Extreme precipitation and climate change at metropolitan scale: Mapping the historical trajectory of flood risk regimes in Grenoble-Alpes-Métropole

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Mohammed Kharbouche[1], Antoine Brochet[2], Yvan Renou[3], Jean-Dominique Creutin[4].

KEYWORDS

History of flood risk, Grenoble, risk regimes, historical institutionalism, socio-environmental conflicts, climate change.

ABBREVIATIONS

ADIDR: Departmental association of communities interested in the development of the plains of Isère and Drac rivers

FRPP: Flood Risk Prevention Plan

GAM: Grenoble-Alpes-Metropole

GEMAPI: Managing Aquatic Environments and Flood Prevention

ILUPP: Intercommunal Local Urban Planning Plan

IPA: Instruments of Public Action

LUPP: Local Urban Planning Plans

SYMBHI: Mixed Syndicate of Hydraulic Basins of Isère River

ABSTRACT

This paper focuses on "risk regimes", understood as institutional configurations characterizing flood risk management in the Grenoble plain since 1219. Based on historical documentation and a series of interviews with actors in the Grenoble-Alpes-Metropole, we model each regime in terms of the nature and recurrence of events, the dominant institutional system, conflicts, associated inequalities and the role of communities. By linking institutional arrangements and mobilized actors to environmental conflicts, this paper provides a better understanding of the socio-institutional changes in relation to extreme events. We conclude by questioning the role of climate change in the characterization of the

[1] Grenoble Alpes University (PACTE)

[2] Grenoble Alpes University (Institute of Environmental Geosciences)

[3] Grenoble Alpes University (PACTE)

[4] Grenoble Alpes University (Institute of Environmental Geosciences)

contemporary regime and the challenges it poses in terms of the pace of policy decisions to adapt to the intensification of extremes.

1- INTRODUCTION

The Climat-Métro research project focuses on climate change, its variability and magnitude at the scale of the Grenoble-Alpes-Metropole (GAM) area and in relation to the water sector. The interdisciplinary approach undertaken is intended to support public action with regard to extreme flood events and their evolution at different scales. In addition, the emphasis is placed on possible socio-economic adaptation strategies.

The research project associates/aggregates the visions of researchers from different disciplines and that of actors and political decision-makers. Based on this guideline, the article presents first results in social science that identify different "risk regimes"[5] as modalities of flood risk management at different periods. The historical approach covers the long run (from the 13th century to the present day), and informs the modalities of flood risk management by public actors, the evolution of conflicts and inequalities as well as the associated infrastructures and protection systems. Ultimately, the objective is to better understand the dynamics of socio-hydrological interactions at the scale of the studied territory.

Our results show an evolution of flood risk management in Grenoble in terms of institutions, levels of intervention, instruments, and financing systems. We show how inhabitants' behaviors evolve with regard to flood risk, which generate more or less important conflicts and inequalities according to the identified institutional configurations. Our research results put into perspective the mechanical link between the type of floods (torrential and river floods that can occur alone or at the same time) and the nature of the actions and political projects implemented. For example, the type of public instruments, the scale of political intervention, the nature of infrastructure and the mobilized financial resources.

2- METHODS

The analysis is based essentially on historical works characterizing the history of floods in the plain of Grenoble between the 13th and 18th centuries. The case of Grenoble is particularly well documented, the plain having been confronted with devastating floods of the two rivers crossing the city: the Drac and the Isère River. In this article, we have selected 11 research papers and books related to the study period, notably those of Auguste Bouchayer and Denis Coeur. Based on these works, our study characterizes the salient facts mapping different past flood risk regimes according to historically documented events, their nature (torrential, riverine and concomitant floods) and their consequences at the political (interventionism of the central state, new instruments of public action, etc.) and social (inequalities of exposure to flood risk, conflicts) levels.

The characterization of the current flood risk regime is based on exploratory interviews conducted by the Climat-Métro team with stakeholders of GAM. It extends the historical and critical analysis to the modern period.

[5] A risk regime is a simplified representation of the interaction, collaboration and contestation between actors (with different interests, knowledge and institutional and political weight) and stakeholders (infrastructure, policy instruments, etc.) regarding the management of an environmental risk.

