Dutch Disaster Risk Reduction & Surge Support (DRRS) Programme

Final Report Porto Alegre, Brazil

August of 2024

Contents

Front Page Photo Credit

Front page photo: Temporary floating pumps (blue on the right) replace the permanent pumping station that was submerged in the flood (far left); photo by: DMAE

Disclaimer

List of abbreviations (alphabetically)

ADCP	Acoustic Doppler Current Profiler
DLL	De Lage Landen Bank
DMAE	Departamento Municipal de Água e Esgotos – Municipal Water and Sewage Department
DNOS	Departamento Nacional de Obras de Saneamento – National Department of Sanitation Works
DRRS	Dutch Risk Reduction and Surge Support Program
IADB	Inter American Development Bank
IPH	Instituto de Pesquisas Hidráulicas – Institute for Hydraulic Research
RGS	Rio Grande do Sul
RVO	Rijksdienst voor Ondernemend Nederland – Netherlands Enterprise Agency
UFRGS	Universidade Federal do Rio Grande do Sul – Federal University of Rio Grande do Sul State
WB	World Bank

1. Summary of Recommended Actions

Porto Alegre, the capital city of Rio Grande do Sul state in the south of Brazil, was impacted by the worst floods in living memory in May of 2024. On request of the municipality, a DRRS team visited Porto Alegre from 5-11 June, with the scope to analyze the flood event and provide concrete recommendations. This report is the outcome of the June DRRS mission.

Chapter 2 elaborates on the **Background and Objectives of the DRRS Mission**.

Chapter 3 presents a **Brief Analysis of the Floods in Porto Alegre and Rio Grande do Sul State**. The main findings are that the flood protection system failed based on a higher than design flood event, with multiple failures of pumping stations (20 out of 23 stations failed), flood gates (failed and absent) and limited overtopping of the dikes and dike breaches in specific areas. A number of clear design errors were encountered.

Chapter 4 presents considerations of the **Time Line for Actions**: urgent (before September 2024), short term (before end of 2025) and medium to longer term.

Chapter 5 focuses on the **Emergency Response and Short Term Recovery**. It recommends to ensure the availability of termporary pumping capacity for emergencies. Short term monitoring of the dike system is recommended, possibly using specialized drones, and preferably before the start of the rainy season. An important recommendations is to acquire emergency, temporary and movable structures that can be used in case of threatened overtopping or breaches.

Chapter 6 presents **Longer Term Recovery and System Adaptation** options. It explores structural and non-structural solutions. In particular, it examines the options (1) to increase the levels of flood protection infrastructure; and (2) to lower the maximum flood levels around Porto Alegre. In terms of structural measures these will lead to very different infrastructural interventions. The chapter also investigates non-structural measures, in particular the possible adaptation of the multi-level institutional governance of flood protection and early warning.

Chapter 7 discusses the design and implementation of a **Flood Early Warning System**. The elements of the system are: Disaster risk knowledge; Detection, observation, monitoring and forecasting; Warning dissemination and communication; and Preparation and response.

Chapter 8 presents a recommendation for follow up with involvement of the DRRS program: a suggested **3-day Cocreation Conference** and hackathon focused on the (1) outline designing the improved flood early warning system; (2) exploring options for structural measures for improvement of the flood protection system; (3) a Round Table Dialogue on the improvement of the institutional arrangements for the flood early warning system.

The report details all the observations, findings, conclusions and recommendations. The recommended actions of this report are summarized as follows, with **details to be found in the text of the main report:**

Urgent – before September 2024

Short Term Recovery

- Determine the ***longitudinal profile of dike crests*** all along their 68 km extent, in the first instance by extracting these from the 2021 LiDAR survey DTM, complemented with ground surveys, where needed
- Prepare a May 2024 ***flood hazard map*** of Porto Alegre, based upon surveying visual flood marks
- Analyse ***sand samples*** of material deposited on the Rio Jacuí bank at Ilha da Pintada
- Define a ***dike crest level to be adopted*** for rehabilitation/heightening of these dikes as temporary measure before the September 2024 rainy season starts
- ***Dike repairs*** according to urgent needs in the period July-August 2024

- Inspection of ***flood gates*** and repairs, replacement or installing an alternative way of protection
- Ensure availability of ***temporary pumping capacity***, including acquisition of material
- Ensure capacity for ***raising dikes temporarily***, including acquisitions and specification of logistics and manpower needs
- Identify ***critical infrastructure*** that will require additional protection by dikes or guaranteed access, such as the airport, access to hospitals, etc.
- Improving current system of ***flood early warning***, to function until a definite system is put in place
- Start with the preparation of a comprehensive ***multi-agency flood response plan***
- Create some realistic form of ***flood awareness*** with the public, e.g. by using public media
- Organize a Three-Day ***Cocreation Conference or Hackathon*** with the theme: "Rethinking the Flood Management System of the Porto Alegre Metropolitan Area"

In Preparation of Longer Term Recovery, System Adaptation and Flood Early Warning

- Perform ***sensitivity analyses*** of various options to reduce flow bottlenecks along Jacuí River Delta and lagoons with existing models (UFRGS), in preparation of detailed studies to increase flood water conveyance and lower flood levels as part of the Flood and Drainage Master Plan
- Commission the installation of ***temporary water level sensors*** (divers) at around 10 locations along the Jacuí River Delta, Guaíba River and Lagoa dos Patos (to be operated at least during the coming wet seasons of 2024 and 2025)
- Measure ***river discharges*** at Ponta da Cadeia, at least twice, under high flow conditions during the 2024 wet season
- Start with the preparation of ***Terms of References*** for the Flood and Drainage Master Plan for Porto Alegre, in coordination and cooperation with the State of Rio Grande do Sul
- Hold a ***Round Table Dialogue*** with all governance levels to explore the scope of change of institutional arrangement for the new flood protection system

