Reviewed research article

What can we learn from previous generations? Álftaver's experience of the 1918 Katla eruption

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Abstract — *Residents in Álftaver are very familiar with the 1918 Katla eruption, which caused rapid and catastrophic glacial outburst flooding of the area. Descriptions of the 1918 events, passed down by older generations, have become an important part of the collective memory. Based on oral and written history, this paper provides a vivid account, including detailed maps, of what people experienced and felt during the 1918 Katla eruption. It also considers how these experiences influence current-day perceptions and the impact this may have on behaviour in relation to emergency response strategies. Until now, much of this history has only been accessible in Icelandic text and through oral stories. The aim of this paper is to unlock these stories for an international audience in an effort to advance understanding of volcanic eruptions and their impacts and, inform future emergency planning. Importantly, these descriptions tell us about the nature of the glacial outburst flood, with a 'pre-flood' devoid of ice and travelling at a much faster rate than the ice-laden main flood. As a future eruption of Katla may impact Álftaver, emergency response plans for glacial outburst floods were developed, and in March 2006 preliminary plans were tested in a full-scale evacuation exercise involving residents and emergency response groups. But Álftaver residents questioned the plans and were reluctant to follow evacuation orders during the exercise, as they felt their knowledge and the experience of their relatives during the 1918 Katla eruption, had not been taken into consideration. Residents were concerned that flood hazards, as well as tephra and lightning, were not appropriately accounted for by officials. In response to residents' concerns, officials developed an alternative evacuation plan (Plan B) that builds on some of the experience and knowledge of Álftaver residents. However, residents were not involved in the development of 'Plan B' and they are not aware of what it constitutes or when it is to be implemented. This paper argues that more needs to be done to promote inclusive dialogue and the co-production of knowledge to ensure emergency response strategies adequately reflect and accommodate local knowledge, perspectives and planned behaviour.*

INTRODUCTION

Katla is one of Iceland's most active and dangerous volcanoes, erupting at least 21 times since Iceland was settled around 874 CE (Guðmundsson, *et al.*, 2007; Larsen and Guðmundsson, 2016). This large volcano, situated beneath the Mýrdalsjökull ice cap in the south of Iceland, has produced on average two major eruptions per century. These eruptions can melt their way through the ∼400m thick ice, breaching the glacier surface Björnsson *et al.*, 2000. The last time this occurred was on 12 October 1918. The first-hand experience of this eruption among the farming community of Álftaver (Figure 1) is the primary focus of this paper.

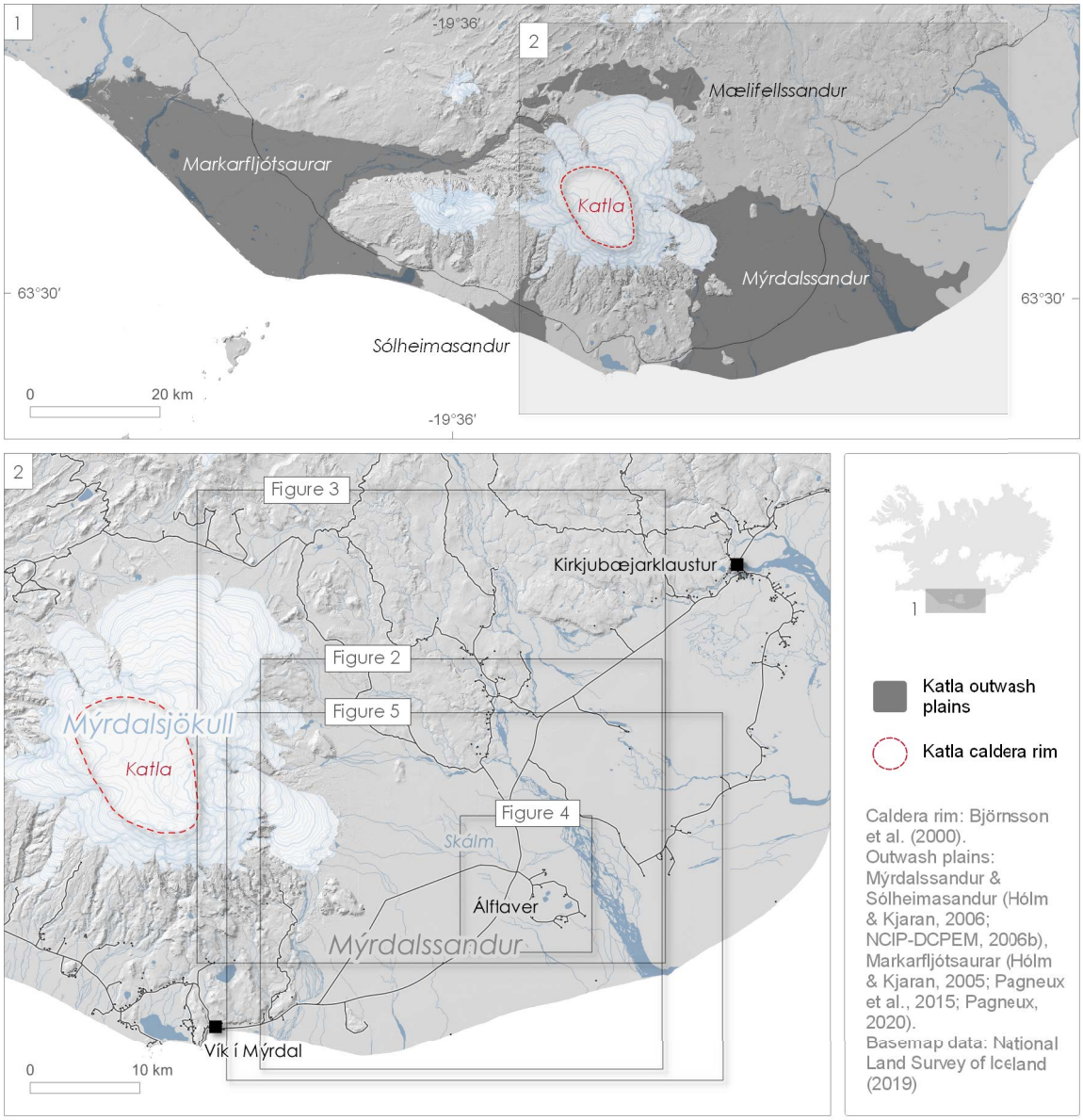

Figure 1. The farming community of Álftaver is situated on the Mýrdalssandur outwash plain, a low-land area prone to glacial outburst floods caused by eruptions of Katla volcano. Of the four outwash plains sustained by volcanogenic floods (top), Mýrdalssandur has been the most active in historical times. Areas displayed in Figures 2–5 are framed. – *Eldstöðin Katla og umhverfi hennar. Efri myndin sýnir helstu áhrifasvæði jökulhlaupa frá Kötlu. Neðri myndin sýnir umhverfi Kötlu þar með talið sveitina Álftaver sem hefur verið í mestri hættu vegna jökulhlaupa frá Kötlu um Mýrdalssand. Rammar afmarka svæðin á myndum 2–5.*

It was a busy time of year in Álftaver in the lead up to the 1918 eruption. Able-bodied men were gathering sheep and herding them down from the summer pastures as part of their routine, annual activities. Other farmers were at the sheep sorting pens north of the Skálm river ready to receive the sheep, while many women, children, youngsters and the elderly, were at home on the farms, preparing for the arrival of the herders and sorters. Based on oral and written accounts, there is no doubt that the eruption took people by surprise. With the spread of people over the region, and due to their initiative in documenting what they witnessed and experienced, they have provided us with a critical insight into the suddenness, and destructiveness of Katla.

Until now, much of this history has only been accessible in Icelandic text and through oral stories, passed down by older generations. The aim of this paper is to unlock these stories for an international audience in an effort to advance understanding of volcanic eruptions and their impacts and, inform future emergency planning. As Pyle (2018, p. 458) highlights "*reading of a wider range of contemporary sources that document the broader personal, social, economic and political impacts of prior events will enrich and add to our capacity to anticipate, prepare for and mitigate the consequences of future events.*"

The importance of this work, however, extends beyond providing an international audience with a vivid account, including detailed maps, of what people experienced and felt during the 1918 Katla eruption. It also considers present-day emergency response strategies, which up until recently focused solely on mitigating the impact of glacial outburst floods produced during a Katla eruption. Following this, the paper describes how the farmers' experiences of the 1918 Katla eruption have influenced current perceptions and the impact this may have on behaviour in relation to emergency response strategies. The discussion section highlights how these findings support the need to adopt participatory approaches for the development of emergency response plans. By including local residents as partners in the planning process, participatory approaches promote critical dialogue and the co-production of knowledge among officials and residents and, they are increasingly recognised as best-practice methods for developing disaster risk reduction strategies[1] (Cronin *et al.*, 2004, Barclay *et al.*, 2008, Cadag *et al.*, 2018).