3- RESULTS

A regime structured around the intervention of communities of inhabitants over the 13th and 14th centuries

Major institutional changes take place over the 11th and 12th centuries, notably the disappearance of serfdom and the establishment of institutions intended for very specific missions (Delphinal Council[6], Governors, Magistrate's Court, Chamber of Auditors, Bailiwicks). This period of history was marked by the flood of 1219, which is considered exceptional in its scale and nature. This event was mainly caused by the rupture of a natural dam on the Romanche River, a tributary of the Drac River (Lake St. Lawrence). The event of 1219 strongly marked the collective memory of Grenoble and consequently favoured the initiation of a flood risk prevention policy (Favier, 2002, pp. 34-35).

Following the event of 1219, a new sharing of power between ecclesiastical authorities, the Dolphin and the communities of inhabitants was initiated by the adoption of a first franchise charter[7] granted by the bishop and the Dolphin to the city in 1226. This gave the city the beginning of an autonomous legal status and extended its geographical limits by including the suburbs on the right bank of the Isère River. Other charters were then granted in 1242, 1279 and then in 1291 which resulted in the extension of the rights of the communities.

The above political developments enabled "local communities to administer themselves" (Letonnelier, 1958, pp. 35-36), leading to collective self-organization to ensure protection against flooding, water drainage and management of dikes and ditches. In other words, the inhabiting and ecclesiastical communities shared a common representation of the flood as a real threat that imposed an effective and reactive collective organization (Leguay, 2005; Quenet, 2010).

Finally, it is interesting to note that apart from the event of 1219, no events are mentioned before 1373.

A risk regime structured around the assertion of urban secular power between the 14th and 17th centuries

During this second period, the plain of Grenoble faces the most striking events of its history. The number of floods increased, and "extraordinary overflows" of the Drac River threatened Grenoble (Bravard, 1989), for example in the period between 1373 and 1377. Other major floods of the Drac River occurred, notably in 1471, 1519 and 1525, causing significant damage.

Contrary to the Drac River, the first mention of a flood of the Isère River dates from 1469, followed by the floods of 1522, 1524, 1579, 1604 and those of 14 and 30 November 1651, which are considered record floods.

In this context, and from the end of the 14th century, the city of Grenoble gradually replaced the action of the communities. The work was essentially carried out on the Drac River and concerned the extension of the dikes or their raising. As for the Isère River the stakes were less important at that time, very few works were built (Cœur, 2008, p.97).

The multiplication of events required interventions to protect the city. Based on this reality, the mobilization of financial resources by the city is essential to develop and protect the plain. Whereas funding had hitherto been borne exclusively by local residents and communities (Cœur, 2008, p.149), a

[6] The Dauphiné is a former province in southeastern of France (correspond to the present department of Isère, Drôme and Hautes-Alpes)

[7] "Franchise charters" were granted in the West in a long movement covering the 12th and 13th centuries. More than "liberating", in the absolute, these charters indissolubly bind by instituting them, right and mutual recognition of a power and a community" (Favier, 2010, p. 40).

taille[8] was authorized by the judge of the Common Court of Grenoble on 12 August 1388, with the aim of "contributing to the costs of diverting the Drac River" (Bouchayer, 1925a, p.131).

The evolution of the financing system is profoundly changing the way flood protection works are carried out. Until now, the protection system was largely organized around non-market relations since the inhabitants intervened most of the time directly by mobilizing their own labor force to carry out the works. From now on, action against flooding depends on more uncertain factors: the administration's ability to collect taxes, the regularity of tax collection rates and bases, the solvency of the city of Grenoble, and the city's political priorities.

Moreover, the importance of carrying out protection work at Grenoble city went beyond protection considerations towards political variables in order to assert the power of Dolphins over the city (Favier, 2002, p.36). Indeed, the creation of a Delphinal Council, whose modalities of power exercise will evolve rapidly, leads to a progressive decrease in the power of religious and communities over the city and to a rise in the power of jurists in the Delphinal government (Ibid, p.44). This then strengthened the role of the city of Grenoble, which was henceforth to intervene on the issue of floods by various bodies.

By becoming more and more rigid, the protection system evolves without necessarily improving the quality of the intervention. The weakness of the monitoring and the administrative and technical supervision of the works leads to works that do not meet the needs or to projects that are not completed. This rigidity is explained by the lack of responsiveness of the set up bodies, which is due to a deficiency of financial resources and to a need of recognition and legitimacy of their intervention.