Before the end of 2025

Short Term Recovery

- More ***detailed inspection*** of the quality of the dikes
- Define a ***dike crest level*** to be adopted for rehabilitation/heightening of these dikes as temporary measure until the safety measures recommended by the Flood and Drainage Master Plan for Porto Alegre have been put in place
- Commission ***temporary measures*** of dike and flood gate rehabilitation/adaptation works to bridge the period until medium and long term measures, following from the Flood and Drainage Master Plan, are in place
- Continue with creating some realistic form of ***flood awareness*** with the public
- Finalize the preparation of a comprehensive ***multi-agency flood response plan***

In Preparation of Longer Term Recovery, System Adaptation and Flood Early Warning

- Finalize Terms of References for the ***Flood and Drainage Master Plan*** for Porto Alegre and commission the study
- Prepare the ToRs for the establishment of the ***Early Warning System*** and commission its installation, in coordination and cooperation with the State of Rio Grande do Sul
- Continue measuring ***water levels and discharges*** during 2025
- Prepare a ***permanent water level and discharge measuring program***, based upon radar sensors and telemetry, to support the Flood and Drainage Master Plan study and the Flood Early Warning System
- Commission a ***bathymetric survey*** of the Jacuí River Delta, Guaíba River and at least the northern part of Lagoa dos Patos

- Commission a ***sediment particle size and sediment depth*** survey for the same area
- On the basis of the outcome of the Round Table Dialogue, ***commission a study*** into the current and ***desired future institutional arrangements*** for designing, implementing and managing flood protection systems and infrastructure, as well as early warning systems. The analysis should encompass, and be carried out in in consultation and coordination with, all governance levels (municipal, state, federal)

Period 2026 until 2030

- Conclude ***financing arrangements for the investments*** proposed in the Flood and Drainage Master Plan for Porto Alegre
- Finalize ***institutional arrangements*** to implement, operate and maintain these investments
- Implement the ***flood risk reduction measures***, recommended in the Flood and Drainage Master Plan for Porto Alegre
- Implement the ***Flood Early Warning System***

2. Background and Purpose of the Mission

Porto Alegre is the capital and largest city of the Brazilian state of Rio Grande do Sul. The city has a long coastline on the Guaíba Lake. In the lake, where the Jacuí river enters the lake as a braided river, a maze of islands facing the city creates an archipelago of low-lying partly inhabited islands.

The northern part of the city is also a low-lying area in the floodplains of the river system and has been protected through a dike system since the construction of the Porto Alegre metropolitan flood protection system in the early 1970s. The polder area is equipped with flood gates and pumping stations that drain the area, and that includes the location of the international airport of Porto Alegre.

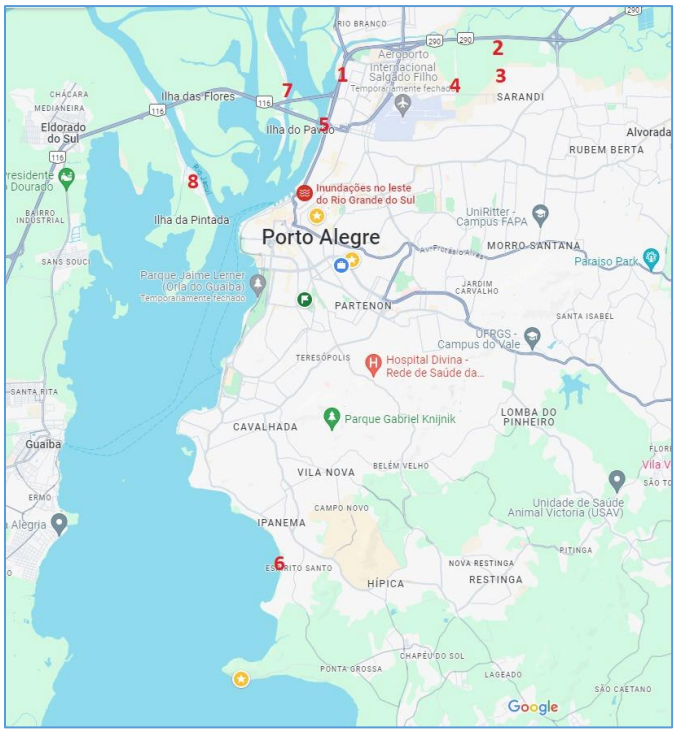

Figure 1: Porto Alegre location

The southern part of the city along the Guaíba lake has no flood protection system. The area is partly flat along the lake shore and although it is not very low lying, it suffers from storm surges due to strong southerly winds in combination with high lake levels.

The map of Fig. 1 shows the polder areas 1 to 5 that were flooded in the May 2024 floods, the worst in living memory in RGS state and Porto Alegre.

Area 6 in the south of the city is where storm surge flooding damaged many homes along the lake shore.

Areas 7 and 8 are on the islands, where both low and high end residential areas were completely flooded.

In September 2023, for the first time since long, parts of the city were affected by high water levels. Contacts were established between the municipal water and sewage department DMAE, that operates the drainage and flood protection system, and the Dutch Risk Reduction Program, through the Netherlands Business Support Office (NBSO) in Porto Alegre.