To provide context, we first consider the community of Álftaver and flood hazards[2] from Katla before detailing experiences of the 1918 eruption.

ÁLFTAVER AND FLOOD HAZARDS FROM KATLA

Eruptions within the Katla caldera (Figure 1) are commonly followed by catastrophic outburst floods called jökulhlaups. The outburst flood in 1918 emanated from the Kötlujökull glacier outlet, about the same time as the eruption column was observed in the Vík village (Jóhannsson, 1919).

Outwash plains associated with jökulhlaups caused by Katla eruptions can be found in the lowland west, south and east of Mýrdalsjökull ice cap but also to the north (Figure 1). Mýrdalssandur–the eastward outwash plain–was flooded on eight occasions in the last 400 years because of Katla eruptions (Larsen, 2018). The resulting jökulhlaups are a mix–in various proportions–of water, boulders of ice and slush, rocks, sediments, and tephra; proportion not only varies between floods but also for each flood as they propagate on the outwash plain (Larsen, 2018).

Due to the speed at which these outburst floods develop and their sheer size in terms of velocity, volume and debris load, the jökulhlaups caused by Katla

[1] "Disaster risk reduction strategies and policies define goals and objectives across different timescales and with concrete targets, indicators and time frames. In line with the Sendai Framework for Disaster Risk Reduction 2015–2030, these should be aimed at preventing the creation of disaster risk, the reduction of existing risk and the strengthening of economic, social, health and environmental resilience." https://www.undrr.org/terminology/disaster-risk-reduction

[2] "Hazards may be natural, anthropogenic or socionatural in origin." https://www.undrr.org/terminology/hazard. In this paper, we refer to hazards as those associated with natural processes and phenomena, unless stated otherwise.

eruptions pose a grave risk[3] to the small farming community of Álftaver, which is situated on the Mýrdalssandur outwash plain some 35 kilometres away from the volcano (Figure 1).

Records show that only two people have been killed during Katla eruptions (Loftsson, 1930). These deaths occurred in 1755 and were caused by associated lightning strikes at the farm Svínadalur in Skaftártunga (Sigurðsson, 1755 in Loftsson 1930). Despite the great risk that people have faced over the centuries, no one is reported to have lost their lives to jökulhlaups (Loftsson, 1930). Nevertheless, Katla eruptions have had a severe effect on Álftaver's population. Impacts of a Katla eruption, especially those caused by tephra fall, last for decades ruining farming land, killing livestock and, ultimately, causing farm abandonment (e.g. Sveinsson, 1919 in Loftsson 1930, Gísladóttir 1980, Gísladóttir and Margrétardóttir 2004).

When Katla erupted in 1918 (Figure 2), there were 16 active farms in Álftaver (Table 1) and a population of 129 people (The National Archives of Iceland (Þjóðskjalasafn), no date). The population was young with 49% below 18 years of age and only 4% older than 60 years. A year later, three farms were abandoned, and the population had diminished by 17%. By 1920, the population was 99.

As with many farming areas of Iceland, Álftaver's population has since diminished further. In 2019, a total of 28 people lived on eight farms (personal information, Sandra Brá Jóhannsdóttir head of the Skaftárhreppur district, 12 August 2020), i.e. only 22% of the population prior to the 1918 eruption (The National Archives of Iceland (Þjóðskjalasafn), no date). However, this figure is not representative of the actual number of people in the region at any given time. As the region continues to diversify with tourism (Bird and Gísladóttir 2018), a growing number of people travel through and stay overnight in areas at risk to hazards produced by Katla (Pagneux 2015).

The next section details farmers' experiences in the lead up to and during the 1918 Katla eruption. This information is based on oral stories passed down to the lead author by relatives who experienced the eruption and their descendants (see Acknowledgements). Published accounts (Gíslason 1919, Sveinsson, 1919 in Loftsson 1930, Oddsson 1968, and Bjarnason 1985) translated in English by the lead author provide verification of these oral stories and further context.

While the following descriptions of what people experienced and felt during the 1918 Katla eruption include accounts of jökulhlaups, tephra fall and lightning hazards, our analysis focuses on outburst flooding (jökulhlaups). Reasons for this are twofold. Firstly, oral and written histories provide a very detailed account of specific places impacted by the 1918 Katla jökulhlaups which enabled detailed mapping of the flooding. Secondly, present-day emergency response strategies, as described later in the paper, were up until recently solely focused on mitigating the impact of jökulhlaups.

Table 1. Farms in Álftaver in 1918 (16 in total).*
*– Býli í Álftaveri 1918 (samtals 16 býli)**

Name of location	Number of farms at location
Skálmarbæjarhraun	1
Skálmarbær	1
Holt	3
Jórvík	2
Herjólfsstaðir	2
Hraunbær	1
Norðurhjáleiga	1
Þykkvabæjaklaustur	2
Hraungerði	1
Sauðhúsnes	1
Mýrar	1

*Three farms became deserted after 1918 (Skálmarbæjarhraun, one of the Holt farms and Sauðhúsnes).
**Þrjú býli lögðust í eyði eftir Kötlugosið 1918 (Skálmarbæjarhraun, einn bæjanna í Holti og Sauðhúsnes).*

[3]Here, risk is referring to 'disaster risk' which the UNISDR defines as: "The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity." https://www.undrr.org/terminology/disaster-risk

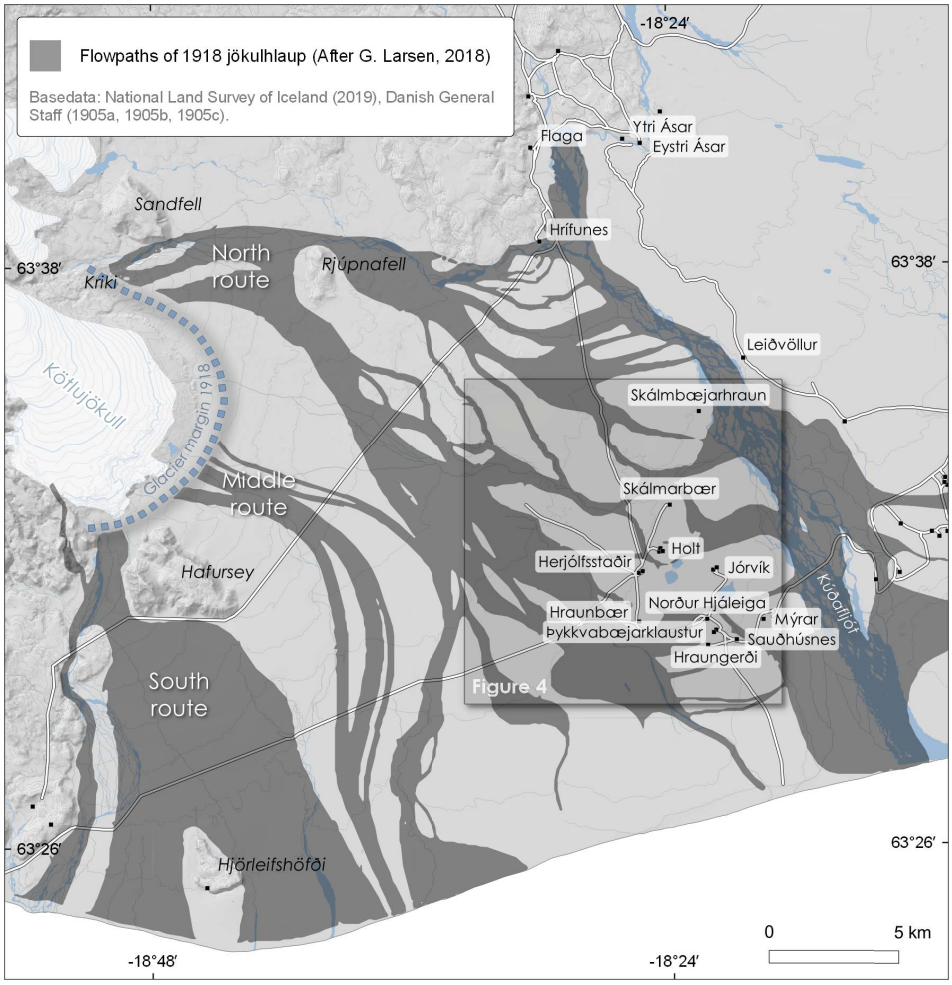

Figure 2. Footprint of 1918 jökulhlaup (based on Larsen, 2018). Farm locations in Álftaver (see Table 1) and road networks are according to maps from the Danish General Staff (1905a,b,c). For location see Figure 1. – *Útbreiðsla jökulhlaupa til austurs og suðurs frá Kötlujökli 1918 er samkvæmt skýrslu Guðrúnar Larsen (2018). Lega býla (sjá töflu 1) og vegakerfi byggir á dönsku Herforingjaráðskortunum frá 1905.*

