

以大众为主体的 气候变化适应性多视角制图

MULTIPERSPECTIVAL CARTOGRAPHIES FOR DEMOCRATIC CLIMATE ADAPTATION

1 引言

印度尼西亚灾害地图 (PetaBencana.id) 是一个旨在帮助印度尼西亚居民应对洪水等极端气候灾害的在线服务平台。受气候变化影响, 雅加达的极端降水事件愈发频繁。这座三角洲巨型城市拥有13条河流, 并且约30%的土地高程低于海平面, 河水泛滥和城市内涝等屡屡导致居民流离失所——这不仅破坏了交通网络, 也严重威胁了人们的生命安全。PetaBencana.id作为一个收集和分享实时洪水信息的中心处理平台, 致力于帮助居民和应急管理人员更好地了解整个城市的洪水情况, 以降低降雨和洪水的影响。居民通过移动设备上的社交媒体和第三方应用程序所进行的信息交流将被平台采集, 从而生成相应洪水报

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摘要

印度尼西亚雅加达市每年都会经历河水泛滥、城市内涝和沿海洪水。愈发变化多端的气候条件使市民频频面临极端气候事件的威胁。尽管人们对于实时传导数据的应用热情高涨, 但如果缺乏精心设计的数据整合平台, 那么这些数据将毫无意义。印度尼西亚灾害地图 (PetaBencana.id) 是一个免费的在线平台, 可供居民和应急管理人员实时绘制洪水地图。而后, 公众、政府和企业可利用平台所提供的地图来制定相应的洪水响应决策。虽然项目的初衷仅是收集实证信息来模拟洪水状况, 但制图、交叉验证, 以及为居民和政府提供洪水信息等过程本身俨然已成为一种有助于减轻洪水影响的数字元基础设施。来自居民的报告体现了洪水期间的地面实况, 能够用于校准卫星等其他传感器平台生成的地图。本文演示了如何从这一洪水地图催生一种能从多结构角度和多尺度协同绘制城市动态变化的方法, 从而拓展城市基础设施的管理方式与范围, 提升其极端事件应急能力。

关键词

洪水; 气候; 基础设施; 适应; 印度尼西亚灾害地图

ABSTRACT

Jakarta in Indonesia experiences annual fluvial, pluvial, and coastal flooding. As weather patterns become increasingly unpredictable residents regularly face extreme weather events. While the proliferation of data has been enthusiastically adopted to transform real-time response, data is meaningless without designed platforms of considered assembly. PetaBencana.id (Disaster Map Indonesia) is a free online platform that enables residents and emergency managers to map flooding in real-time. The map is used by the public, government, and business to enhance decision-making in response to flooding. Contrary to the project's initial aim of collecting empirical information to model flood conditions, the work of mapping, cross-validating, and disseminating flood information for residents and government has become in itself a form of digital meta-infrastructure that helps mitigate the impact of flooding. Resident reports are now the de-facto ground truth for flood information, and are used to calibrate other sensor-platforms (e.g., satellite imagery). This essay reflects on how the map developed a methodology for collaboratively mapping the dynamic fluctuations of the city from multiple textural perspectives and at multiple scales, thereby diversifying the means and scope of participation in urban infrastructure and its response to extreme events.

KEYWORDS

Flood; Climate; Infrastructure; Adaptation; PetaBencana.id

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1. PetaBencana.id平台生成的地图可实时显示居民的洪水报告和政府对水深的核验结果。
1. PetaBencana.id map showing real-time resident flood reports and government validations of water depth

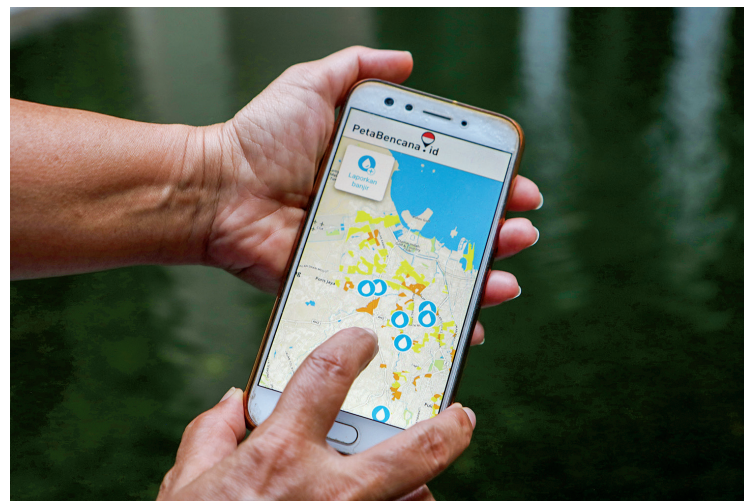
告。报告内容涵盖水深估值和现场照片，可供用户在地图上实时查看（图1，2）。通过PetaBencana.id平台，应急管理人员还可汇总居民拨打的紧急服务电话等其他相关数据来源以完善居民上报的信息，进而协调基层的应急响应措施，同时将实况共享到地图上，以便居民查看政府应对洪水的情况（图3）。