Flood management policy is an attempt to solve a natural problem, but it imposes political choices that generate socio-political conflicts at territorial scale. For instance, the works on the Drac River moved the river westward, towards the slopes of the Vercors mountains, thus diverting the floods on the communities located on the west bank of the torrent and causing several conflicts thereafter. An agreement was concluded in 1493 between the provincial administration and the communities. This agreement provided a compensation for the repairing costs of protectection works to all the inhabitants as well as to the city. Despite these agreements, the succession of floods still generated environmental rivalries and latent conflicts throughout this period of time.

A centralized and hierarchical regime marked by the implementation of instruments of public action between the 17th and 18th centuries

During this period, the succession of flooding episodes makes their management more problematic. Indeed, several waves of flooding affected the Grenoble area between 1661 and 1778[9].

Flood risk management becomes more comprehensive by following pre-established plans (Bravard, 1989). From the reign of Louis XIV, the State intervened massively by setting up technical, political and financial resources to protect the plain of Grenoble. This centralization led to a strengthening of the State's presence in the field through the creation, in the 1670s, of a new centralization agent named the Intendant, but also through the establishment of an administration in charge of development projects, regulation and flood risk control. State intervention was also reinforced by the royal decision to send a first civil engineer in 1679 to deal with the problems of the Drac and Isère rivers (Cœur, 2003, p.164). As for the financing of works, a finance office was created in 1627 in

[8] The *taille* was a direct annual tax that weighed only on commoners. The end of the *taille* in 1634 led to the extension of the pruning tax to the three orders.

[9] The main floods during this period are: the Isère floods (1673, 1739 and 1740), the Drac floods (1674 and 1679) and the concomitant floods of 1733 and 1737.

Grenoble, marking the important role of the State in this respect, and taking over provincial taxes at the city level (Cœur, 2003, p. 215).

On the other hand, increased State action is reflected in the implementation of new Instruments of Public Action (IPA). For example, a first IPA sets a 120 *toise* (ca. 240 m) strip of land on which communities must not cultivate land, graze or even cut wood. A second IPA is implemented by the order of November 7, 1758, it is an expropriation procedure for the realization of public works.

This centralized flood risk management has been widely challenged. The royal intervention generated several conflicts, such as the Fayolle project (opening of a new Drac canal on the west bank of the river, i.e. on the territory of the communities of Seyssins, Seyssinet and Fontaine). "According to them [the communities], in fact, their territory was once again sacrificed to ensure the protection of Grenoble. Faced with the unilateral commitments of the administration, they demanded the right to participate in decisions on matters that, according to them, directly concerned them" (Coeur, 2003, p. 196). Following this conflict, negotiations took place that allowed the communities affected by the developments to receive compensation starting in the 1750s.

However, it was above all through the letters patent of July 8, 1768 that the state attempted to resolve the problem of unequal protection. Through these letters, a global approach to risk at the regional level will be implemented by specifying the phases of implementation of flood control projects. In addition, the communities and the rest of the interested parties will, from then on, have the power of initiative for the works, while the role of the State will remain limited to the technical and financial control of the projects (Ibid, p.249). Finally, for the first time, these letters propose sustainable financing of the works, which is provided by the State for "all the streams and rivers of the province" (Ibid, p.233).

A decentralized regime favoring a very localized reproduction of inequalities between 1789 and 1914

This period is marked by floods of the Isère River in particular in 1837, 1828, 1838, 1840, 1844, 1845, 1846, and of the Drac River in 1816, 1840 and also a concomitant flood of both rivers in 1843.

The post-revolutionary period allowed a rise in the power of syndical associations of riparian owners[10], in particular with the adoption of the law of September 16, 1807. Another explanation is the occurrence of a major flood of the Drac River in 1816 that gave rise to the "union of owners interested in repairing the dikes on the right bank of the Drac" in 1819.

Existing syndical associations of containment at that time differed greatly according to the degree of state intervention at their creation. In the case of the syndicate on the right bank of the Drac initiated by the State, the action of the syndics appears from the outset to have been closely supervised technically and administratively by the State engineers and the Prefect[11]. Above all, the syndicate's project is imposed by the administration and does not seem to be shared by the owners involved in the association, as attested by the numerous conflicts affecting the syndicate.