THE EVENTS OF 10–12 OCTOBER 1918

Experience of the sheep herders and sorters

The second roundup of sheep from Álftaver's summer upland pastures began on 10 October 1918. Three days of herding lay ahead before the flock would be brought to the Fossarétt sheep sorting pens, north of the river Skálm (Figure 3). On 10 October, 13 men started early in the morning from Álftaver south of the river Skálm, heading towards the summer pastures close to Mýrdalsjökull (Bjarnason, 1985). The sheep herders were all men and young. The average age was 25 years; six of them were between 17–19 years of age and four between 21–27 years. One was at the age of 46 and the oldest was a farmer of the age 53 who was also the fjallkóngur, that is the head of the herders and the decision maker (Bjarnason, 1985, and The National Archives of Iceland (Þjóðskjalasafn), no date).

The herders knew the area very well and had often been herding there either on foot or horseback. The annual sheep roundup took place according to a traditional plan, with the first roundup for this season completed three weeks earlier (personal communication, Þórarinn Eggersson, 13 August 2020). On 10 October, the three areas of Merkigil, Axlir and Sandfell were herded to Atlaey (Figure 3).

In the evening the herders went with their horses to the shepherd hut near the river Hólmsá (Figure 3) where they spent the night. On 11 October, the four areas of Brytalækir, Háfjöll, Utanundir and Öldufell were herded, on foot and horseback. By the end of the day all sheep were rounded and kept overnight between Hólmsá and Leirá rivers. The sheep herders again stayed overnight with their horses at the shepherd hut near Atlaey.

It was a mild autumn day on 12 October 1918, and the sky was clear except for a greyish mist shrouding the Mýrdalsjökull ice cap, hiding it from view. The herders left Atlaey together and herded the flock south of the river Leirá. There the men separated: one group herded the sheep onwards to the Fossarétt sorting pens, while the other went off to round up sheep on the mountain Rjúpnafell. The Rjúpnafell group split in two, one group going west of the mountain to the pastures closest to Mýrdalsjökull, while the other went east of Rjúpnafell and worked the pastures to the east and south. Two men herded the so called Sandar (Figure 3) east of Rjúpnafell and the remaining group herded on the outwash plain area further to the east.

The roundup went well, and by around 3pm on 12 October, the herders and sorters were in various locations on the outwash plain in the Upphagar pastures between Rjúpnafell and the Skálm river, the northern part of Selhólmur and just south of Hrísneshólmur.

Then, events unfolded rapidly. On Selhólmur, the men had taken a short break, and from one hillock there was a view to the west. One herder, Vilhjálmur Bjarnason from Herjólfsstaðir, noticed a commotion in the west and realised that an eruption had begun in Katla. Vilhjálmur (Bjarnason 1985, pages 159–160) described what he saw: "*I looked across the area around us and over towards the waterfall Hrúthálsafoss (Figure 4). Although it was now some distance away, its sound reached us quite loudly, fluctuating with the wind. [I thought] [n]othing interesting about that, it was just the waterfall. But the waterfall was tricking my ears now. Of course, the sound of the flood had begun to merge with the noise of the waterfall, although we did not realise it. I looked further along the Hrúthváls ridge, where the southernmost tip reached the outwash plain as a series of quite high sandy knolls that I knew well. But now I sensed a change there, something unexpected. A bank of fog was moving across, caused by the outburst flood of course, so that visibility was not good at this distance. I can hardly believe my eyes. Inside the fog everything seems to be in motion. What on earth is happening? I wonder. I watched for a while, stunned by this terrifying sight. The flood that emerged east of the mountain Hafursey (Figure 3) raced across there and had barely begun to spread out. So it looked like a mountain side that hurtled forwards with a shifting surface on which dark icebergs towered and the floodwave sprayed water in all directions, depending on how the crest of ice rolled forward. Katla! I immediately thought.*"

After experiencing this, the companions hurried off, one to warn the men herding in the Upphagar pastures, others towards the sorting pen to warn the sorters. Bjarnason (1985, page 161) describes the flood in this area in more detail: "*When we first saw the main flood, I estimated that it was about 5 km away from us, but on the outwash plain glacial water was flooding out, filling the Skálm [river] and several of its tributaries. This pre-flood, as you might call it, didn't carry any ice to slow its progress, and was much closer than the main flood which rolled a mass of ice ahead of it, including towering icebergs. When we noticed this pre-flood, which was scarily close, it was obvious that it was more than enough to make the Skálm impassable once it reached its main course.*"

The sheep sorters were now becoming concerned. They had heard a strange hum and thudding that seemed to come from Mýrdalsjökull. One of the sorters, Sigurður Jónsson from Þykkvabæjarklaustur in Álftaver, rode along the Ljósavatnaháls ridge (Figure 4), which commanded a good view of the sheep-sorting pen towards the northwest, and there he met