In May of 2024, with the largest flood in living memory affecting the whole of RGS state, the Porto Alegre flood protection system failed, with the consequence that the above mentioned parts of the city were flooded. In Porto Alegre municipality alone, approx. 160,000 people were directly affected and 40,000 buildings were impacted.[1]

DRRS mission to Porto Alegre

Approximately one week after the floods, in the first half of May of 2024, DMAE, the water, sanitation and drainage department of the PA municipality, contacted the DRRS team and requested for assistance with the objective to assess the floods, and to support the municipality

[1] Assessment by the Municipality

to rethink the current flood protection system, and advise on potential future measures to enhance the flood protection of the city (see annex 1). In response, the DRRS program envisaged two separate missions to Porto Alegre: the first at short notice, carried out in June, with the main purpose of fact finding and shorter term recommendations, and a still to be defined second mission focusing on additional structural and non-structural measures to enhance flood protection for the Municipality of Porto Alegre. The first mission was carried out from 5 - 11 June of 2024. This report presents the outcomes of that mission.

The mission team consisted of:

- Ben Lamoree, Team Leader and Institutional Development Expert
- Adri Verwey, Drainage and Flood Management Expert
- Peter Glerum, Emergency and Early Recovery Expert
- Durval Bacellar, Water Management Expert

São Paulo based Consul General Wieneke Vullings accompanied the DRRS team from 5-7 June.

Apart from contacts with DMAE, the Mayor and his team, and municipal institutions, the mission team met with the Governor and his team, with the team of the Federal Ministry in RGS State, with the RGS Federal University and others. The mission program and visited institutions can be found in annex 2.

Figure 2: Flood Impact in Porto Alegre

3. Brief Analysis of the Floods in Porto Alegre and Rio Grande do Sul State

The municipality of Porto Alegre is located in the eastern part of the state of Rio Grande do Sul, in the Guaíba river basin. It lies on the banks of Jacuí Delta and Guaíba Lake, which form a complex and unique hydrodynamic river system.

The Jacuí Delta consists of an archipelago formed by the mouths of the Jacuí, Caí, dos Sinos and Gravataí rivers. It covers a hydrographic group of sixteen islands, channels, swamps and ponds. The Delta flows into Lake Guaíba at a place called Ponta do Gasômetro.

Guaíba Lake, after the mouth of the Jacuí Delta, drains a total area of approximately 84,760 km², about 30% of Rio Grande do Sul territory. The Jacuí River is responsible for most of the flows (about 85%), followed by the Sinos, Caí, and Gravataí rivers, with 7.5%, 5.2%, and 2.7%, respectively.

Figure 3: Guaíba Lake Drainage Area

The morphology of Lake Guaíba is characterized by low depths and hydraulic bottlenecks. The average depth is 2.0 m, with the exception of the channel dredged to allow navigation, which is approximately 6 m deep.

Lake Guaíba flows into Laguna dos Patos, which consists of one of the largest lagoons in the world, with a surface area of around 10,360 km², an average depth of 5 m, and is also considered a shallow lagoon. The Lagoon is connected with the Atlantic Ocean through a single channel located at its southern end, named Barra de Rio Grande. This channel is 2 km wide and approximately 16 m deep.