每当洪水来临，雅加达的社交媒体上都会涌现出大量的信息流，这为PetaBencana.id平台的构建提供了灵感。PetaBencana.id的独特性恰恰在于其将社交媒体视为与受灾居民进行沟通，并辅助其收集数据的一种方式。在2014年开展的一项试点研究中，从社交网络推特上捕捉到的降水事件期间的“推文”样本显示，当城市河流泛滥时，居民倾向于将社交媒体当作一种数字通知系统来分享洪水警报信息。基于这一发现，研究人员开发了一款名为“CogniCity”的开源软件以主动搜寻社交媒体上关于洪水的帖子，并通过聊天机器人向对方询问更多信息^[1]——这也正是这一方法的新颖之处，因为以往的研究通常只是被动使用社交媒体数据，即主要使用统计模型来分析社交媒体上的帖子以量化和绘制洪水情况。

迭代的人种学研究不断识别利益相关方的需求和设计需求，为CogniCity软件的设计和开发提供了依据。在本文中，PetaBencana.id项目的联合创始人之一托马斯·霍尔内斯和现任负责人纳欣·玛塔妮回顾了催生这一设计决策的最初灵感，以及未来项目将如何改进数据获取，以应对东南亚其他城市的不同挑战。

2 以居民报告作为地面实况

在雅加达，河水和地表径流的流动通常受限于排水沟、运河和水泵等一系列正规或非正规的基础设施，而在这些设施中，水的流动并不依赖于自然的海拔落差。在这一背景下，洪水的成因主要有三点：

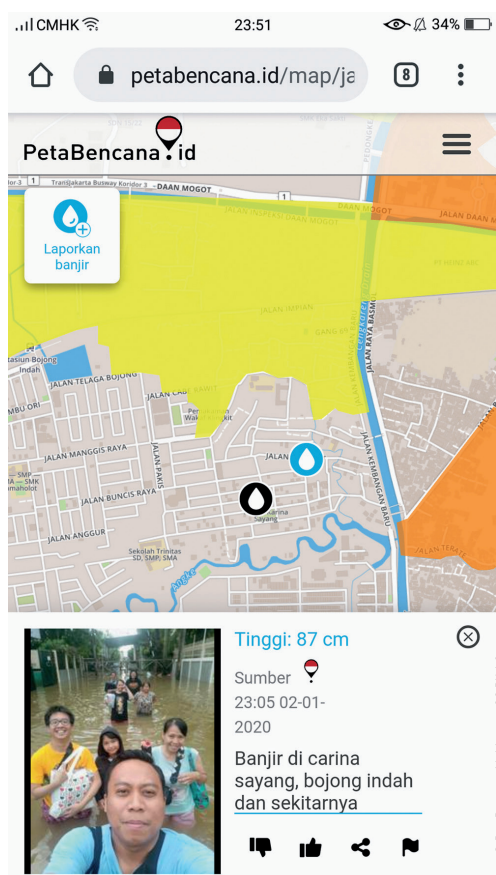


1) 降水强度暂时超出排水基础设施承受能力；2) 水路网络发生灾难性故障（如堤坝垮塌）；3) 由风暴潮带来的沿海洪水。这三种洪水模式可能同时发生，并在城市内部极速蔓延。因此，针对特定降雨或风暴事件，预测建模技术难以准确识别出真正存在洪水风险的地区。这类事件中的最大威胁是夜间灌入房屋中的洪水，它们会迅速淹没一层和二层的房间，极大危害了生命安全（造成居民触电身亡或溺亡）。为了应对这一问题，居民、应急救援人员和应急管理人员可综合降雨强度（通过观测、计量和雷达探测获得）、河流水位及以往洪水多发地的信息来组织和确定应急措施。然而，在当前不断变化的降雨模式下，这种方法的局限性也日益显现^[2]。