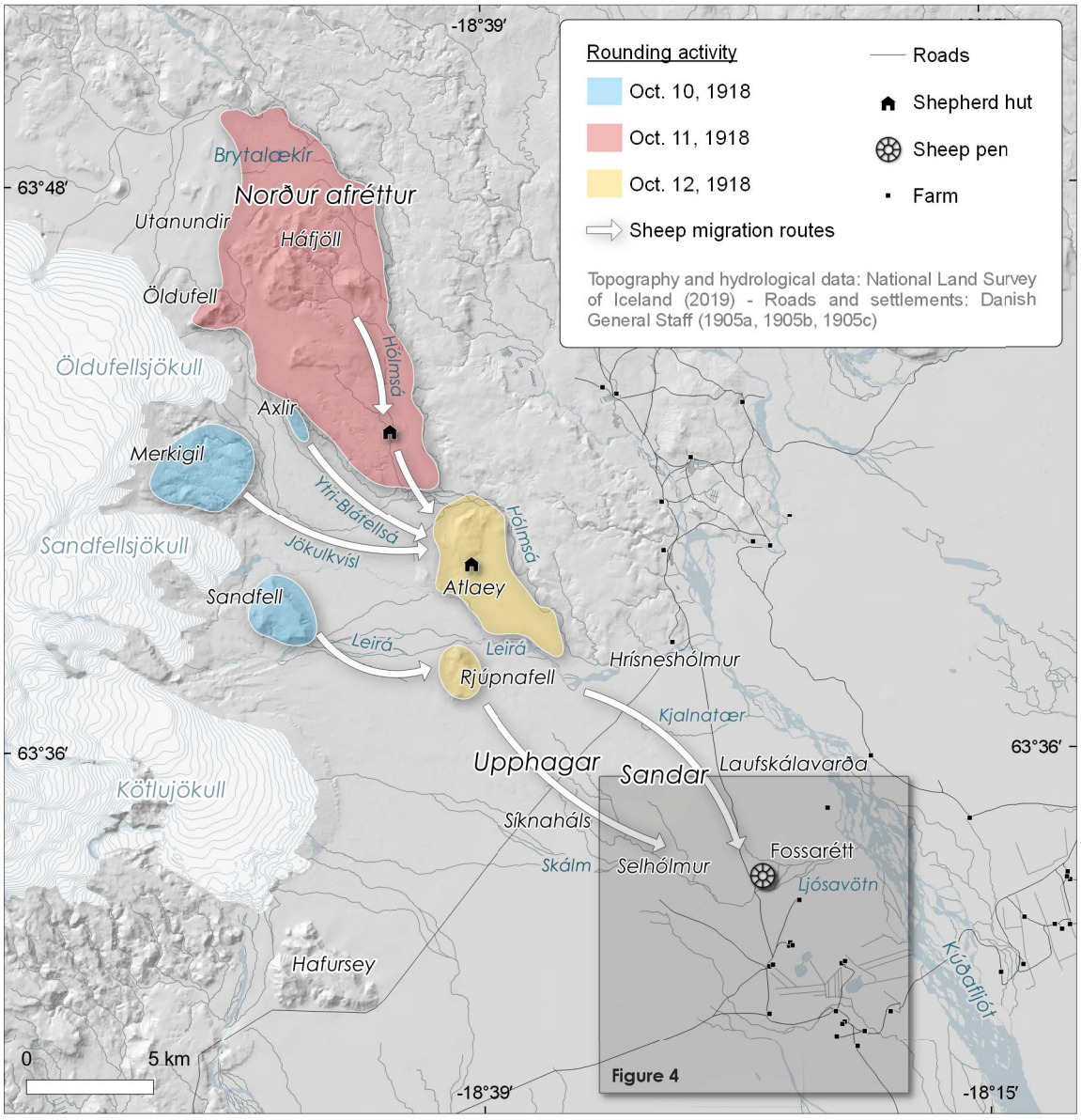

Figure 3. The sheep round up activity on 10–12 October 1918. Based on Bjarnason (1985), and estimation by Þórarinn Eggertsson, farmer at Hraungerði and Páll Eggertsson, farmer at Mýrar (personal communication 2020 and 2021). Shepherds' huts are shown in black and outlet glaciers and rivers are labelled in blue. Regional location is shown in Figure 1. – *Leitarsvæði og leið safns á milli svæða á afrétti dagana 10.–12. október 1918 (byggt á grein Vilhjálms Bjarnasonar, 1985, mati Þórarins Eggertssonar (bónda í Hraungerði) og Páls Eggertssonar (bónda á Mýrum) árið 2020 og 2021). Svæði sem voru smöluð 10. október eru sýnd í bláum lit, 11. október í ljósrauðum lit og 12. október í gulum lit. Gangnamannakofar eru merktir með svörtu tákni og nöfn áa og skriðjökla eru í bláum lit.*

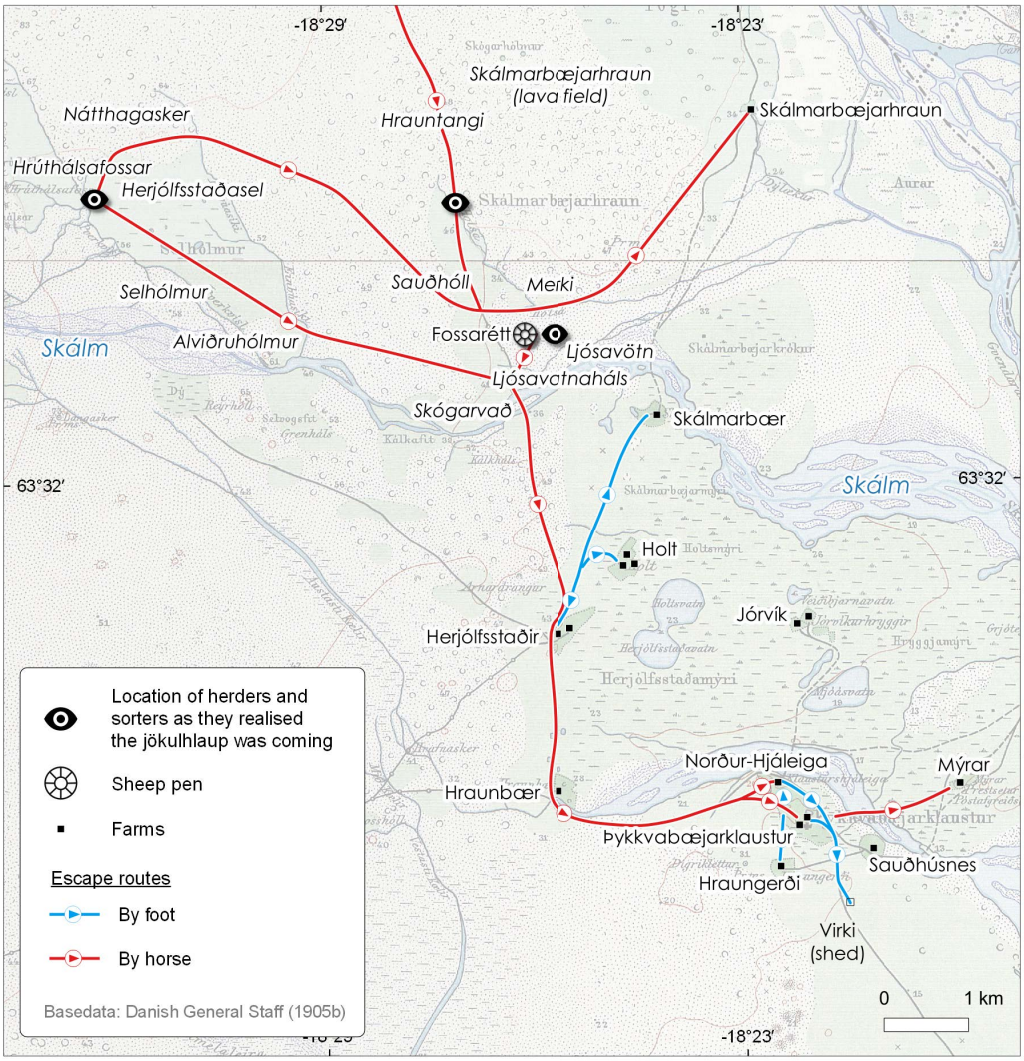

Figure 4. Escape routes of herders, sorters and residents in Álftaver by horse or by foot when they realized that Katla had erupted and the jökulhlaup was approaching. The location of herders and sorters is based on GPS points provided by the late farmer Gissur Jóhannesson (at Herjólfsstaðir) and assessment of Þórarinn Eggertsson (farmer at Hraungerði) and Páll Eggertsson (farmer at Mýrar). The location of routes is based on contemporary descriptions (Gíslason (1919), Magnússon (1919), Oddsson (1968), Vilhjálmsson (1985), and assessment of Þórarinn Eggertsson (farmer at Hraungerði), Páll Eggertsson (farmer at Mýrar) and passed relatives of Guðrún Gísladóttir one of the authors of this article. – *Flóttaleiðir smala, réttarfólks og íbúa í Álftaveri sem flýðu ríðandi (rauðar örvar) eða gangandi (bláar örvar) þegar þeim var ljóst að Kötlugos væri hafið og að jökulhlaup nálgaðist óðfluga. Staðsetning smala og réttarfólks byggir á staðsetningum Gissurs heitins Jóhannessonar (bónda á Herjólfsstöðum) og mati Þórarins Eggertssonar (bónda í Hraungerði) og Páls Eggertssonar (bónda á Mýrum). Flóttaleiðir eru byggðar á samtímalýsingum (Gíslason, 1919, Magnússon, 1919, Oddsson, 1968, Vilhjálmsson 1985), mati Þórarins Eggertssonar (bónda í Hraungerði) og Páls Eggertssonar (bónda á Mýrum) ásamt frásögnum liðinna ættingja Guðrúnar Gísladóttur.*

Vilhjálmur Bjarnason coming helter-skelter with news of the eruption. Sigurður rushed away to the sheep sorters, and the people at the sorting pens managed to cross the Skálm river at the Skógarvað ford just 1–2 km away ahead of the floodwater front, shortly before the flood reached the river. Vilhjálmur, who had ridden in distress for seven kilometres, crossed the Skálm and parted with Sigurður. He and the sorters who were located at the Fossarétt sheep sorting pen made the crossing just before the flood entered the river (Bjarnason, 1985). Other sorters who were not by the sorting pen had to go a long way to cross the river Skálm and rode towards Skálmabæjarhraun. When the sorters had crossed the river Skálm they saw the flood wall, in an estimated 10-minute travel time from their location (Jóhannsson, 1919).

When news of the flood reached the herders in the Upphagar pastures they rode as fast as they could by Nátthagasker, and when they approached the rocks north of Ljósavatnaháls they became aware of the flood that streamed across the outwash plain west of Laufskálavarða (Figure 3), and so they headed straight for Skálmarbæjarhraun lava field and Skálmarbæjarhraun farm (Figure 4).