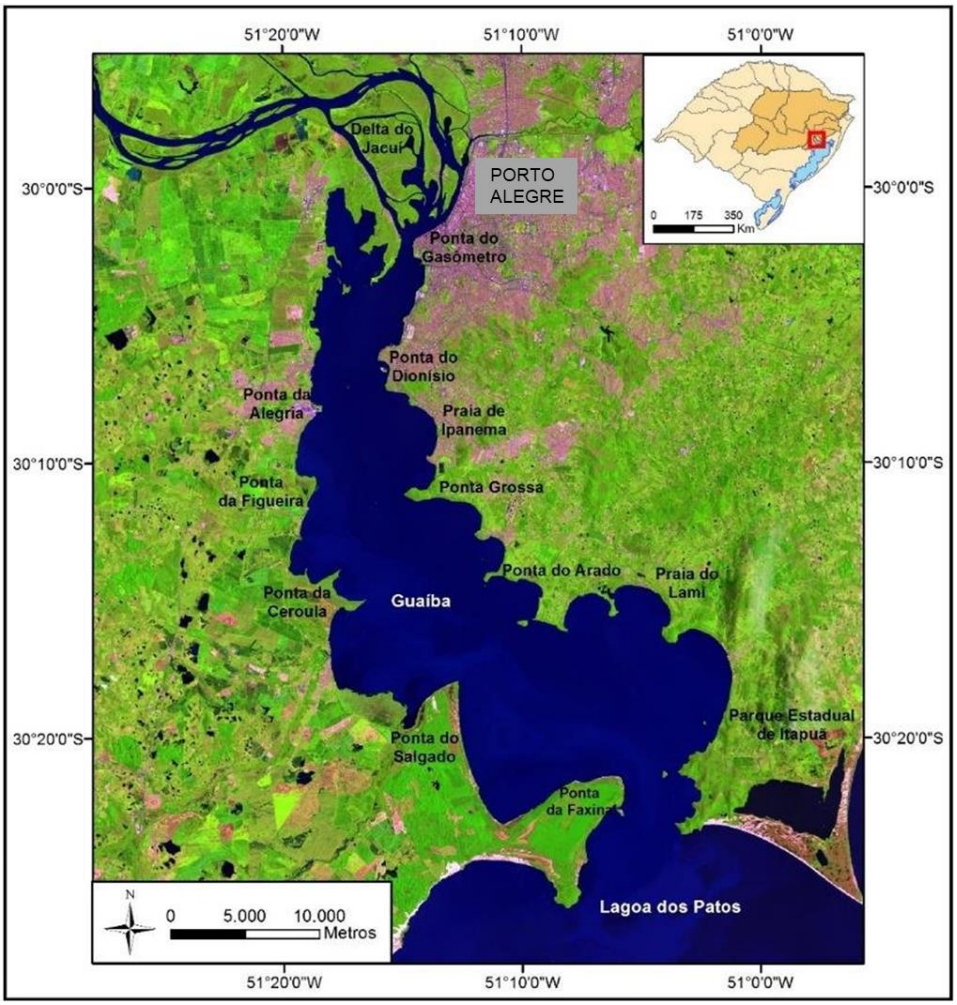

Figure 4: Lake Guaíba Water System

The hydraulic behavior of this hydric system is influenced mainly by the following physical conditions:

- Contribution flows to the Jacuí Delta;
- Difference in water levels between Lake Guaíba and Laguna dos Patos, and between Laguna dos Patos and the Atlantic Ocean, which determine the hydraulic load and preponderant direction of flow;
- Wind direction and speed of current in Lake Guaíba and Laguna dos Patos;
- Siltation conditions in the Lakes.

These conditions determine a hydrodynamic context that is quite sensitive and difficult and complex to predict. However, the physical conditions of the region surrounding Porto Alegre, made up of vast plains, demonstrate that the area is susceptible to potential flooding.

The May 2024 Flood Event

Between the 29th of April and the 6th of May 2024, the State of Rio Grande do Sul was subjected to a climatic event resulting from a combination of meteorological factors that overlapped in an anomalous way and whose effects resulted in unprecedented rainfall events in the State, in addition to major floods in the Jacuí Delta, Lake Guaíba and tributary rivers.

Briefly, the RS State was affected by an overlap of three climatic phenomena: i) the generation of high instability areas in a large part of the State; ii) the arrival of a humid air mass from the Amazon region; and iii) a mass of cold and wet air front from the Atlantic Ocean. These events collided in the north-

central portion of RS State and were unable to dissipate to the north due to the presence of a mass of hot, dry high-pressure air located in the center of Brazil. Thus, the entire volume of water was concentrated and precipitated in a short period of time and at high intensities.

Figure 5: Climate Event as it occurred

In addition, the period between the end of April and the beginning of May 2024 was still influenced by the El Niño phenomenon, responsible for warming the waters of the Pacific Ocean, also contributing to areas of instability over the State. Some sources indicate that above-average temperatures in the Atlantic Ocean, (resulting from climate change) may also have contributed to the increase in volumes evaporated in the Ocean and precipitated over the State and also for the warm barrier on the Atlantic.

As a result, the State was affected by precipitation, as shown below.

Table 1 Precipitation between the end of April and the end of May 2024

County	**Precipitation**		**River Basin**
Cruz Alta	**447**	**mm**	Upstream Jacuí River Basin
Soledade	**780**	**mm**	Upstream Jacuí River Basin
Santa Maria	**782**	**mm**	Jacuí River Basin
Tupanciretã	**592**	**mm**	Jacuí River Basin
Caxias do Sul	**1023**	**mm**	Taquari River Basin
Bento Gonçalves	**961**	**mm**	Taquari River Basin
Vacaria	**558**	**mm**	Caí River Basin
Rio Pardo	**780**	**mm**	Jacuí River Basin
Grande Porto Alegre	**731**	**mm**	Lake Guaíba River Basin
Source: MetSul			

Porto Alegre city is the only city within the state with a dedicated system for control and retention of flooding, covering Dikes, Floodgate Systems and Pumping Systems, as follows:

- The Retention Systems cover a total of 68 km of protective dikes and 14 hydraulically operated floodgates, which consist of protective structures that block the passage of water, aiming to prevent flooding. In the event of a flood, these openings must be closed in advance. Protection was established for the water level at a level of 6 meters, taking as a reference the maximum level of the 1941 flood above the level of Guaíba (1.75 m) and adopting a safety margin of 1.25 m.
- The Pumping System covers a total of 23 Pump Houses (total capacity of 170 m^3/s), which fulfill the role of connecting the Protection System with the Urban Storm Drainage System. When the Guaíba water level is higher than the rainwater drainage system, these structures are activated to allow rainwater from lower areas of the city to be drained.
- Since 2019, the system was incorporated into DMAE, which carries out its operation and provided investments in modernizing pumps and hydromechanical systems.