On the contrary, on the Isère River, the mobilization of the riparian owners was strong and since at least the 18th century, "private initiative is the master and never the State [...]" (Agard, 1942). The sharing of common practices between riparian landowners in this part of the territory allowed a certain effectiveness of the unions in the fight against floods. Thus, in the 1830s, "at the time when modern

[10] a group of landowners who jointly carry out improvement or maintenance work.

[11] In terms of ownership of the works, "the sub-purchasers of the lands located along the dikes of the Drac River [...] formally renounce [...] all rights of ownership which they claimed to have acquired [...] over the stone dikes, their footboards, the earthen counter-dikes, the ties that link the dike to the counter-dikes, and the embankments of the said counter-dikes and ties [...]" (decision of the Minister of Finance of 24 April 1835, cited by Coeur, 2009: 19).

dikes were beginning to rise in the midst of the vegetation of the upstream Savoyard plain, a good part of the course of the Isère River in the Grésivaudan was already bordered by dikes that connected more or less well with each other, bending to the sinuosity of the river rather than restricting its course" (Ibid.).

This period has seen a number of the most disastrous events in the history of the Grenoble plain, it is from the historical flood of 1851 and 1852 that a considerable number of flood protection devices were calibrated, as mentioned in the following table.

Year	Event	Response
1851 & 1852	Flood of Isère	1850-1910 : works carried out by syndicates (raising and consolidation of dykes + straightening downstream of Grenoble) but meanders are left (La Taillat, Bois français, les Sablons) for fear of aggravating the situation of the agglomeration
1856	Flooding of the Drac and Romanche rivers which mainly affect the right bank (lower dykes) + flooding of the Isère river	1856 : series of measures carried out by the engineer Bonont
		1860 : diking project of the engineer Gentil
		1862 (Napoleon III decree): reorganization of the syndicates of the right bank (fusion of two syndicates) and of the left bank (fusion of seven syndicates) - syndics chosen by the prefects) and creation of sewerage canals
1858	big flood of the Drac	
1859	last great flood of the Isère	Law of June 21, 1865 on the syndical associations
1878	Flood of Isère	1870-1895 : flooding field in the Grésivaudan and chantournes (especially on the right bank). Agricultural trial
1888	Flood of the Drac and Isère rivers	1870 : Claude Bernard and de la Graille quays are built
		1871-1878 : raising of the dikes against the continuous raising of the bed
		1874 : project to consolidate and complete the dikes on the right bank
		1890 : new project of consolidation of the works of the right bank syndicate (including flooding of the Gresse)
		1894 : project of new fortifications and of a diversion canal in order to make the basin unsinkable (not realized)
		1896 : Creation of the Hydrometric Service of the floods by the Ponts et Chaussées (19 stations of announcement and 12 of studies)
		End of XIX : diking completed : "the diking of the Isère delivered the plain" (F. Gex)

Table 1: Major events and decisions taken to strengthen protection

From the French Revolution until the middle of the 19th century, the State thus appeared as a facilitator of the development of owners' unions, but also as a constraining actor with exorbitant prerogatives of public power that allowed it to supervise the action of the unions. This modernization towards less direct State interventionism has been confronted with a multitude of conflicting local interests around the riverbanks, between urban and rural areas and between local residents. In other words, the indirect interventionism of the State through the unions has resulted in a reproduction of inequalities, but on a very localized scale.

A regime that favoured economic development and major infrastructure projects over flood protection between 1914 and 2000

At the beginning of the 20th century, several floods occurred in the Isère River, notably in 1910, 1914, 1928 (Drac and Isère rivers), 1937, 1940, 1944, 1948, and finally 1968.

The conclusion is indisputable: the merger of trade unions and reinforced State supervision did not make it possible to find a lasting solution to the problem of protecting the plain of Grenoble. The bed of the Isère River and the outlets of the drainage canals rose almost continuously, the hydraulic section became insufficient, and the river islets became vegetated. The situation was deemed critical after the great flood of 1914. An inter-ministerial commission was set up to consider how to respond to this situation. After much procrastination, the following were created: in 1930, a public service for the development of the Isère region, which was responsible for carrying out studies and projects; in 1936, the "Departmental Association of Communities Interested in the Development of the plains of Isère and Drac rivers - ADIDR", a sui generis organization officially associating public players and local residents' associations.