The men herding the flock in Upphagar, between the rivers Leirá and Skálm (Figure 3), first noticed that something serious was happening. When they were some distance south of Laufskálavarða, they had heard increasing thudding and crashing but could not see the flood, as they were in a sandy hollow with ridges on both sides which obscured the view to the west. They continued towards the Fossarétt pen. But when "*we were far south of Laufskálavarða and north of the grassland we could see that some are leaving the sheep-sorting pen and crossing Skálm, and just then we saw men [from Upphagar] riding as fast as they could from the west and crossing the Ljósuvatnaháls and heading to the east towards the pen (Figure 4). And we had only a short distance to the grassland, but as the sheep became tired from all the travelling, we walked with the sheep and towed the horses behind*" (Oddsson, 1968, page 6). During this, one of the lambs became separated from the flock. One herder, Jón Gíslason from Norðurhjáleiga, turned around to get the lamb into the flock, and Brynjólfur Oddsson from Þykkvabæjarklaustur is quoted as saying that when Jón had turned round he said: "*So it's Katla!*" (Oddsson, 1968 page 6–7). Brynjólfur estimated that the flood was not over 100 metres away from them (Oddsson, 1968).

Jón Gíslason's description of events is as follows: "*What I saw will stay with me for a long time. Behind us was raging an enormous, terrifying flood which tore along the depression between the two lava ridges... We moved as fast as we could, heading south to Ljósavatnaháls. When we got there, we saw that the flood was spreading eastwards out of the river Skálm, to the south of us; so, it was not possible to continue that way. We changed direction then and carried on towards Skálmarbæjarhraun. We galloped the horses at the depression which lies between Ljósavatn and the lava field and tore straight across ditches and streams. It was touch and go whether we or the flood would win. Still, we reached the edge of the lava before the flood hit it, but it was so close that it broke over our trail 40–50 metres from the edge of the lava field.*" (Gíslason 1919, page 35)

Once they were up on the lava field, they continued towards a rock islet in the western part of the lava field, where the other herders from the summer pastures and the sheep sorters who had been unable to cross the river Skálm had congregated. People kept together and watched the flood (the branch of the outburst flood that emerged on the outwash plain west of Laufskálavarða, Figure 3) as it raced with tremendous power and speed, sweeping along icebergs and flowing over everything in its path (Gíslason, 1919). The leading edge of the flood pushed up soil and vegetated land (like rolled-up pancakes), which then became mixed with the glacial water and was destroyed (Gísladóttir and Margrétardóttir, 2004, p. 7). The outburst flood was dark brown and formidable, according to their description, with a strong stench of sulphur. The men did not think it was advisable to stay on the rock, with their many horses and no vegetation. The flood was heading around the islet west of Skálmarbæjarhraun (Figure 2), so they made for the Skálmarbæjarhraun farm which was the northernmost farm in Álftaver and the only farm north of Skálm (Gíslason, 1919).

By now the flood was travelling incredibly fast along the Kúðafljót river and more than filled the river course between the lava field and Leiðvöllur and was approaching the Skálmarbæjarhraun farm (Figure 2). People began to move everything portable northwards from the farm up onto the edge of the lava field, and the farmers, herders and sorters (about 30 people) spent the night in sheep sheds in a more elevated position on the lava field. People could not sleep that night because many things were now unusual; there was constant thunder and crashing, a heavy sound of unseen water, falling tephra and total darkness, except when lightning flashed and illuminated the sky (Gíslason 1919, Oddsson 1968).

By morning of 13th October, the wind was from the east, so the tephra cloud no longer hid the view. Water had encircled the farm and there was a waist-high crest of ice by the farmhouse. People realised that the flood had receded but all around were enormous icebergs across the outwash plain where the flood had passed and the area looked like a jagged new lava field. It was impossible to travel around the area on horseback, and the herders and sorters who were on Skálmarbæjarhraun the night of the flood (12/13 October) decided to leave the horses behind and scramble over the ice fields, across the Skálm river and home to Álftaver (Figure 4). It was a week later that the horses were collected from Skálmarbæjarhraun (Gíslason 1919, Oddsson 1968).

Experience of those on the farms in Álftaver

The day of the eruption, it was mostly women, children and the elderly people at home on the farms in Álftaver, although after the eruption began, some men returned from the Fossarétt sheep sorting pen. The farms stood at various elevations and some were at risk of flooding.

Two of the sorters, Gísli Magnússon from Norðurhjáleiga and the aforementioned Sigurður Jónsson from Þykkvabæjarklaustur, who managed to cross the river Skálm, rode as fast as possible towards their farm area locally known as Sunnanbyggjaratorfa (this area included the farms Þykkvabæjarklaustur, Norðurhjáleiga and Hraungerði, Figure 4). With the flood entering the river Skálm just behind them (approximately 167 m), they arrived at the farm Herjólfsstaðir from where they could see how the flood was spreading to the west. As they reached the farm Hraunbær the flood was about 400–500 m away from them. With the flood that tore across the mudflats west of Hraunbær hard on their heels, they rushed as fast as possible all the way to their farms and when they arrived the flood had just reached Norðurhjáleiga and Hraungerði (Loftsson, 1930).

It was obvious by those who stayed at the farms that Álftaver was being flooded, and people had begun to gather at the farms. A woman from Hraungerði had reached Norðurhjáleiga with her six children, and Gísli directed people from the farms south to the Virki sheep sheds on higher ground (Figure 4). Jón Brynjólfsson, from Þykkvabæjarklaustur rode east to Mýrar, where a widow with two children and a servant girl were at home (Magnússon, 1919). Guðmunda Oddsdóttir (age 12) from Þykkvabæjarklaustur was among those who fled to Virki. She clung to her handicapped brother who had difficulties walking and was very worried that she would lose him. Their journey was horrific; across from them the flood with huge, hurtling icebergs had arrived between the farms and filled the marshes surrounding Þykkvabæjarklaustur, reaching the churchyard.

The people from the farms at Sunnanbyggjaratorfa made it to the sheep sheds and spent the night there, but it was a terrifying experience. It was pitch dark from the tephra and people could hardly see their own hands, but lightning lit the sky and thunder crashed endlessly, with barely a break and in the darkness they could hear the floodwaters which were close by but not visible.

At Holt there were three farmhouses and families with many children and elderly people (a total of 32 people (The National Archives of Iceland (Þjóðskjalasafn), no date) out of which two were herders), but two men from the sheep sorting pen made it home to Holt before the floodwaters entered the Skálm river, and they knew that the flood was not far from the farms. Holt is 1–2 km from the Herjólfsstaðir farm which stands higher, and the men instructed all the residents to flee to there; and so, they walked along a strip of grassland towards Herjólfsstaðir. When they were about halfway, one woman realised that

she could not recall putting out the kitchen fire. So, the men returned, and the others hastened to Herjólfsstaðir. When the men had ensured that all was secure at Holt, they turned back, but when they reached the hollow between Holt and Herjólfsstaðir a powerful and impassable river cut their path. They turned back, but the river rose rapidly and soon Holt was surrounded by glacial water and they were trapped (Bjarnason 1985).

Around 40 people sheltered at Herjólfsstaðir overnight, (residents from the two farmhouses at Herjólfsstaðir plus those from Holt except the two people who were trapped in Holt). They looked to each other for emotional support; people said that it was as though the sky had been in a wild dance that threatened their very existence, screaming thunder, thuds and flickers of light. When the lightning lit the sky, it was like glittering lines that flashed across the tops of the charged cumulus clouds lighting up the entire surroundings for just a moment. However, it is likely that the loud murmur of water which emanated from all parts of the flood that coursed around Álftaver, close to the farms and distant, was the greatest cause of terror and horror for the people (Bjarnason 1985).

At Skálmarbær, a farm close to the river Skálm, Sigríður Gísladóttir was home alone with her two young sons. Sigríður's husband, Vigfús Gestson was one of the sheep sorters that was stuck on the other side of the river Skálm. At that time, Auðunn Oddsson was visiting in Herjólfsstaðir. After the aforementioned Vilhjálmur Bjarnason arrived back at Herjólfsstaðir and announced what was happening, Auðunn immediately returned to Skálmarbær (Figure 4) as he knew that Sigríður was home alone with her two young sons Gísli (5 years) and Gestur (3 years). By the time Auðunn arrived in Skálmarbær the flood water was very close to the farm and Sigríður and her two sons were very relieved to see him. Auðunn pulled a boat that was near the farm up the steps to the front door and promised not to let the flood harm them. Auðunn continued to keep watch all night, walking around the home and singing as he monitored the flood level at the front door. About three o'clock that night, after having been out to look at the flood level, he told Sigríður to go to bed with her sons because the flood had begun to recede and he would continue to keep watch until daylight (personal communication Þórarinn Eggertsson and Páll Eggertsson, February 22–26, 2021).