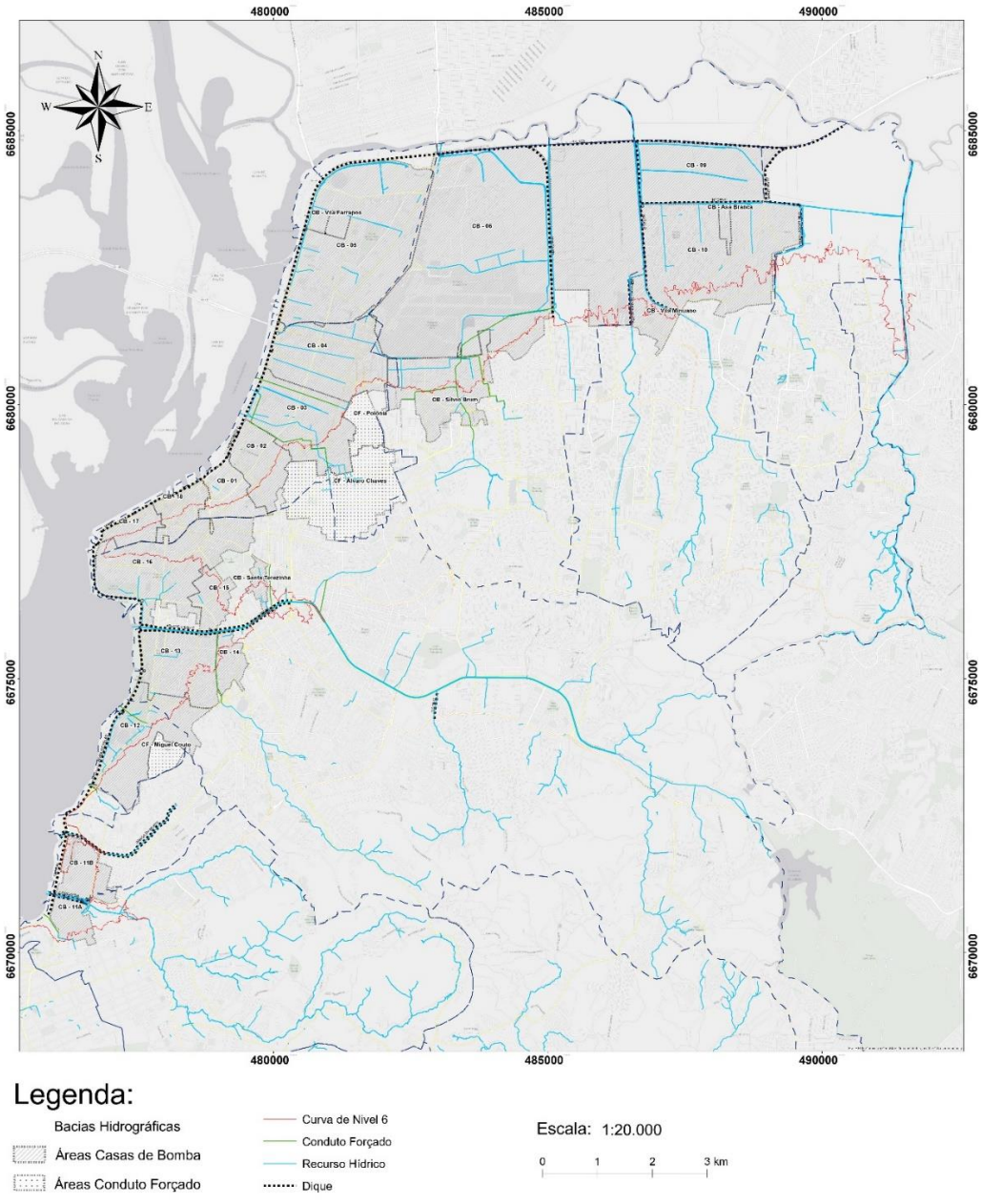

Figure 6: Flood containment system in Porto Alegre

The chronology of the main flood events that occurred between April and May 2024 is summarized below.

25/04 – First reports from the Civil Defense of Rio Grande do Sul warning that, in the following days, storms would bring the risk of flooding, strong winds and overflow of water courses in several parts of the State.

26/04 - First intense rainfalls began in the west and south of the state.

27/04 – Occurrence of windstorms, tornadoes and hailstorms in the central region of the State. Civil Defense alert for possibilities of flooding in floodplain areas.

30/04 – Occurrence of continuous rain and the beginning of flooding in a large part of municipalities in the State. Starting of flooding events in Lake Guaíba.

01/05 – Floods begin on Taquari river. RS State declares State of Public Calamity.

02/05 - Dam collapse process at July 14th Hydroelectric Plant, located on Taquari river Basin.

03/05 – Start of flooding in Porto Alegre city (elevation above 3.6 m). Occurrence of flooding and forced operational stoppage in part of the pump houses of the flood protection system in Porto Alegre.

04/05 – Almost all of the pump houses of Porto Alegre city were switched off preventively, so that water would not invade their engines. Water level reaches the El. 5.0 m.

05/05 – 374 municipalities affected by flooding in the State. In Porto Alegre, the water level reached its peak, at an elevation of 5.35 m, which left several neighborhoods in the city flooded.

08/05 – 500 thousand people without water and 425 municipalities affected

The following figure illustrates the water level in Guaíba Lake during the period of the events. Note the rapid rise in the water level between May the 2nd and 5th. In contrast, the time required for the Lake to deplete to pre-flood levels was about 1 month.