This new institutional landscape enables the State to strengthen its ability to impose constraints on the ~~labor~~ unions. Under the new scheme, project management for the three rivers is no longer the direct responsibility of the owners' unions, but of ADIDR, with the State financing almost all the expenses. However, the owners' unions remain responsible for the tributaries and retain the important task of establishing easements and rehabilitating and recalibrating the drainage canals of the plain (630 kilometers of network).

From the 1940s to the 1990s, little protection work was undertaken, except in the post-war period, when dredging, reinforcement of the dikes and cutting of a loop of the Isère River were carried out. This situation can be explained by the priority given to the economic and demographic development of the conurbation (organization of the Olympic Games, etc.) and characterized by massive urbanization and the construction of highways and major infrastructure projects. In this context, the public authorities were able to control floods thanks to modern engineering techniques.

A contemporary regime integrated but threatened by social vulnerability and the inherent events due to climate change from the 2000s

This period is marked by increased torrential risk in the metropolitan area that may result from either increasing vulnerability or change in extreme rainfall. Despite the investments made, some areas are still exposed to the risk of flooding, in particular at many junctions between torrents and rivers. In addition, climate change complicates protecting decisions.

At the institutional level, a twofold far-reaching change is taking place., The creation in 2004 of the Symbhi (Mixed Syndicate of Hydraulic Basins of Isère), a new syndicate that absorbed ADIDR in 2019 and the assumption/acceptance in 2018 of the responsibility for Managing Aquatic Environments and Flood Prevention (GEMAPI) by the Grenoble metropolitan area. Within this new framework, Grenoble-Alpes-Métropole entrusted the Symbhi with the management of the three main rivers (Isère, Drac, and Romanche rivers), kept the responsibility of torrential tributaries, a field that had hitherto remained the responsibility of the syndicate associations. As a result, since 2019, riparian landowners are no longer directly involved in flood protection projects in the Grenoble plain, except for residual missions of plain drainage and maintenance of side protection works like canals. However, the obligation to maintain the banks by the riparian owners, inherited from the Roman law, remains and the peripheralization of the syndicate associations was not self-evident.

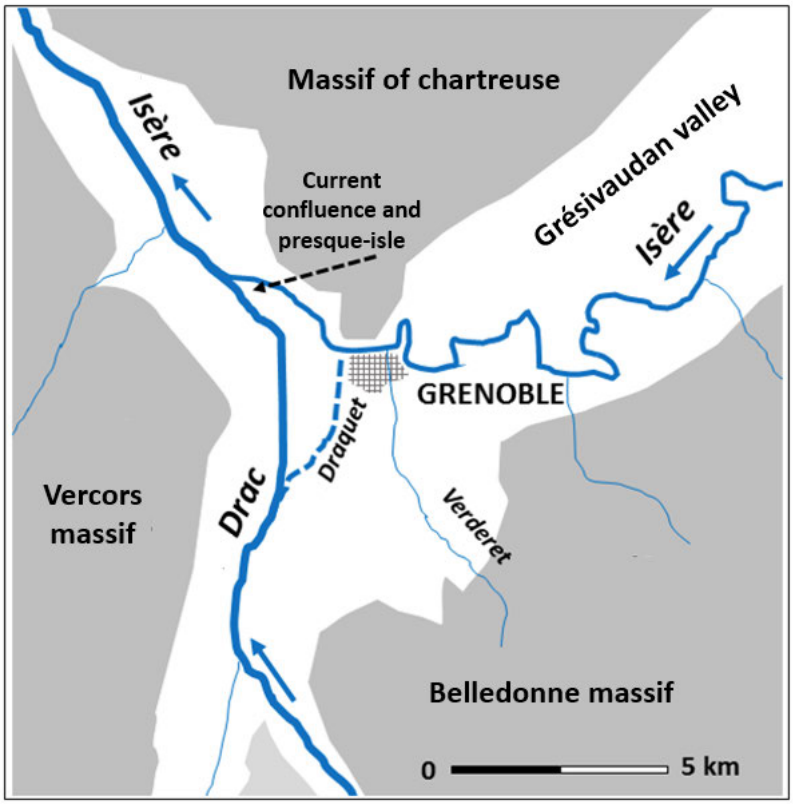

Figure 1. Grenoble and the confluence of the Drac and the Isère rivers

The idea of a major development plan for the Isère River was gradually imposed in order to requalify the protection system. This takes the form of the upstream Isère project, approved in 2007 and carried out under the supervision of the Symbhi. A second structuring project for the Drac River has been approved and will be implemented shortly.