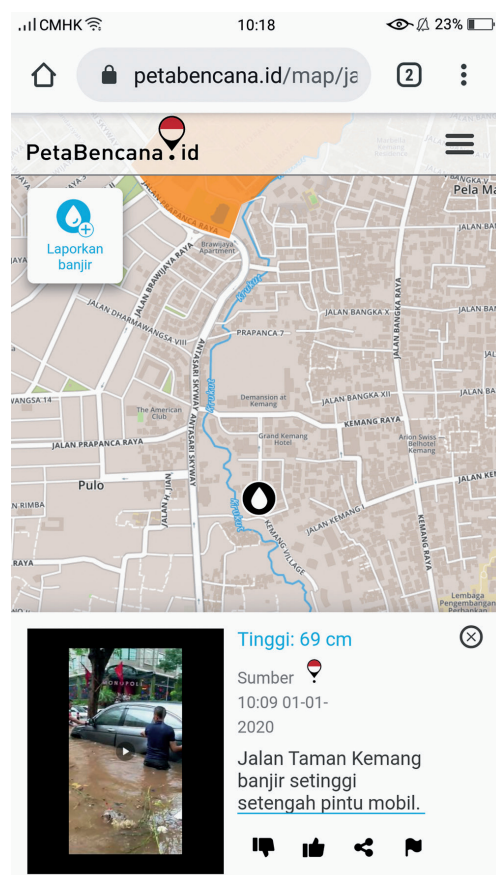
当灾害来临，一旦国家层面的治理举措出现滞后，基层组织便会及时介入。这种基层响应实例在全球范围内广泛存在，且形式多样。例如，新冠肺炎（COVID-19）在印度尼西亚加速爆发期间，社区负责人对国家政府决策的优柔寡断和拖延感到失望，于是在街区范围内自行实施了封闭措施以遏制病毒的传播^[3]。在季风季节，应对灾害的即时响应和疏散工作也多数由街区来协调。此时，PetaBencana.id平台为居民提供了一种可以帮助其迅速避灾的报告机制，这种机制以数字化的方式延续了他们对洪水态势的感知与对所在城市的深入了解。平台利用政府预估的洪水深度、河流水位和卫星图等二手信息来完善居民上报信息，以尽可能如实反映情况。

在雅加达，之所以将社交媒体的调查作为洪水报告来源，是因为当前基于地理空间数据的解决方案难以适用于灾害响应：在这个住宅密度颇高的城市中，许多社区的主要街道只有臂展宽，低于用来绘制洪水范围的地球观测传感器的分辨率。再者，当前所布设的电子传感器和闭路摄像头也不足以持续监测供水网络以防基础设施故障。

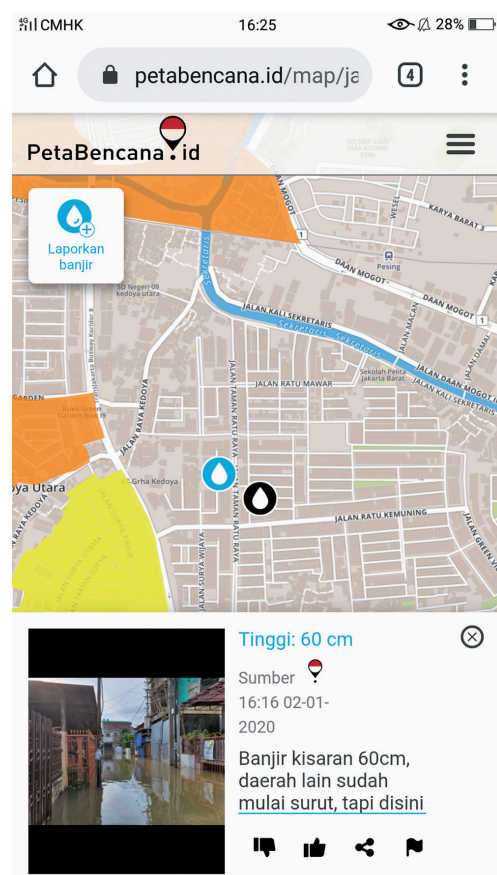
自2014年以来，政府机构、居民和应急救援人员持续使用PetaBencana.id平台，生成的众源数据报告愈发合理有效，大大推动



2-1



2-2



2-3

- 2-1. 2020年1月雅加达洪水期间PetaBencana.id平台的地图截屏。居民通过提交“自拍”生成洪水报告，对当地情况进行共享。PetaBencana.id平台积极鼓励居民在“自拍拯救生命”话题（#SelfiesSaveLives）中分享洪水报告。
- 2-2. 2020年1月雅加达洪水期间PetaBencana.id平台的地图截屏。居民通过照片描述了洪水与汽车的相对高度，共享了有关道路通行与否的信息。
- 2-3. 2020年1月雅加达洪水期间PetaBencana.id平台的地图截屏。居民们分享了一张有关周边洪水情况的图片，并表示当前的洪水水位保持在60cm，并且没有消退的迹象，但此时雅加达其他地区的洪水都已经逐渐消退。

- 2-1. A screenshot of the PetaBencana.id map during flooding in Jakarta in January 2020. Residents submit a "selfie" as a flood report to share local conditions. PetaBencana.id actively encourages residents to share reports throughout the #SelfiesSaveLives campaign.
- 2-2. A screenshot of the PetaBencana.id map during flooding in Jakarta in January 2020. Residents describe the height of the flood in relation to a car, in order to share information about road accessibility.
- 2-3. A screenshot of the PetaBencana.id map during flooding in Jakarta in January 2020. Residents share a picture of the flood condition in their neighborhood, describing that the flood level remains at 60 cm and has not subsided for several days, despite flood levels having subsided in other areas of the city.