In the latter half of the night the sound of water seemed to diminish, and people all over Álftaver hoped that the greatest risk of flooding was over. When day dawned the flood had receded, but it was evident that floodwater and ice had spread over all the district's lowland, which at the peak of the flood had been like an ocean. Most of the farmhouses in the district stand on high ground and were undamaged by the flood, but a crest of ice and icebergs lay close to the farmhouses and over much of the lowland (Bjarnason 1985). Although most of the danger had passed after the first 24 hours, the eruption had not ended. It lasted for 24 days (Loftsson 1930). Many sheep are known to have died in the flood, abandoned by the herders fleeing from the flood.

PRESENT DAY EMERGENCY RESPONSE STRATEGIES

Due to the danger an eruption poses to the region, Katla has been monitored for many years (e.g. Sigmundsson *et al.*, 2009) and emergency response strategies for jökulhlaups have been in place since 1973 (Friðfinnsson, 2003; Jóhannesdóttir and Gísladóttir, 2010; Bird *et al.*, 2011). Increased earthquake activity in Katla in the 1990s called for a risk assessment and revision of emergency response strategies for jökulhlaups (Guðmundsson and Gylfason, 2005). This included the development of evacuation plans for all areas exposed[4] to jökulhlaup hazards. These plans were developed by the local civil protection committee and police in consultation with the Department of Civil Protection and Emergency Management of the National Commissioner of Police (DCPEM-NCIP). The plans were premised upon eruption scenarios prepared by the Institute of Earth Sciences, University of Iceland (Guðmundsson and Högnadóttir, 2006) for

[4] "The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas." https://www.undrr.org/terminology/exposure

DCPEM-NCIP, and numerical simulations of resulting jökulhlaups performed by the engineering company Vatnaskil (Hólm and Kjaran, 2006).

Simulations of two key jökulhlaup scenarios (Table 2) were presented to the local population in 2006 (Magnús Tumi Guðmundsson, personal communication, July 7, 2020) as well as an evacuation map prepared by DCPEM-NCIP that builds on the results of the simulations. One could not single out, from the evacuation map, any of the modelled scenarios: the scenario-based inundation extents were combined into a single inundation area; flow travel times were also combined to show the least flow travel times one can expect on the outwash plain, all simulations being considered (see Figure 5). The inundation extent and flow travel times obtained from the combined scenarios do not depict, strictly speaking, a worst case among the hazard scenarios simulated–they exceed those of each scenario considered separately–but were used by DCPEM-NCIP as a conservative, out-of-an-abundance-of-caution reference in the contingency plan (Ágúst Gunnar Gylfason, personal communication July 8, 2020). The evacuation map was eventually featured in information brochures intended for local residents and tourists visiting the region (DCPEM-NCIP 2006a, 2006b). The brochure intended for local residents was distributed in 2006 to every home in areas exposed to jökulhlaup hazards.

To gauge its effectiveness, implementation of the plans was rehearsed in March 2006 with residents and all agencies responsible for emergency response procedures (Bird *et al.*, 2011). As per the plan for Álftaver, residents received a telephone call on their landline or a notification (SMS) to their mobile phones, with a message from DCPEM-NCIP informing them that they had 30 minutes to evacuate the area and go to the emergency relief centre in Kirkjubæjarklaustur (Figure 5 – inset map). Police at Kirkjubæjarklaustur were to ensure compliance with the evacuation order, rather than the responsibility resting with the local rescue team in Álftaver.

Research by Jóhannesdóttir and Gísladóttir (2010) showed that Álftaver residents were confused and concerned about emergency response strategies that had been developed prior to 2006. In follow-up to Jóhannesdóttir and Gísladóttir (2010) research, Bird and Gísladóttir (Bird *et al.*, 2011, Bird and Gísladóttir 2012) have captured Álftaver residents' current knowledge, perceptions and planned behaviour in relation to Katla, its associated hazards, the 2006 evacuation exercise and in light of their experience of the 2010 Eyjafjallajökull eruption. The next section summarises the key findings of that research.

Table 2. Key jökulhlaup scenarios presented to the public in 2006 for an eruption within the Katla caldera and jökulhlaup beneath Kötlujökull (personal communication, Magnús Tumi Guðmundsson, January 26, 2021). The North, Middle and South conveyance routes on Mýrdalssandur are shown on Figure 2. – *Helstu sviðsmyndir jökulhlaupa undan Kötlujökli í tengslum við Kötlugos sem voru kynntar íbúum í Álftaveri árið 2006 (persónulegar upplýsingar frá Magnúsi Tuma Guðmundssyni, þann 26. janúar, 2021). Norður-, mið- og suðurleiðir jökulhlaups á Mýrdalssandi eru sýndar á 2. mynd.*

Scenario	Conveyance routes on Mýrdalssandur	Peak discharge (m^3/s)	Historical event
1	South	250,000	1918 CE
	Middle	15,000	
	North	35,000	
2	South	50,000	Might have happened during the 934 CE Eldgjá fissure eruption.
	Middle	200,000	
	North	50,000	

CURRENT PERCEPTIONS AND PLANNED BEHAVIOUR IN RELATION TO EMERGENCY RESPONSE STRATEGIES

Everyone interviewed in the Álftaver district was familiar with the history of Katla's eruptions and the associated dangers (Bird *et al.*, 2011). Residents had familiarised themselves with stories of Katla eruptions and, the experiences of Álftaver farmers in 1918 had been passed down the generations. About half of the people interviewed believed they were in greatest danger due to the outburst floods, but residents also considered risks from tephra and lightning, based on