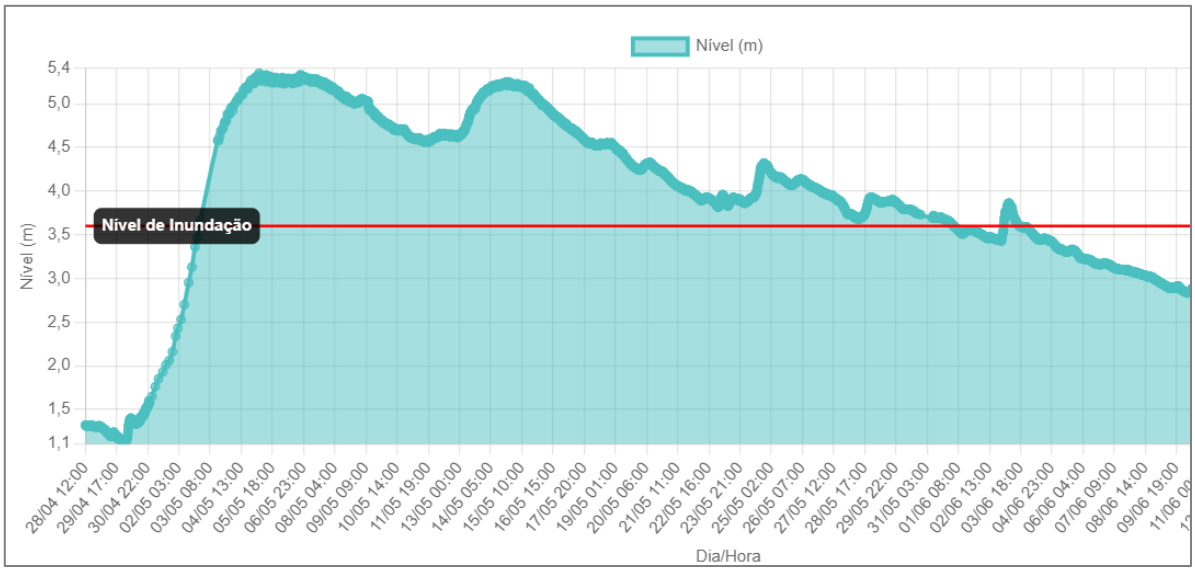

Figure 7: Water levels in Lake Guaíba (near Porto Mauá)

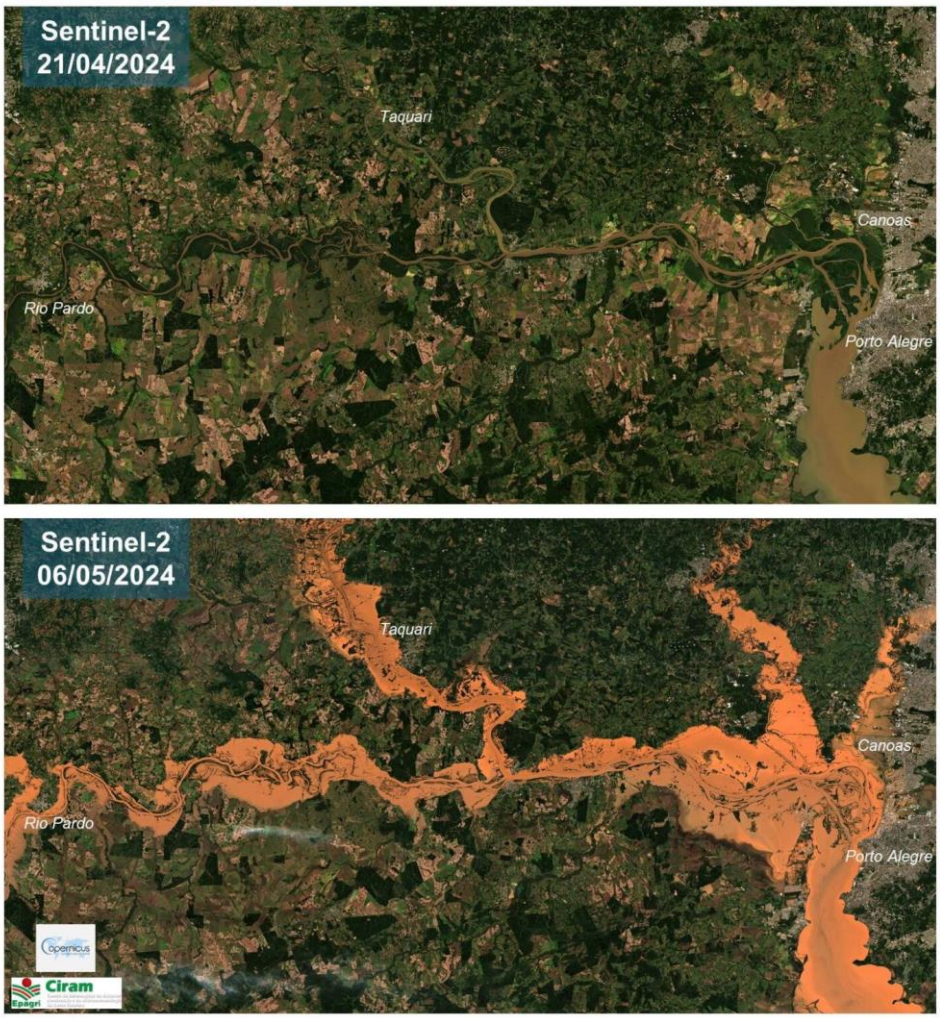

Figure 8: Floods in the Jacuí, Taquari, Sinos, Caí and Jacuí Basins Delta

Short Diagnostic of the Flood Event

The most relevant factors identified that contributed to the increase of floods effects in Rio Grande do Sul are listed below, with emphasis on Porto Alegre context:

Climatic and physical factors:

