration was in accordance with the dipole-dipole method and the electrode interval was set at 1m.

3. Estimation of Water Paths Using Conventional Survey Methods

(1) **Groundwater level observation**: Figure 3 shows the frequency distribution of groundwater level generation. On observation slopes, places where groundwater level is generated were fixed independent of the amount of rainfalls. We estimated these places of high frequency as routes of water paths.

(2) **Survey of underground temperature at 1 m depth**: It is said that points where there are water paths demonstrate low temperatures during the summer season (Takeuchi et al., 1978). In the ground temperature distribution measured on July, 2005, this trend was clearly confirmed. Thus we connected low temperature points to define water paths.

(3) **Electric survey**: Locations of low resistivity were defined as water paths using the distribution of resistivity of each measurement line.

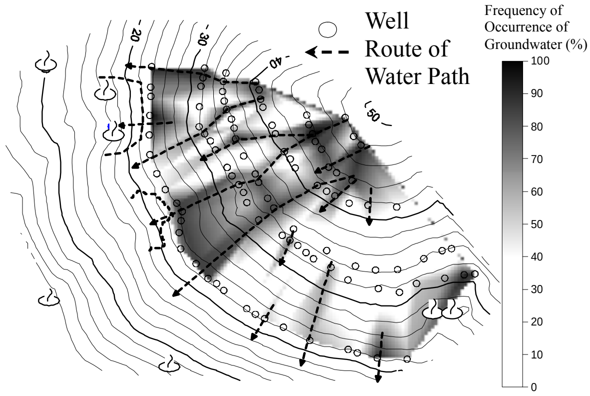

Figure 3 Routes of Water Path Estimated
Using Frequency Distribution Generation of Groundwater

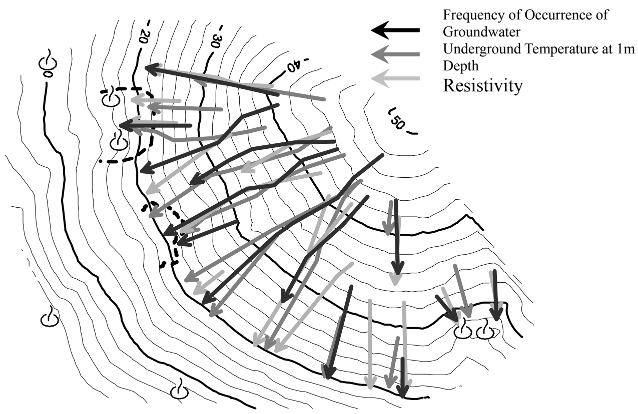

Figure 4 Routes of Water Paths Estimated Using
Conventional Water Path Survey Methods

We mapped those locations on the flat to define routes of water paths. We also carried out surveys in a vertical direction and found water paths in vertical directions which connect the soil layer and bedrock.

Figure 4 shows routes of water paths estimated by each survey method other than the groundwater aeration sound survey. Every one shows a similar route and we have identified locations where many routes repeat as the most probable routes of water paths.

4. Accuracy of Identifying Water Paths Using Groundwater Aeration Sound Survey Method

Figure 5 shows the distribution of groundwater aeration sounds measured on November, 2004. The darker the color, the higher the groundwater aeration sound level shown. In the groundwater aeration sound survey method, since a position where the sound level is high is estimated as a route of a water path (Tada et al. 2006), routes of water paths such as → shown in Figure 5 can be estimated.

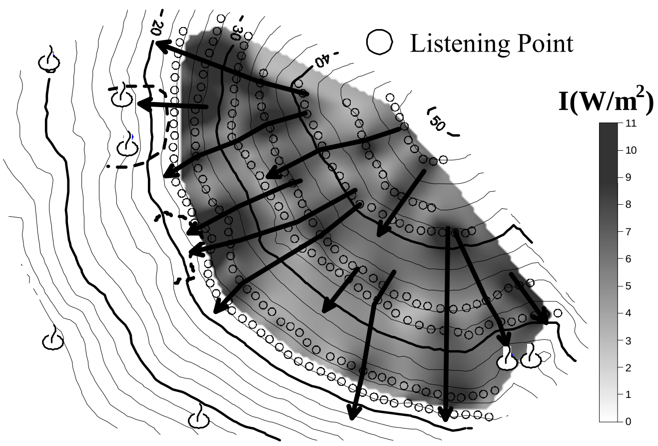

Figure 5 Distribution of Groundwater Aeration Sounds
and Estimated Routes of Water Paths

Figure 6 maps the most likely water paths estimated by the distribution of groundwater aeration sounds measured on November, 2004 and other survey methods. The most probable water paths estimated by multiple conventional survey methods and the high point of groundwater aeration sound levels are aligned. We judge that the groundwater aeration sound survey can identify water paths with the same level of accuracy as conventional methods.

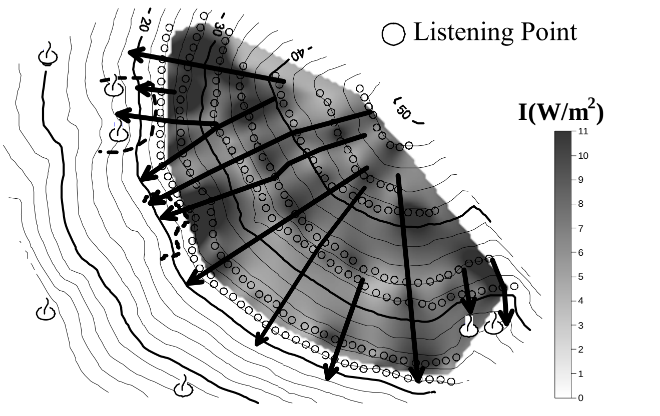

Figure 6 Comparison of Distributions of Groundwater Aeration
Sounds and Routes of Water Paths Estimated by Using Three
Conventional Methods

5. Conclusion

The groundwater aeration sound survey can identify routes of water paths in shallow soil with the same level of accuracy as the survey method for estimating routes of water paths, which has been carried out on steep slopes in the past. In addition, it is not mentioned in the article, this measuring device is very light weight and is able to measure a large area in a short time. We consider the groundwater aeration sound survey to be effective in identifying route of water paths, which are involved in collapses on steep slopes.

Cited References

Atsuo Takeuchi et al. (1978): "Drainage works based on the results of surveys of underground temperatures at 1m depth on landslide area in Miyakami and their effects", Land Slide, Vol.50, No.1, pp.17-22

Yasuyuki Tada et al. (2006): "Estimation of underground water pathways by underground aeration sound", Annual Journal of Hydraulic Engineering, No.50