The Use of Geographical Information Systems in the Planning Phase of a Fieldwork Project

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This article will demonstrate how a digital elevation model for a catchment area on the Faeroe Islands has been used in a geographical information system to select suitable sites for rain gauge mounting in order to reflect the orographic conditions. Furthermore, it will demonstrate how to identify one or more locations in the terrain, from where all the rain gauges are visible. The localization of such viewpoints may be of great value when selecting optimal positions for setting up a levelling instrument to determine the exact coordinates of the rain gauges.

Keywords: *Geographical information systems, digital elevation model, fieldwork planning, rainfall monitoring, visibility.*

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The potential of digital elevation models in the planning of fieldwork projects related to drainage basin analysis is great. When using a simple, grid-based geographical information system (GIS), it is possible to derive much topographical information from a digital elevation model. This information may be most useful when contemplating optimal locations for siting climatological or hydrological measuring devices in the field. Algorithms for calculating visibility may also be of help when it comes to the selection of areas qualifying as viewsheds.

As a part of the preparation for an investigation in 1988 on the island of Vagar in the Faeroes in the North Atlantic Ocean (62°N, E 7°E), a digital elevation model for a catchment area of 6.2 km^2, with an outlet to Lake Fjallavatn, was produced and analyzed. The scope of the course was mainly to introduce various field techniques to a group of under-graduate physical geographers. Due to a 10-day time limitation for the field period, careful preparation was necessary before arrival. It was the objective of the student team to monitor the water balance of the catchment area during this period. Two automatic weather stations were established in the area of study, and as a supplement a number of local rain gauges were placed within the catchment area to monitor local differences in precipitation due to the orographic effect.

This paper will illustrate how it is possible to use a GIS to suggest potential locations of rain gauges and how to assess the areal contribution made by each of these gauges when estimating the total precipitation for the area of study. Furthermore, it will illustrate how to find one position, or several positions, in the landscape from where all the local rain gauges are visible will be demonstrated. The latter may be useful for checking the rain gauges from afar or identifying sites where a levelling instrument could be erected to measure the exact position of the rain gauges in the terrain.

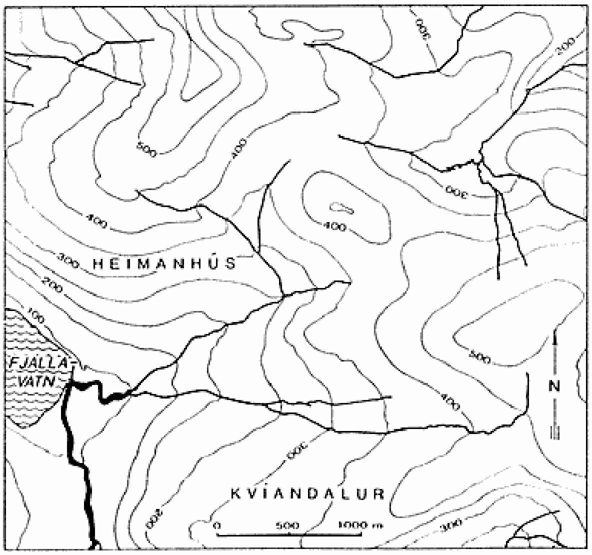

Fig. 1. The area of investigation on the island of Vagar, the Faeroe Islands, UTM zone 29V N6890000-6886000, E589000-593000.

It is not within the scope of this paper to evaluate the results of the field course, such as the observed precipitation in relation to the orographic conditions. The data collected in the field are discussed in the students' report (Naturgeografisk Hovedfagskursus, 1988). This paper will only illustrate how very simple GIS analysis may be of assistance in the planning phase of a fieldwork project.