了对灾害的即时响应（图4，5）。当前，平台的规模正不断扩大，并获得越来越多专家的认可，收集到的数据也已被运用于多重时空尺度下的各类气候适应工作。自2020年起，为支持国家应急管理机构的工，平台向全国各地的居民开放了使用权限，支持他们报告洪水、森林火灾、雾霾、火山爆发、极端大风和地震等各种地理灾害情况（图6）。

2020年1月，来自PetaBencana.id的实时众源数据报告帮助美国国家航空航天局（NASA）的喷气推进实验室快速生成了首份校准后的洪水淹没卫星专题地图。该实验室高级快速成像和分析团队的灾害响应负责人允尚浩（音译）博士明确表示，通过来自地面的众源数据报告来验证卫星地图对于准确绘制洪水范围而言意义重大^[4]。在与PetaBencana.id的讨论中，允博士解释说，遥感影像变化检测方法有时会因为某些无法解释的反射情况而错误地反映洪水的范围。为了解释这种卫星无法捕捉到的粒状变异，允博士的团队需要借助已通过验证的全城地面数据来辅助判断。

2020年1月1日，随着罕见强降雨逐渐淹没雅加达，居民开始主动在PetaBencana.id平台分享有关被淹没社区、基础设施故障和应对措施的信息，平台活跃度随即增加了24 000%（图4-2，4-3，5-2）。由于

PetaBencana.id平台收集的实时数据所覆盖的空间范围足够大、分辨率也足够高，NASA团队得以以空前的速度验证了哥白尼计划中的哨兵1号卫星所收集的合成孔径雷达数据的准确性。目前，这些结构数据不仅支持实时分析，也可作为输入信息用于遥感影像变化检测分析，以优化监督分类等基于规则的图像处理技术。

洪水淹没卫星专题地图可用于指导国家级和区域尺度政策与规划的制定，因此每个像素的成像质量都至关重要，它将影响到有关基础设施建设和维护的循证决策、为增加地下水补给率和减缓雨水径流而实施的城市用地分类管理政策，以及针对特定地区的景观基础设施激励措施。地图的呈现对象和呈现方式是关注的重点。通过校准不同尺度的地图体系，各个部门可以实现对城市基础设施的共同监测与管理，并制定更具包容性的框架来解决和应对城市挑战。

3 以大众为主体的气候变化适应性数字地图

正如在城市中发生的其他极端气候事件一样，雅加达的洪水对城市贫困人口产生的负面影响更加严峻。一项针对居民和社区团体的人

种学调查表明，并非所有人都信任数据收集项目。此外，许多着眼于雅加达殖民历史并结合地面激光扫描或采访形式开展的研究也显示，当地居民未能认识到数据收集项目为社区带来的益处。与此同时，政治腐败和严重的社会不平等现象已大大降低了政府公信力。鉴于此，PetaBencana.id平台为应急管理人员提供了极大帮助，因为免费获取的地图促生了一个平等、透明的交流界面，成为他们在洪水事件中向居民分享政府应对举措的一个媒介。

在日益恶劣的气候条件下，雅加达不堪重负的水利和水文基础设施持续失效，遗留的技术官僚现代主义作风继续把持着这座城市的洪水管理工作。“河流标准化”工程项目是当前已开展的众多防洪项目之一，主要利用混凝土将河道渠化。在过去，雅加达居民通过频发的洪水事件总结出了一套实用的观测策略，即通过追踪漩涡模式、湍流程度和水的颜色等物理指标来预测洪水情况。但“河流标准化”工程项目一类的干预措施改变了城市洪水的自然发生方式，居民赖以识别环境状况的指标随之失效。

日益复杂的城市问题亟需通过不同尺度的治理手段来疏解——或更加关注于本土化行动，或更为灵活多变、能够摆脱层层政策的限制。那么，如何才能充分调动居民群体的主观能动性，鼓励其参与制定可行且合理的决策？不同于以往由少部分人主导的远程监测决策模式，PetaBencana.id平台采用了一种分权决策支持工具。数以百万计的居民通过手机即可访问平台提供的免费关键信息，进而制定基于个人和社区的实时响应战略。项目设计人员同时搭建了一个“轻松数据”平台，可与居民比较熟悉的即时通讯、社交媒体和短信等沟通方式无缝衔接，以供资金不足的社区、技术手段有限的机构和不太熟悉数据获取方式的个人使用；人们无需通过高强度且昂贵的培训即可理解和掌握平台使用方法。通过PetaBencana.id平台，所有居民都有资格参与决策及基础设施和资源管理^[5]。平台也不存在学历水平限制，任何人都

可以匿名提供个人的经验观测值并生成洪水报告，城市中的不同人群均可轻松读取平台提供的信息。为了保障数据的匿名化，平台不会追踪用户个人信息。相反，平台致力于呈现人们在城市空间中的不同经历：它们反映了人、环境和基础设施的交互关系，是构成城市应对气候变化适应性的不可或缺的一部分。

4 结论

任何平台——包括更加广泛意义的设计干预——都脱离不了对一系列社会和经济约束、现有技术及体系、权力制度和河流生态过程的考量。在开发韧性基础设施的过程中，厘清人、环境和基础设施之间的复杂关系。