- Combination of meteorological conditions that overlapped in an anomalous way to generate a rainfall event with a magnitude unheard of in the State of Rio Grande do Sul. The precipitation occurred in a short period of time, generating very high peak flows and water levels;
- It is estimated that the events are associated with a Period of Recurrence of more than 100 years;
- Presence of southwest winds, in an opposite direction of the river and lakes flows, both in Lake Guaíba and in Laguna dos Patos, during and after the occurrence of intense rains.
- This phenomenon reduced the depletion capacity of these water bodies, backwatering their accumulated volumes and keeping water levels high.
- Effects of high tides and lake backwaters, further reducing the flow capacity at the ocean outlet;

- Existence of hydraulic bottlenecks in the water flow to the Ocean, with emphasis on: i) mouth of Guaíba Delta in Lake Guaíba (Ponta do Gasômetro area, on Metropolitan Region of Porto Alegre); ii) intermediate points of Guaíba Lake (due to low depths); and iii) where Lake Guaíba meets Laguna dos Patos;
- Due to the occurrence of flood events in 2023, there is a high possibility that the level of silting in some stretches of water bodies will have increased, impacting their hydraulic capacity.

Thus, the above-expected elevation of the Jacuí Delta and Lake Guaíba was mainly due to the rainfall volume significantly higher than normal conditions, associated with both natural and exceptional limitations of flow from Lake Guaíba to Laguna dos Patos.

Flood monitoring and forecasting systems:

- Hydrological data collection network compromised or inoperative during the hydrological events;
- Mathematical flood prediction models did not have efficient data input during the events;
- Inefficient population alert system regarding the size of events;
- Alerts made at the beginning of the events were underestimated by state and municipal entities;
- Lack of efficient flood forecasts and early warning of the population in other municipalities besides Porto Alegre;
- Even though warnings were issued predicting torrential and intense rains, the warnings were generic and did not allow for accuracy over risk areas, based on existing hydrological and hydraulic models, due, in large part, to the lack of data on monitoring in certain areas of the State.

The State has specialized technical teams responsible for modeling and forecasting floods in the main water courses (mainly UFRGS – IPH), however, there is a relative lack of monitoring data in many areas / water courses in the State.

Flood protection and control systems in Porto Alegre:

- Pumping systems were sized based on old historical data, and with a technical lag regarding their sizing;
- Rainfall levels were above project parameters dating back to the 1960s;
- Many gates did not operate efficiently, presenting numerous leaks or small ruptures. Some emergency gates warped due to the high pressure of the flood. Thus, in general, they were not able to stop the volumes coming from Guaíba;
- The operational levels of the pumps, including their electrical and automation controls, were exceeded by water levels. Due to this, the electrical supply was necessarily turned off to avoid the risk of short circuits;
- Lack of emergency energy alternatives to supply pumping equipment (e.g.: generators);
- Return of flow in pumps due to lack of check valves;
- Verified lowered dikes in some locations, in addition to the presence of informal settlements in certain sections thereof;
- Not all areas have protective dikes, particularly in areas with informal settlements

- Overtopping of some protective dikes;
- The Dikes and Floodgates System has been under operation by DMAE since 2019, but as the recent disaster has shown, without a robust system of action in the face of upcoming emergencies. Despite this, the post disaster emergency reaction from DMAE has been very effective.