AREA OF STUDY

The catchment area studied is located in the central part of the island of Vagar, UTM zone 29V N6890000-6886000, E589000-593000. The size of the catchment area is approx. 6.2 km^2. The lowest areas, 94 m asl., are found around Lake Fjallavatn in the SW and the highest areas, approx. 560 m asl., are found in the NE. The area is dominated by Tertiary basalts. The deposits have been heavily eroded since then, especially during the Quaternary glaciation. Several dykes have been deeply eroded and two major river systems are today found between the mountain regions of Heimanhus and Kviandalur, figs. 1 and 2. The climate is cool temperate maritime with an

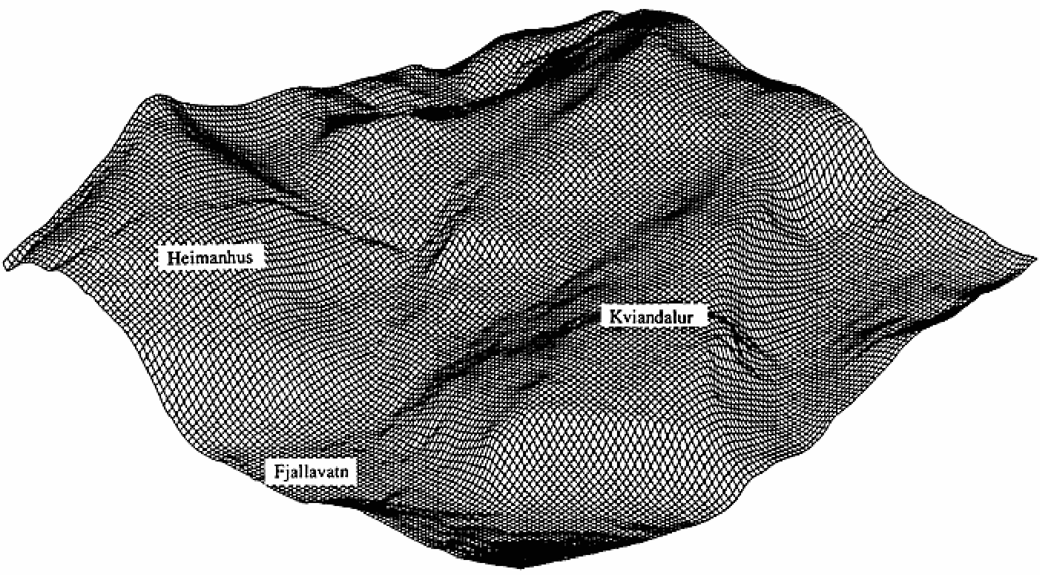

Fig. 2. Perspective view of the digital elevation model. The study area is viewed from SW. Vertical exaggeration: approx. 3x.

average temperature for the period 1964-87 of approximately 6°C, (warmest month, August, 10°C, and coldest month, January, 2°C). The annual precipitation is approx. 1645 mm. Cloud cover is, in general 6-7/8 and the prevailing wind directions are W and SE (Naturgeografisk Hovedfagskursus, 1988).

METHODS

Elevation and Slope Aspect

A digital elevation model was created from a set of digitized elevation contours mapped at precise, 10-metre intervals. Before this advance in technology, the elevation model used to be created from a stereo-pair of panchromatic aerial photographs at a scale of approximately 1:10,000. For the analysis, a grid-based GIS called OSU-Map-for-the-PC, (OSU-Map-for-the-PC, 1989), was used. The contours were transformed into a regular grid using SURFER software (Golden Software, 1989). In order to cover the entire catchment area, it was necessary to establish a dataset covering a total of 4 km by 4 km. The grid-based version of the elevation data was converted to a format 128 x 128 grid cells in the GIS where each cell represented an area of 32 m by 32 m in the field.

It was planned to place a number a rain gauges in the terrain in order to assess the orographic effect. Thus, the relief factors, elevation and exposure, were to be investigated and compared. To get an idea of these conditions, the following two maps were derived from the elevation model:

a) ALT6SLIC, fig. 3, showing the elevation model divided into 6 height intervals.
b) ASPECT5, fig. 4, presenting 4 slope face directions and flat surfaces (northern, eastern, southern, western and horizontal aspects).

A comparison of the two maps presented in figs. 3 and 4 will indicate where to match a specific elevation interval with a specific aspect. A cross-combination of all the zones of the two maps would ideally produce 6x5=30 classes. However, when combining the two extreme levels of the elevation model to their nearest interval classes, the number of elevation zones may be reduced to 4, so that the number of cross-combinations will be reduced to 4 x 5 = 20. As the occurrence of flat areas is limited to the banks around the lake, see figs. 1 and 2, the number of cross-combinations may be reduced to 4 x 4 + 1 = 17. The resulting 'cross-combination' map, ELEVASP, is presented in fig. 5.