通过持续的迭代协同研究，PetaBencana.id平台的应用范围正在不断扩大。相应地，平台的结构部署也在不断适应各种局面变化：制图、交叉验证及为居民和政府提供洪水信息等过程本身已经成为一种有助于减轻洪水影响的数字元基础设施。雅加达灾害管理局应急监测负责人巴苏基·拉赫马特表示，“在平台尚未建立的时候，人们很容易忽视灾害警告。但自从这个项目启动以来，人们对灾害有了更多的了解，并且愿意彼此分享信息。通过信息共享，人们提高了对洪水威胁的认识，这大大有助于减少灾害风险。”因此，搭建平台的过程本身就是一种增强社区韧性、拓展基础设施管理和维护网络的重要途径。LAF

致谢

PetaBencana.id平台由美国国际开发署支持构建。平台的顺利推行亦离不开项目合作伙伴夏威夷大学太平洋灾难中心和人道主义开放街道地图团队、执行合作伙伴印度尼西亚国家灾难管理机构和雅加达灾难管理局，以及数据合作伙伴地图盒子、推特、Qlue智慧城市程序和PasangMata市民新闻平台等的大力支持。



3. 印度尼西亚应急管理中心的一名操作员正在查看PetaBencana.id平台有关全国各地洪水的报告。
3. An operator in Indonesia's Emergency Management Center views PetaBencana.id reports of flooding from across Indonesia.

1 Introduction

PetaBencana.id (Disaster Map Indonesia) is an online service that helps residents in Indonesia respond to extreme weather events, such as flooding. Jakarta is experiencing increasingly extreme rainfall events as a result of climate change. As a delta megacity with 13 rivers and about 30% of land below sea level, pluvial and fluvial flooding frequently displace residents, disrupt transport networks, and represent a danger to life. PetaBencana.id works to mitigate the impacts of rainfall and flooding by operating as a central platform to collect and share real-time flood information, helping residents and emergency managers better understand flood conditions across the city. Flood reports are collected from residents using their mobile devices, communicating with the platform via social media and third party applications. Reports, including estimates of water depth and photos can be viewed on the map in real-time (Fig. 1, 2). Emergency managers use PetaBencana.id to collate resident reports with additional data-sources (e.g. calls from residents to emergency services) to coordinate response at the neighborhood level, which is also shared with the map, so that residents can see how the government responds to flood conditions (Fig. 3).

Originally inspired by the significant volumes of social media activity observed in Jakarta during flood events, PetaBencana.id is unique because it uses social media as a means of communication with affected residents to gather data. In a 2014 pilot study, samples of “tweets” from

the social network Twitter captured during rainfall events showed that as the city’s rivers overflowed residents turned to social media as a digital notification system to share alerts about flood conditions. The project developed “CogniCity,” an open source software that actively listens for social media posts about flooding and uses a chat bot to ask for further information^[1]. This approach is novel because previous studies had focused on using social media data passively by analysing social media posts to try to quantify and map flood conditions using statistical models.

Stakeholders’ and design requirements were identified through a process of iterative ethnographic research, which was fed into the design and development of the CogniCity software. In this essay, Tomas Holderness, one of the project’s co-creators and Nashin Mahtani, the project’s current director reflect on the inspiration points for the initial design decisions and how the project is developing in the future to capture data to address different urban challenges across South East Asia.

2 Resident Reports as Ground Truth

The movement of both river water and surface runoff in Jakarta is controlled by a set of formal and informal infrastructure (e.g. drains, canals, and pumps) where flow is not dependent on elevation. Flooding principally occurs for three reasons: 1) the drainage infrastructure is temporarily overwhelmed by rainfall intensity; 2) catastrophic failure of the waterways network (e.g., levee collapse); and 3) storm surge resulting in coastal inundation. All these three modes of

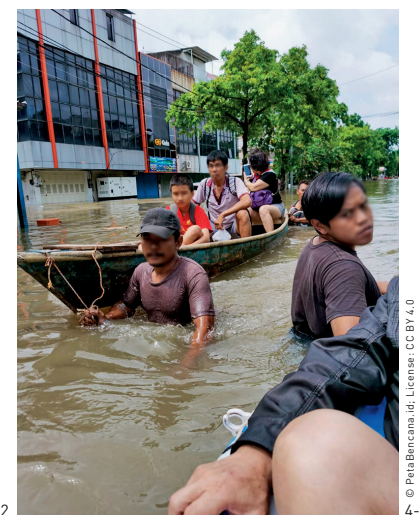
- 4-1. 提交到PetaBencana.id平台的照片显示：2017年，受洪水影响，雅加达的水渠墙身发生了坍塌。
 - 4-2. 提交到PetaBencana.id平台的照片显示了2020年1月雅加达被洪水淹没的社区。
 - 4-3. 提交到PetaBencana.id平台的照片显示：2020年1月，受洪水影响，雅加达的居民正在疏散。
- 4-1. Photo submitted to PetaBencana.id showing canal wall collapse in Jakarta in 2017.
 - 4-2. Photo submitted to PetaBencana.id showing flooded neighborhood in Jakarta in January 2020.
 - 4-3. Photo submitted to PetaBencana.id showing resident evacuation in Jakarta in January 2020.