At the same time, a set of documents and development tools dedicated to inter-municipalities and integrating the flood risk have been put in place. For example, in 2019, the Grenoble metropolitan area (which includes 49 municipalities) will approve the Intercommunal Local Urban Planning Scheme (ILUPS), which will replace the communal LUPS (Local Urban Planning Scheme) and set the rules for development and land use at a metropolitan scale. This ILUPS devotes particular importance to natural risk by proposing flood risk reduction measures. For example, a FRPP (flood risk prevention plan) is prepared and sets the rules for reducing vulnerability while specifying the areas where new construction is prohibited.

These documents all share a new vision of the protection against extreme events, which is reflected in a renewed representation of protective structures that are no longer perceived as bulwarks against floods but as fallible structures. The new doctrine is organized around the following principle: "There is no such thing as zero risk", which translates concretely into the fact that: "even if all the dikes have been rebuilt, this will not necessarily change the exposition maps" (excerpt from an interview).

This new institutional configuration produces new inequalities of protection due to the much varied political and economic weights of the inter-municipalities adhering to the Symbhi. For example, the Symbhi devotes 17.5% of expenditure to the Metropolitan area but only 2.5% to the less populated inter-municipality of the Grésivaudan, situated upstream.

CONCLUSIONS

At the end of these respective overviews, it seems established that the modeling of the dominant risk regimes in the Grenoble plain allows a better understanding of the natural stakes related to water and of the socio-institutional arrangements that manage the problem of floods. Nevertheless, the societal stakes related to risks remain historically scattered between the Drac and Isère floods, making the construction of protection works and the implementation of large-scale development projects complex and complicated. In certain periods, political choices are made according to the severity of the events of each river. In this sense, we are witnessing in the contemporary regime to a complexification of stakes notably by the rise of the torrential risk and the problem of co-occurrence of extreme events and their frequency.

The initiator of the protection policies has been historically varied between community action led by the residents or the administration, showing a difference of interventionist scales of the State and its power. It also appears that the action of the State wishing to take control of the governance of flood risk is not necessarily more effective than the action of communities. Often, this public action is based on available financial resources, tax base and political priorities, which further complicates protective projects. Also, governance failures are sometimes displayed with projects that are not completed or not adapted to the needs. Finally, public interventionism can generate societal conflicts at the local level between the protected areas and the areas sacrificed to ensure this protection, and societal arrangements must be found to deal with the risk.

The establishment of an IAP for the first time between the 17th and 18th centuries defining a strip on which communities should not cultivate, graze or even cut wood, marks a new approach to risk management that displays a new relationship between Man and nature tolerating a withdrawal of economic activity to allow overflows in areas with low social and human impact. This doctrine is reinforced in the contemporary regime and strategic risk documents that show a tolerance of risk and a definition of acceptable risk even after the reinforcement or reconstruction of dikes and protective infrastructure reinforcement. Therefore, managing risk no longer means the will to control through protection works but a balance between infrastructure works, vulnerable areas with low constructability and societal acceptability of the investments made, other financial balances are to be found between protection and financing of damages.

Climate variability and the challenges of climate change marked by predictive uncertainty further complicate risk governance and lead to the modeling of a multi-actor risk regime adopting an integrated approach. In this sense, the analysis remains to be deepened in order to characterize the contemporary regime in a context marked by climate uncertainty and socio-economic complexity. The balance between demographic, economic and industrial development and climate risk remains difficult to define with the need to adopt an approach based on the adaptive rather than the curative.

We believe that an in-depth characterization of risk regimes through a historical approach will better inform adaptive decision-making to climate change. Based on the experiences and the contextualization of different historical investments, this characterization remains to be coupled with contemporary scientific knowledge on climate and on the adaptation processes of territories. Such an approach can allow, in our opinion, the production of useful knowledge for the decision giving rise to the proportionality and flexibility of the policies put in place and the integration of the stakeholders, in particular the communities that have historically contributed to the protection against floods.

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