Areal Representation of the Rain Gauges

The size of each ELEVASP-region is listed in table 1. All areas belonging to the same class are summed up so that the table expresses hypsographic information as well as orientation. The areal contribution of each rain gauge measurement may be used to estimate the total amount of water added during a rainfall period if it is assumed that precipitation is constant within each ELEVASP-region.

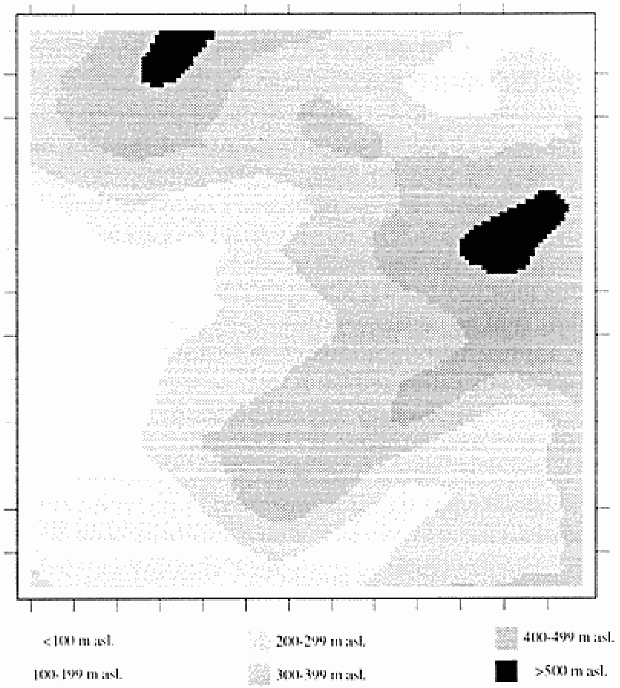

Fig. 3. The digital elevation model divided into 6 intervals (ALT6SLIC). Areal extent: approx. 4.1 km by 4.1 km.

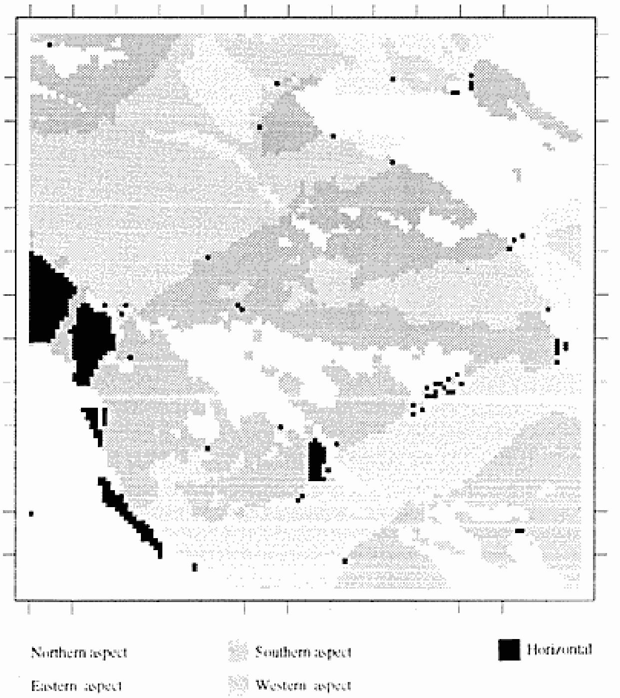

Fig. 4. Slope aspect (ASPECT5). Areal extent: approx. 4.1 km by 4.1 km.

Gauge no.	1	2	3	4	5
area, km²	0.28	0.48	0.50	0.31	0.43
Gauge no.	6	7	8	9	10
area, km²	0,62	0.33	0.45	0.70	0.38
Gauge no.	11	12	13	14	15
area, km²	0.28	0.20	0.52	0.33	0.34
Gauge no.	16	17			
area, km²	0.13	0.15			

Table 1. Areal representation of the rain gauges.

Inside each of the 17 ELEVASP-regions, 17 places were selected at random as potential sites for rain gauges.