4-1



4-2



4-3

flooding may happen simultaneously, and operate at intra-urban scales and at high speed. For this reason predictive modelling approaches fail to accurately map spatial risk of flooding for a given rainfall or storm event. The principal danger to life in such events is water entering homes in the night and rapidly filling ground and first floor rooms. Mortality is the result of electrocution or drowning. In response, residents, first responders and emergency managers use a combination of rainfall intensity (from observation, gauges, and radar), river levels, and tacit knowledge of prior locations where flooding has occurred in previous events to organize and target their response. This approach, however, is increasingly limited by changing rainfall patterns^[2].

During disasters, when national scales of governance lag, community organizations are often the first to step in. Such examples of grassroots' response are widespread and manifold globally. During the accelerated outbreak of COVID-19 in Indonesia for example, frustrated with the indecision and delay of national government policies, community leaders enacted self-imposed lockdowns at a neighborhood scale to curb the spread of the virus^[3]. Throughout the monsoon season, immediate response and evacuation efforts are coordinated at the neighbourhood level as well. PetaBencana.id aims to complement residents' agility of response towards disaster by providing a reporting mechanism that exists as a digital continuation of their expertise rooted in situational awareness and local knowledge of the city. The platform augments residents' reports with secondary sources of information, including government-estimated flood depths, river levels, and satellite layers to provide the best representation of conditions possible.

The investigation of social media as a source of flood reports in Jakarta was prompted by a lack of suitability of existing geospatial data solutions: the density of residential dwellings in the city means that principal thoroughfares in many neighbourhoods are only arm-width wide, which is below the resolution of Earth observation sensors that can be used to map floodwater extents. Similarly, the density of electronic sensors and closed circuit television cameras required to continuously monitor the water network for infrastructure failure is not feasible.

The sustained use of the platform by government agencies, residents, and first responders since 2014 has enforced the validity and legitimacy of crowdsourced reports in supporting immediate response (Fig. 4, 5). As the platform continues to scale and gain further trust of various experts,

the data gathered by PetaBencana.id is now also being adopted for a variety of climate adaptation efforts occurring at multiple spatial and temporal scales. In 2020 PetaBencana.id began to support Indonesia's National Emergency Management Agency by allowing residents from across the country to report on a variety of geographic perils, including flooding, forest fire, haze, volcano, extreme wind, and earthquake (Fig. 6).

In January 2020 real-time crowdsourced reports from PetaBencana.id enabled NASA's Jet Propulsion Laboratory to rapidly generate a calibrated satellite flood proxy map for the first time. Dr. Sang-Ho Yun, lead of disaster response for NASA's Advanced Rapid Imaging and Analysis team at the Jet Propulsion Laboratory, articulated the significance of corroborating satellite overviews with on-the-ground crowdsourced reporting in order to accurately map flood extents^[4]. During a discussion with PetaBencana.id, Dr. Yun explained that change detection approaches can sometimes misrepresent flood extents due to unaccounted-for reflections. To account for such granular variabilities (that a satellite is unable to capture), Dr. Yun's team required verified ground-data spanning the extents of the city.

On January 1, 2020, when record-breaking rainfall inundated Jakarta, PetaBencana.id experienced a 24,000% increase in activity as residents actively shared information about flooded neighborhoods, infrastructure failures, and response efforts (Fig. 4-2, 4-3, 5-2). The real-time data collected by PetaBencana.id covered a sufficient spatial extent at a fine-enough resolution to enable the team at NASA to verify the accuracy of the SAR data collected by the Copernicus Sentinel-1 satellites at an unprecedented speed. The textural data not only supported real-time analysis, but is also now being used as an input to refine rule-based classification image processing in change detection analyses.

As flood proxy maps are utilized to guide policy and planning at a national and regional scale, the representative quality of each pixel can be pivotal in making evidence-based decisions about the construction and maintenance of infrastructure, policies governing the typology of urban surfaces to increase rates of aquifer recharge and decelerate stormwater runoff, and measures to encourage landscaping infrastructure in particular areas. What is represented and how it is represented, is what is likely to be attended to. Calibrating multi-scalar cartographic ontologies multiplies the possibilities for co-representing and co-managing urban infrastructure; shaping the way urban challenges are addressed and responded to through far more inclusive frameworks.

3 A Digital Map for Democratic Adaptation to Climate Change

As in all extreme weather events in cities, the urban poor are disproportionately negatively impacted by flooding in Jakarta. As part of ethnography with residents and community groups, it became clear that there was a distrust of data-collection projects. Numerous studies have followed Jakarta's colonial history, and be it with terrestrial laser scanning or interviews, have extracted knowledge from local residents with little evidence of the benefits for the community. Secondly, political corruption and severe inequality have created a culture of distrust between residents and the government. To this end, emergency managers place value in the platform because the (freely available) map provides them with an equal and transparent interface to share data about their response with residents during flooding.