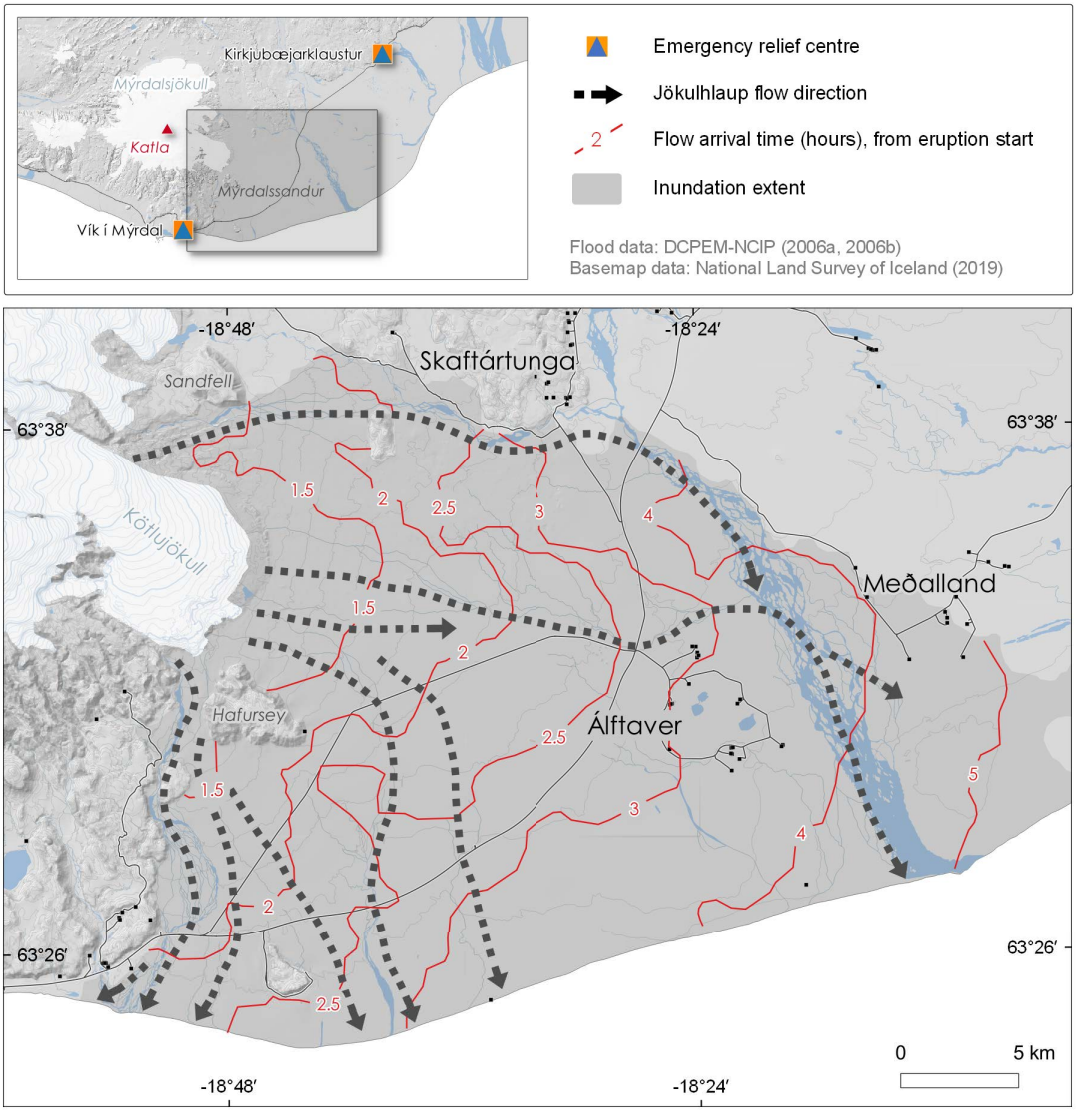

Figure 5. Inundation extent, main flow directions and minimum flow arrival times after the start of a Katla caldera eruption, according to map and brochure published by DCPEM-NCIP (2006a,b). Jökulhlaups of peak discharge 300,000 m^3/s, surging from Kötlujökull onto Mýrdalssandur were considered (see scenario specifications in Table 2). Scenario outputs were mashed by DCPEM-NCIP to produce a conservative reference for the contingency planning. Regional location is shown in Figure 1. – *Jökulhlaup á Mýrdalssandi af völdum eldgosa í öskju Kötlu. Flóðasvæði, meginrennslisleiðir flóðvatns og lágmarks ferðatími flóðbylgju frá upphafi goss í klukkustundum talið. Byggt á korti og bæklingi útgefið af Almannavörnum (DCPEM-NCIP, 2006a,b). Á kortinu og bæklingnum voru niðurstöður sviðsmyndanna steyptar saman og útkoman notuð sem viðmið við gerð rýmingaráætlunar. Í sviðsmyndum var hámarksrennsli jökulhlaupa fram Mýrdalssand miðað við 300.000 m^3/s (sjá töflu 2).*

relatives' accounts of the 1918 eruption: "*Jökulhlaup [as the most serious] but lightning can be very serious. Lightning is greatly feared in this region... Even though tephra was quite small the lightning was so severe that it looked like the middle of the day even though it was night in October [during the 1918 eruption]*" (Bird *et al.*, 2011, p. 1215).

Álftaver residents participated in the 2006 evacuation exercise and most complied with evacuation instructions, even though they were not happy. Poor visibility and bad weather often obscure the view to Katla and, owing to past generations' experience of flood pathways down Mýrdalssandur and poor visibility due to tephra fall, residents believed they would be endangered by travelling towards or across the flood, as the men in the upland pastures had done in 1918. Thus, most residents of Álftaver stated that they were reluctant to comply with the evacuation plan, and none said that they would follow it if the weather was bad or visibility poor.

"*We had mixed feelings about the exercise because we were supposed to evacuate against the flood. This is a very dangerous area. These feelings have been imbedded in us since 1918. This region to the east of here was badly affected in 1918. It went under very quickly.*" (Bird *et al.*, 2011, page 8, Appendix E).

"*I'm not so afraid that we are in real danger, but it may become completely dark [due to tephra fall] and this would be a huge mental strain to deal with. I know of farmers who were out in the complete dark [due to tephra fall] and they had to use the fence to find their way [back to the house during the 1918 Katla eruption]. This would be very difficult to deal with.*" (Bird *et al.*, 2011, p. 1215).

"*If I could not see anything, I would not follow the procedure. And it also depends on how much time we have.*" Bird *et al.*, 2011, p. 10, Appendix F).

Instead, Álftaver residents called for a Plan B to enable them to shelter locally rather than driving to Kirkjubæjarklaustur. Based on the farmers experiences in 1918, Álftaver residents thought it would be more sensible to shelter at Herjólfsstaðir or Mýrar settlements (Figure 4), as both stand at elevations–ridge or headland–that were not flooded by the jökulhlaups in 1918. An old schoolhouse and two farms are in Herjólfsstaðir, with sufficient space for Álftaver residents, they thought, and the fellowship of locals would be a source of strength.

"*I thought it was so silly that we should go against the flood. I told them [the police] that I would go to Herjólfsstaðir or Mýrar, that I would never go to Kirkjubæjarklaustur.*" (Bird *et al.*, 2011, p. 8–9, App. E).

"*I would follow my forefathers and go to higher ground.*" (Bird *et al.*, 2011, p. 10, App. F).

Bird and Gísladóttir (2012) revealed that following their experience of complete darkness due to tephra fall during the 2010 Eyjafjallajökull eruption, Álftaver residents were still very concerned about the requirement for them to evacuate to Kirkjubæjarklaustur during a Katla eruption. They were therefore still in favour of adopting a 'Plan B' for sheltering at Herjólfsstaðir or Mýrar. In 2010, however, a Plan B had still not been officially outlined (Bird and Gísladóttir 2012), despite discussions between residents and the police in 2008.

"*The police chief is working with us for a Plan B, especially if the weather is bad. It is not official yet, but he is in favour. We will go to Mýrar or Herjólfsstaðir.*" (Bird *et al.* 2011, p. 1217).

Since then, a Plan B has been developed which designates the farmhouses in Mýrar and Herjólfsstaðir as places to shelter. This plan is outlined in a public document by The Chief of Police in South Iceland, the Civil Protection Committee of Rangárvellir- and V-Skaftafellssýsla and the National Commissioner of Police (2017), available on the DCPEM-NCIP website. However, recent discussions with the current and past heads of the local rescue team in Álftaver suggest that Álftaver residents are not aware that Plan B is official and have not seen either of the 2013 or 2017 reports where Plan B is outlined (personal communication, Páll Eggertsson, 6 August 2020 and Örvar Egill Kolbeinsson, 8 August 2020).

DISCUSSION

Advocating for the development of plans through participatory approaches

The oral stories of the 1918 Katla eruption provide a vivid account of the event, and an insight of what

people expect to experience during the next eruption. The stories provide meaning, with the descriptive details placed in the environment present day residents know and understand. There is no doubt that the descriptions from Álftaver farmers, of their experience of the 1918 Katla eruption, have influenced current knowledge and perceptions.

This inherited, experiential knowledge substantially influences people's willingness to comply with emergency response strategies and evacuation plans. Local residents have considerable, insider's knowledge of Katla eruptions and its associated hazards but prevalence of experience in their representation of risks make them reluctant to accept scenarios that differ from how past events unfolded. This includes complying with emergency response plans that do not consider other hazard risks such as tephra and lightning.

Notably, officials have adopted local advice and made room for the sheltering-in-community option – Plan B for Álftaver. However, it appears that local residents were not involved in the development of Plan B, despite the critical knowledge they have of their local area from both a social and environmental perspective. At the very least, this information needs to be socialised with the local population so that it is clear what Plan B means and under which circumstances it should be activated so that there are no surprises to anyone. Furthermore, sheltering-in-community requires a high-level of preparedness and, self-reliance and self-sufficiency of those residents who choose to do so (Whittaker *et al.*, 2017). Residents therefore need adequate time to prepare themselves to implement Plan B and remain self-sufficient for any given length of time until the risk (posed by jökulhlaup, lightning and/or tephra hazards) has passed.

It would also be beneficial to compliment official advice with the detailed descriptions from 1918. The oral stories add a more human aspect to risk assessments and, they can be used to bring emergency response strategies to life.

Of course, one should not rely solely on the 1918 experience for predicting the inundation extent of future events, the flood routes, and flow arrival times at specific locations. The simulations (Kjaran and Hólm, 2006) upon which the early response plan was built suggest that Álftaver could be reached by flood water at a faster rate than that which occurred in 1918, if key scenario 2 (Table 2) were to happen. Also, a different interplay between the flood conveyance routes on Mýrdalssandur may occur, as the front of Kötlujökull recedes due to climate change (e.g. Sigurðsson, 2010) and subglacial topography turns into proglacial landscapes. One cannot exclude for instance that the north route (Figure 2) might become deactivated in the near future. During a future eruption, this would result in all floodwater surging on the outwash plain through the middle and south routes, in a similar fashion as in 1823 and 1860 (see Larsen, 2018).