The Selection of Optimal Viewpoints

Using the facilities of the GIS with respect to field of vision investigations, it is possible to identify areas where specific conditions concerning visibility are satisfied in the field. The following example illustrates how to find specific locations inside the area of study from where a maximum number of rain gauges are visible at the same time. This may be of interest if one wishes to record the true coordinates for the positions of the rain gauges in the terrain using a levelling instrument. To do this in practice, it is preferable to work with as few mountings of the levelling instrument as possible. Finding one or more suitable locations in the terrain from where to level for as many rain gauges as possible, without having to move the levelling instrument, the use of the GIS is beneficial. During the field period, it may also be of interest to know the points from where all the rain gauges are visible if one wishes to do a remote check (i.e. using binoculars) to see, for example, whether the rain gauges are still mounted to their poles or not.

This investigation, using the GIS, may be based on the calculation of the field of vision using the elevation model and the rain gauge positions.

If we assume that the coordinates of the weather station near the lake represent a fixed point, it will be possible to determine the coordinates for all rain gauges by finding one, or more, point(s) from where all instruments are visible. To perform this analysis using the GIS facilities of the OSU-Map-for-the-PC, the analysis will be performed in four steps namely:

- Step 1: Find all the areas visible from any rain gauge.
- Step 2: Combine all visible areas found in step 1 to form a map showing viewpoints from where a maximum number of rain gauges are visible.
- Step 3: Investigate the viewpoints found in step 2 with

respect to which specific rain gauges are visible in the terrain.

- Step 4: Examine how many locations one has to select to view all the rain gauges in the terrain, ensuring an overlap of at least 1 rain gauge for each set-up site of the levelling instrument so as to enable the transfer of at least one fixed point from one site to another.

Step 1: All the areas visible from any rain gauge are found and recorded on individual maps like fig. 6.

Step 2: The visible areas found in step 1 are combined to form a map which indicates the location from where as many rain gauges as possible are visible. For the area of study, only 5 major clusters of locations are found, fig. 7, from where 10-13 rain gauges are visible at the same time.

Step 3: As the map in fig. 7 does not say anything about which specific rain gauges are visible, one has to investigate the visible areas from each of the 5 major clusters found in step 2. During this step, the contiguity of the 5 clusters was tested. This test proved that from all individual cells within the clusters exactly the same gauges were visible. The result is listed in table 2.

Step 4: From table 2 it can be deduced that from either viewpoint 2 or 4, combined with viewpoint 5, all the rain gauges may be seen. In total, 3 more gauges are visible from viewpoint 2 than viewpoint 4. Furthermore, 7 rain gauges are visible from both viewpoint 2 and 5 but only 4 gauges are visible from both viewpoint 4 and 5. Hence, whether location 2 or 4 is selected as the viewpoint site for levelling is of no consequence.

The approximate locations of the selected viewpoints can be roughly estimated from their position in the grid-based GIS. The row and column positions can easily be transformed to approximate UTM-coordinates as each cell has a size of 32 m by 32 m in the field. The locations of the viewpoints may then be transferred to the topographic map, fig. 1.

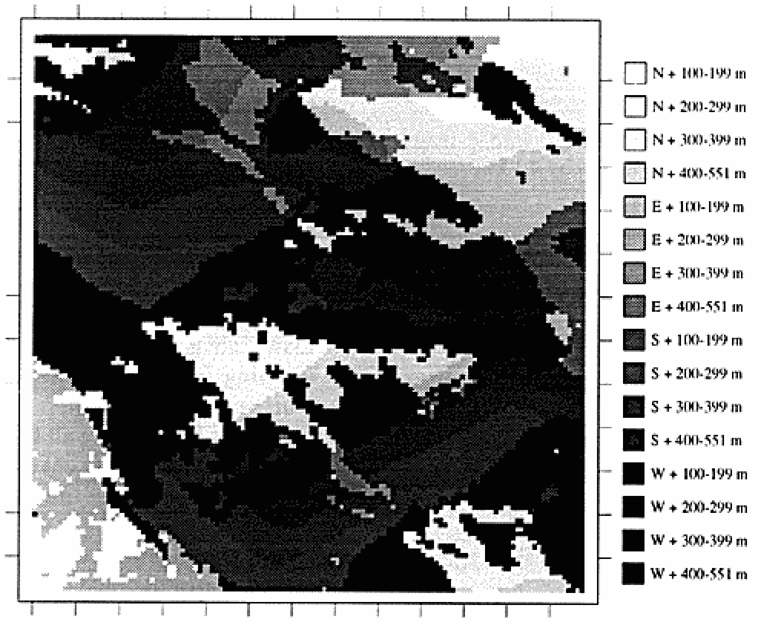

Fig. 5. The result (ELEVASP) of the cross-combination of the interval elevation model (ALT6SLIC, fig. 3) and the map showing aspects (ASPECT5, fig. 4). Due to the availability of only 16 grey tones for printing, all horizontal areas have been added to region W + 400-551 m. Areal extent: approx. 4.1 km by 4.1 km.