As Jakarta's overburdened hydraulic and hydrological infrastructure continues to fail under the pressure of intensifying weather patterns, the legacy of technocratic modernism continues to drive the city's approach to flood management. Among the various projects currently underway to mitigate flooding is "normalization," i.e. the channeling of the city's waterways by replacing the river's banks with contiguous concrete edges. Jakarta has always experienced flooding, and residents had previously devised strategies to anticipate the water's behavior through attendant observations

of physical indicators (including the pattern of eddies, the degree of turbulence, and the water's color). Interventions such as the normalization project have transformed the way flooding happens in the city and annulled the indices by which residents had learned to read their environment.

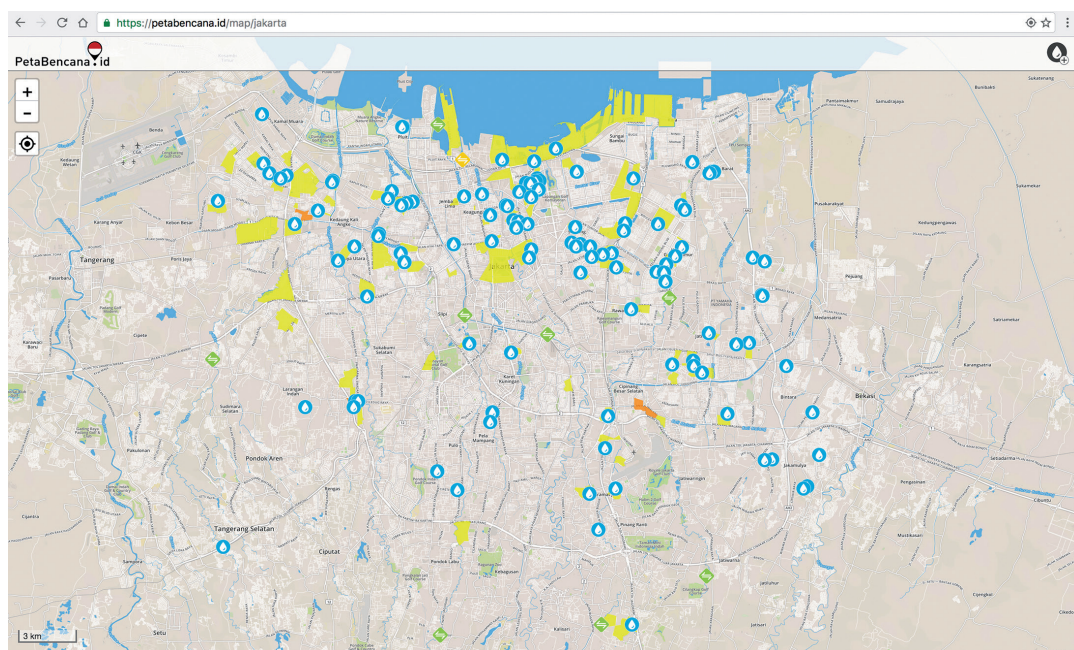
Increasingly complex urban challenges necessitate different scales of governance—ones that are more attentive to localized behaviors and ones that can be more agile and less restrained by convoluted chains of command. How can we reinforce agile resident units and give them the agency to make feasible and informed decisions? Instead of concentrating decision making within a small group of people monitoring dashboards in remote control rooms, PetaBencana.id adopts an approach that decentralizes decision support tools. By making critical information freely available and accessible through the mobile phone, millions of residents are able to strategize personal and community-based efforts for response in real-time. Through the design of a "data-light" platform that operates smoothly with other existing instant messaging, social media, and SMS-based communications that are already familiar to residents, the platform is designed for underfunded communities, agencies with limited technical means, and individuals with modest means for data usage to access; it encourages these groups to both understand and use the system effectively without extensive or costly training. The platform thereby grants eligibility to all residents to participate in decision-making, infrastructure management, and resource management^[5]. By

5-1. 2017年2月PetaBencana.id平台的地图截屏显示了当时的洪水范围。阴影区域表示政府已采取应急行动的街区，阴影的颜色代表洪水深度（黄色为10-70cm，橙色为71-150cm，红色为超过150cm）。

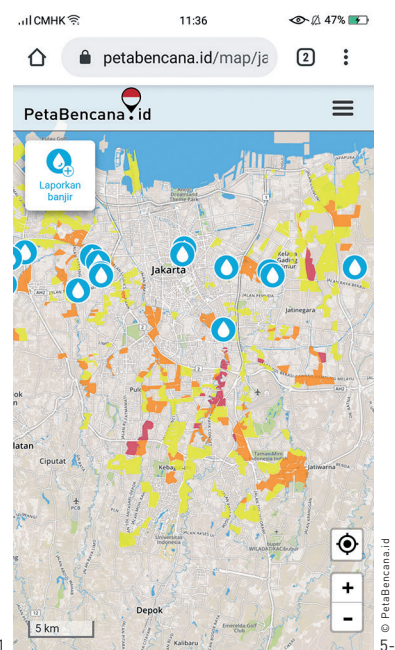
5-2. 2020年1月PetaBencana.id平台的地图截屏显示了当时的洪水范围。阴影区域表示政府已采取应急行动的街区，阴影的颜色代表洪水深度（黄色为10-70cm，橙色为71-150cm，红色为超过150cm）。

5-1. Screenshot of PetaBencana.id map from February 2017 showing the extent of the flooding. Shaded areas indicate neighbourhoods where government response was underway and indicate depth of flood waters (yellow: 10 – 70 cm, orange: 71 – 150 cm, red: over 150 cm).