Clear, concise, transparent and ongoing communication is therefore critical at all stages of developing and implementing emergency response strategies. And ongoing work is needed, given Katla's continued unrest and the length of time since the last confirmed eruption in 1918, which historically speaking, is a long time between Katla eruptions (Icelandic Meteorological Office (Veðurstofa Íslands), 2016). Authorities responsible for the design and organisation of such plans must collaborate with local residents to ensure all parties fully comprehend the factors that impact decision-making processes. From a residents' perspective, this paper has highlighted many environmental factors that will influence public response to evacuation orders. For example, residents' decision-making will be influenced by visibility – whether it is day or night, the weather is bad, or tephra fall is impacting the area. These findings underscore the importance for combined scenario modelling to incorporate differing environmental conditions as well as other hazard risks alongside of jökulhlaups. As reported by Barsotti *et al.* (2020), tephra fall alongside flood hazards from a Katla eruption, is likely to cause disruption to road travel in the region.

Of equal importance is the consideration of social factors that impact decision-making. Bird *et al.* (2011) and Bird and Gísladóttir (2012) revealed that alongside the environmental factors, some Álftaver residents planned not to evacuate so that they could remain on-hand to care for their livestock. Non-compliance to evacuation orders is not unique to

Álftaver. Bird and Gísladóttir (2018) report that some residents did not comply to evacuation orders during the 2010 Eyjafjallajökull eruption due to caring for elderly and incapacitated family members, caring for livestock or believing the messages were not relevant to them. As livelihoods diversify from agriculture into tourism (see Bird and Gísladóttir 2018), further non-compliance may occur as a result of duty of care to patrons who are out sightseeing and unaccounted for. These are just a few of the environmental, social, individual-level and event-orientated variables that impact decision-making in response to warnings (Mileti and Peek, 2000, Lindell and Perry, 2004, Dash and Gladwin, 2007, Sorenson and Sorenson, 2007, Lindell and Perry, 2012).

Collectively, these studies highlight the need for participatory approaches that promote ongoing and inclusive dialogue that leads to the co-production of knowledge. It is within this space that realistic plans that address residents', as well as officials' concerns can be developed and implemented. Ongoing considerations of 'social scenarios' combined with the physical, will ensure that authorities, scientists and local residents alike have a more holistic understanding of the diverse and complex range of events that might occur. Without collaboration among all stakeholders, participatory approaches are likely to be ineffective at the policy level (Mercer *et al.*, 2008). In some countries, such as New Zealand, the United States and Colombia, governments mandate participatory approaches (Cadag *et al.*, 2017). An excellent example of the success of this in Colombia is provided by García and Mendez-Fajury (2017).

While the full-scale evacuation exercise held in 2006, deemed a success by emergency management officials, tested different situations (e.g. actors were employed to role play residents that refused to evacuate), it was developed as an official top-down activity (Bird *et al.*, 2009). That is, residents were expected to evacuate upon receipt of the evacuation notice for the mock eruption. Their views of the factors that would impact their decision-making during a real eruption were not taken into consideration. After the 2010 Eyjafjallajökull eruption, Bird and Gísladóttir (2012) report that officials' views appeared to be more aligned with residents in terms of the risks posed by tephra and lightning. However, it is apparent that current plans (i.e. Plan B) have also been developed without local residents' input. As postulated by Powell and Colin (2008), residents have valuable knowledge and perspectives and in our democratic societies, they should at the very least, have a say in decisions that affect their lives.

CONCLUSIONS

Importantly, this paper has contributed to the scientific literature by bringing together detailed accounts of what people felt and experienced during the 1918 Katla eruption. This includes the production of unique visual representations of the sheep round up activity and location of sheep herders and the escape routes they took to travel back to Álftaver once they realised that Katla had erupted and a jökulhlaup was approaching. From their descriptions, and the routes they took, it is clear the farmers at Álftaver knew their environment; at the mention of Katla, they knew exactly where they needed to go to remain safe. The descriptions also tell us about the nature of the jökulhlaups in 1918, with a 'pre-flood' devoid of ice and travelling at a much faster rate than the ice-laden main flood. This pre-flood caused river crossings to become quickly impassable.

Armed with this knowledge, residents questioned emergency response strategies which instructed them to follow evacuation routes that lay bare across the flood conveyance paths, with potentially poor visibility due to bad weather and tephra fall. While officials should be commended for addressing residents' concerns by developing a 'Plan B', it appears that local residents were not involved in its development, despite the critical knowledge they have of their local area from both a social and environmental perspective.

This paper therefore argues for the adoption of a participatory approach, that includes ongoing and inclusive discussions between officials and people at-risk and leading to the co-production of knowledge. From this base, more appropriate emergency response strategies that adequately reflect and accommodate local knowledge, perspectives and planned behaviour

can be developed and implemented. This includes ongoing considerations of 'social scenarios' combined with the physical, to ensure that officials and residents alike are well prepared for a range of situations.

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ÁGRIP

Íbúar í Álftaveri, á Mýrdalssandi, þekkja vel til eldstöðvarinnar Kötlu og Kötlugossins 1918 sem olli skyndilegu hamfarahlaupi á Mýrdalssandi og þar með í Álftaveri. Reynsla og lýsing þeirra sem upplifðu atburðinn 1918 hefur flust frá einni kynslóð til annarrar og hefur síðan verið mikilvægur hluti af sameiginlegu minni íbúanna. Greinin byggir á munnlegum og skriflegum frásögnum þeirra sem upplifðu Kötlugosið 1918 og ítarlegum kortum sem endurspegla aðstæður og flótta íbúa undan hlaupinu 1918. Í greininni er einnig fjallað um hvernig reynsla og þekking íbúa á fyrri atburðum hefur áhrif á skynjun íbúa í dag á hættu vegna Kötlugoss og afstöðu þeirra til neyðar- og rýmingaráætlunar sem íbúum er gert að fylgja komi til goss og hvernig þeir sjái fyrir sér að þeir muni bregðast við rýmingu vegna hamfarahlaups sem fylgir gosi í Kötlu. Fram til þessa hafa frásagnir af viðbrögðum íbúa í Álftaveri við Kötlugosinu 1918 einungis verið aðgengilegar á íslensku, í rituðum heimildum eða munnlegri geymd. Markmið greinarinnar er að þessar sagnir verði aðgengilegar enskumælandi fólki í því skyni að auka skilning á eldgosum og áhrifum þeirra sem og framtíðarskipulagi neyðaráætlana vegna Kötlugoss. Lýsingar heimamanna lýsa vel mismunandi hraða jökulhlaupa sem fóru um Mýrdalssand, allt eftir því hvort um var að ræða hlaup án ísbjarga sem rann mun hraðar en meginflóð hlaupsins sem var hlaðið ísbjörgum. Vegna þess hve langt er um liðið frá síðasta Kötlugosi og að jarð- og jarðeðlisfræðileg vöktun eldstöðvarinnar gefur til kynna að hún sé enn virk ásamt þeirri staðreynd að gos myndi hafa áhrif á byggð í Álftaveri voru neyðaráætlanir vegna hugsanlegs hamfarahlaups þróaðar í byrjun 21. aldarinnar. Í mars 2006 voru þær prófaðar í allsherjar rýmingaræfingu þar sem íbúar, vísindamenn og viðbragðshópar tóku beinan þátt í æfingunni. Íbúar í Álftaveri voru ekki að fullu sáttir við rýmingaráætlunina eins og hún var sett fram og voru tregir til að fylgja fyrirmælum um rýmingu. Þeim fannst að þekking þeirra á hegðan Kötlugosa, þekking á landinu og reynslu ættingja sem upplifðu Kötlugosið 1918 hefði ekki verið tekið nægilega til greina við skipulag áætlunarinnar. Íbúar höfðu áhyggjur af því að almannavarnir hefðu ekki tekið nægilegt tillit til hamfarahlaups, gjósku og eldinga. Til að bregðast við áhyggjum íbúanna þróuðu almannavarnir aðra rýmingaráætlun (áætlun B) sem byggir á reynslu og þekkingu íbúa Álftavers. Íbúar voru þó ekki hafðir með í ráðum við þróun nýju áætlunarinnar og vissu ekki um tilvist hennar eða hvenær hún á að koma til framkvæmda. Í þessari grein er rætt um og lögð áhersla á mikilvægi þess að opið samtal eigi sér stað milli heimamanna og þeirra sem móta neyðar- og viðbragðsáætlanir vegna eldgosavár. Samtalið milli skipuleggjenda og íbúa þarf að eiga sér stað án aðgreiningar til að tryggja að áætlanir endurspegli nægilega vel og komi á móts við staðbundna þekkingu og sjónarhorn íbúa. Slík samvinna er líkleg til að efla traust milli almannavarna og heimamanna og tryggja að rýming og viðbrögð vegna eldfjallavár fari fram á sem átakaminnstan og öruggastan hátt.

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