DISCUSSION AND CONCLUSION

The method sketched here to identify selected sites for rainfall monitoring proved successful in the field. From the report on the amount of rainfall observed in the various gauges, it was possible to discuss the orographic effect. During the study, two periods of rainfall were of note during which the wind directions were N and S-SE, respectively.

The optimal viewpoints were, unfortunately, not ready at the time of the field project campaigns and therefore the viewpoints have not yet been validated. If the terrain model is true, the viewpoint locations should be correct, assuming that no local obstacles, that have not been taken into account in the model, obscure the view from the selected locations.

It has therefore been demonstrated how a basic digital

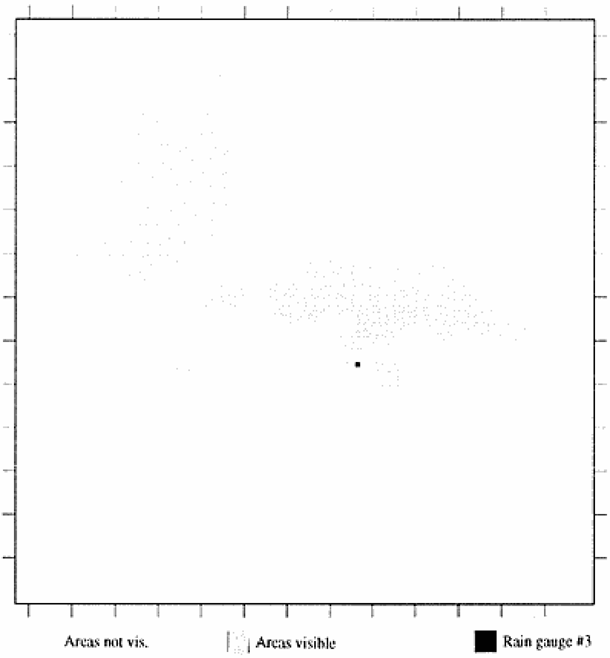

Fig. 6. An example of areas visible and not visible from rain gauge no. 3.

Gauge No.	Viewpoints 1	2	3	4	5
1	x	x	x	x	
2	x	x	x	x	
3	x	x	x	x	
4	x	x	x	x	
5	x	x			x
6		x	x		x
7			x		x
8					x
9	x	x			x
10					x
11					x
12		x	x	x	
13	x	x	x	x	x
14	x	x	x	x	x
15	x	x	x	x	x
16	x	x	x	x	x
17		x		x	
total no. visible gauges	10	13	11	10	11

Table 2. Visible rain gauges from selected viewpoints.

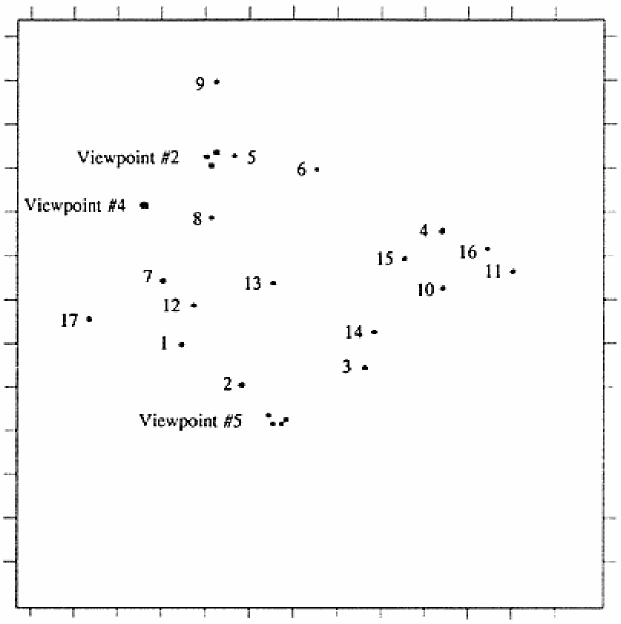

Fig. 7. Map showing the locations of all the rain gauges and viewpoints no. 2, 4 and 5, from where all rain gauges are visible in accordance with table 2.