5-2. Screenshot of PetaBencana.id map from January 2020 showing the extent of the flooding. Shaded areas indicate neighbourhoods where government response was underway and indicate depth of flood waters (yellow: 10 – 70 cm, orange: 71 – 150 cm, red: over 150 cm).



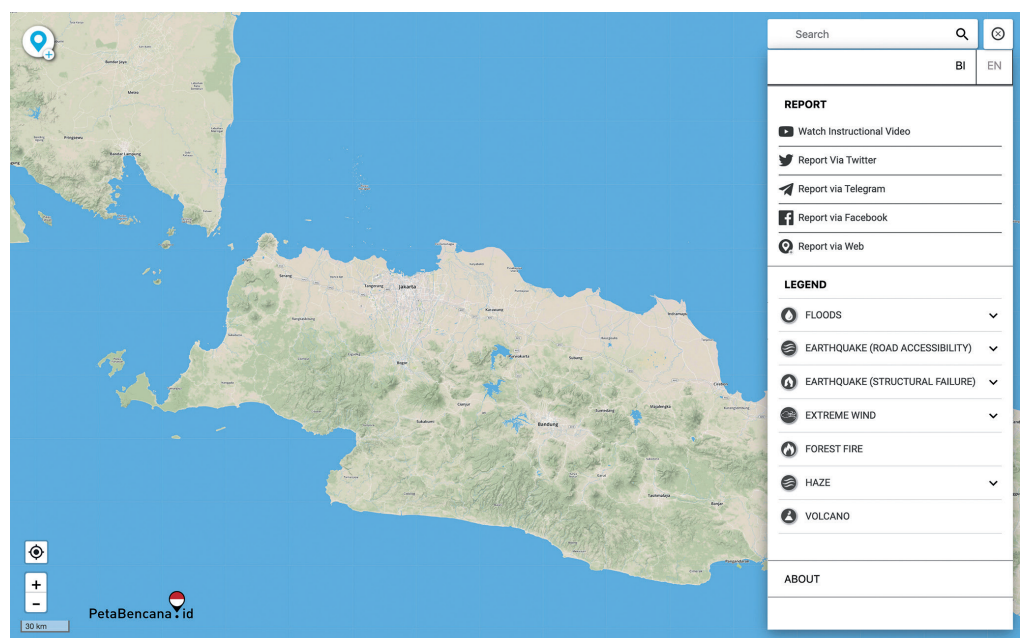
5-1



5-2

6. 2020年，技术人员对PetaBencana.id平台的功能进行了拓展，以将众源数据报告应用于各种灾害响应中，包括森林火灾、雾霾、火山爆发、极端大风和地震等。居民能够通过各种社交媒体和即时通讯应用程序提交实时灾难报告。

6. In 2020, PetaBencana.id expanded to enable crowd-sourced reporting for a variety of hazards including forest fire, haze, volcano, extreme wind, and earthquake. Residents are able to submit real-time disaster reports through a variety of social media and instant messaging applications.



decredentalizing flood reporting—anyone can contribute empirical observations anonymously—the platform also grants equal legibility to the diverse populations inhabiting the city. In keeping the data anonymous, the platform is not concerned with tracing individual users. Rather, it is interested in understanding heterogeneous experiences of urban space as they interact as a system in order to meaningfully address adaptation through the connections between people, environment, and infrastructure.

4 Conclusions

Any platform—and more broadly speaking, design intervention—exists within a set of social and economic constraints, existing technologies and systems, power geometries, and fluvial ecological processes. Developing resilient infrastructure necessitates attention to the entanglements between people, the environment, and infrastructure.

Through a sustained methodology of iterative co-research, the development of PetaBencana.id continues to be shaped by its broader context. Recursively though, the deployment of the platform also inflects its landscape: the process of mapping, cross-validating, and disseminating flood information for residents and government has become in itself a form of digital meta-infrastructure that helps mitigate the impact of flooding. According to Basuki Rakhmat, Head of Emergency Monitoring at Jakarta's Disaster Management Agency, “Before the platform was established, people would ignore disaster warnings. But

since the launch of the project, people are now more informed about disasters and willing to share information with each other. Through information sharing, their awareness of flood threats have increased, which has contributed significantly to disaster risk reduction.”^[6] The process of building the platform is itself a framework that increases community-based resilience and propagates networks of stewardship and maintenance of infrastructure. **LAF**

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