elevation model may be used in the preparatory phase of fieldwork projects. The effort made in establishing a digital elevation model is fully compensated when one considers the time saved in the field. Several maps, other than the ones shown in this paper, may be derived easily from a digital elevation model using a basic GIS. Such maps would be able to elucidate other factors related to drainage basin analysis; slope features, surface irregularity, hill and valley systems, run-off patterns etc. This is indeed the intention of the author, whose investigations up till now have been confined to the selection of suitable sites for setting up local rain gauges and the identification of specific viewpoints from where these rain gauges may be visible. The success gained from these initial experiments must be said to be very encouraging.

References

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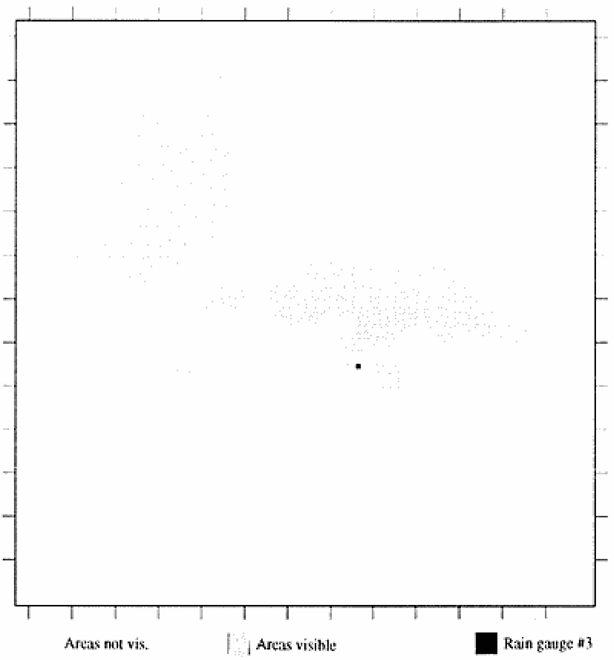

Fig. 6. An example of areas visible and not visible from rain gauge no. 3.

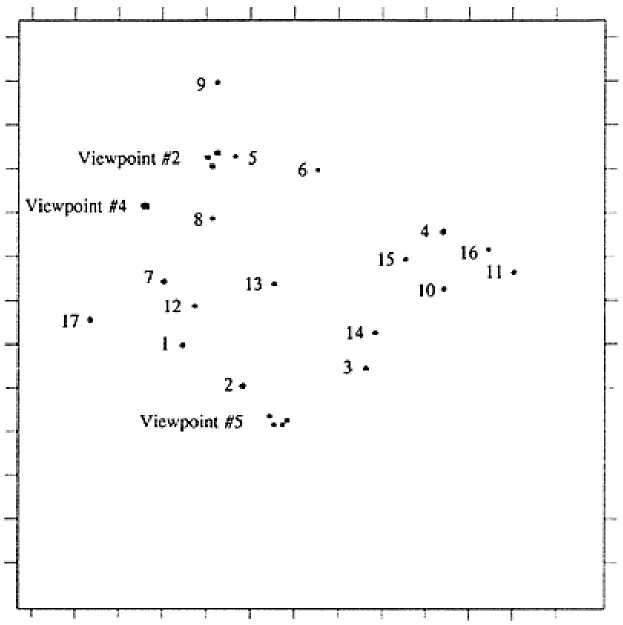

Fig. 7. Map showing the locations of all the rain gauges and viewpoints no. 2, 4 and 5, from where all rain gauges are visible in accordance with table 2.

Gauge No.	Viewpoints 1	2	3	4	5
1	x	x	x	x	
2	x	x	x	x	
3	x	x	x	x	
4	x	x	x	x	
5	x	x			x
6		x	x		x
7			x		x
8					x
9	x	x			x
10					x
11					x
12		x	x	x	
13	x	x	x	x	x
14	x	x	x	x	x
15	x	x	x	x	x
16	x	x	x	x	x
17		x		x	
total no. visible gauges	10	13	11	10	11

Table 2. Visible rain gauges from selected viewpoints.

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