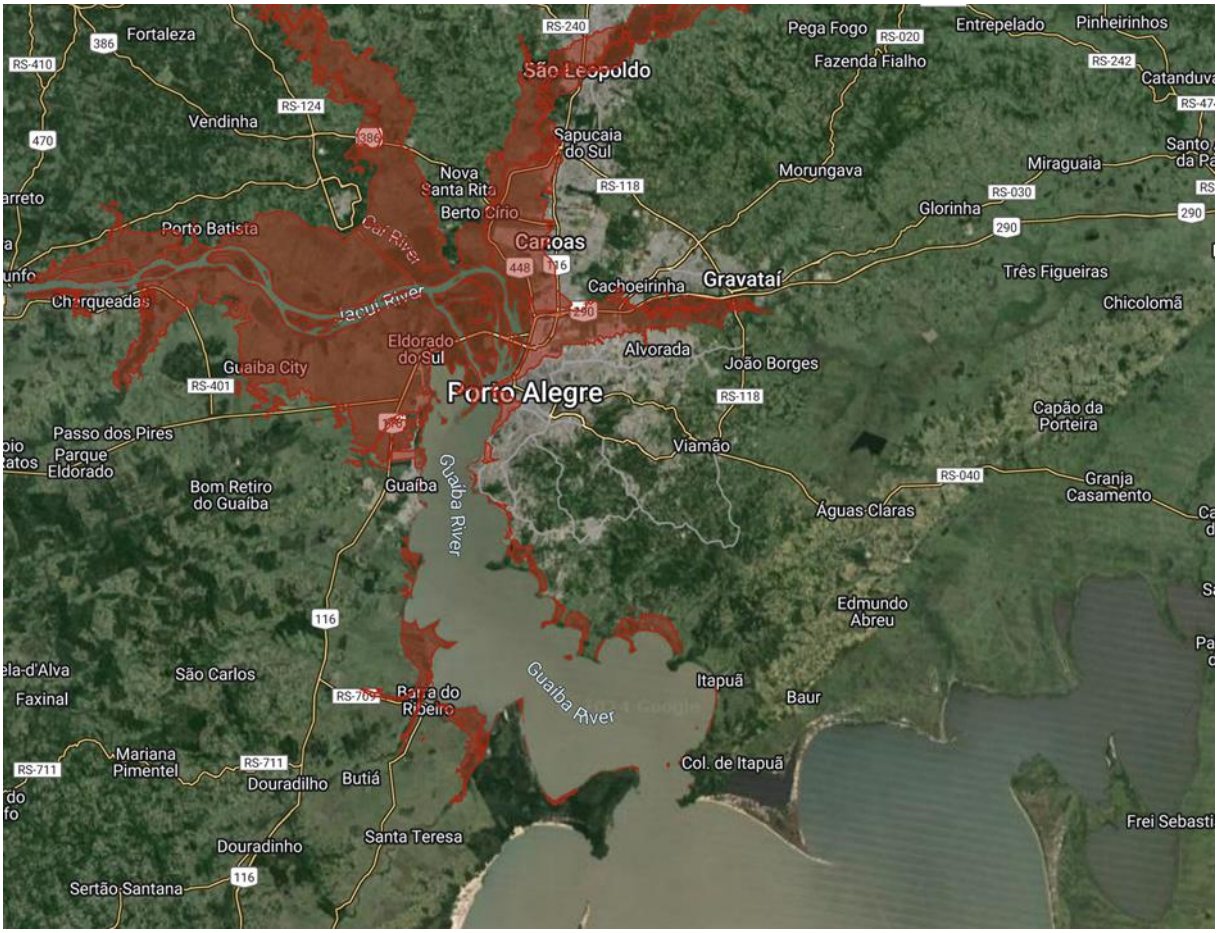

Figure 9: Flooded areas in the larger metropolitan area on 6 May 2024 (peak of the flood)

4. Timeline for Recovery and Reconstruction

In this chapter a general and tentative timeline is presented for the improvement of the flood management system in Porto Alegre (and the State of Rio Grando do Sul).

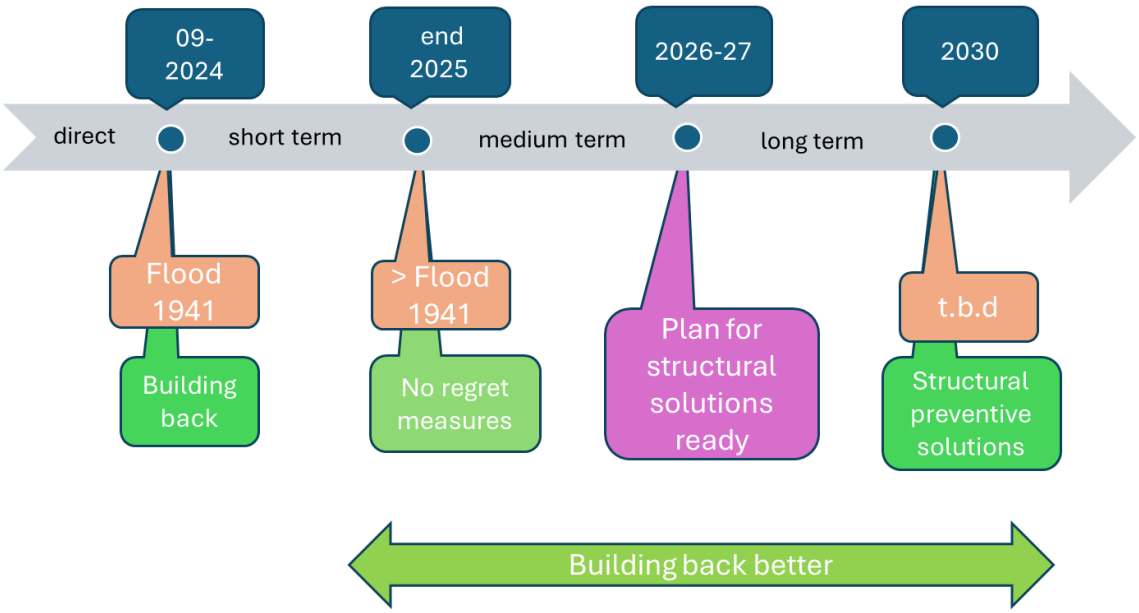

Figure 1: Tentative time line of improvements

A structural improvement of the flood management system in Porto Alegre is not possible within a short time period. It requires thorough study and analysis of the system.

Based on international experiences the study, development and decision making for a masterplan for structural improvement of the flood management will take at least 2 years. If budget is made available on time and if building permits and procurement processes run smoothly implementation of the measures could be achieved within four years after approval of the plan.

Meanwhile temporary measures need to be taken for rehabilitation of the existing flood protection system and preparation for floodings should be in place. In September the rainy system starts, which is historically the period with high water levels (for example flooding in autumn 2023). This implies that before September 2024 the system should be rehabilitated as much as possible through building back combined with emergency measures.

Full rehabilitation will take longer but should be still achievable before the end of next year which is defined as short term. In this phase a start can be made by building back better.

5. Emergency Response and Short-term Recovery

Before the mission, the DRRS team already presented a list of recommendations/points of attention for the emergency response/early recovery phase. General recommendations based on international experiences covering the topics: Public Health, Debris/Sediment removal, Waste Management, Restoring of Infrastructure, Damage assessment, Financial support and Preparing for the next flooding. This list of recommendations is attached as Annex 3 to the report.

In this Section recommendations for the short term are given, limited to the preparedness for a new flooding. Short term is seen here as the period until the end of 2025, with a focus on the period until September this year. It is not expected that before the rainy season starting in September, the flood protection system will be back on the design level based upon the 1941 flooding. This despite the tremendous efforts of DMAE, it's contractors and those of other municipality departments.

A prioritisation of the planning of rehabilitation activities is needed to optimise the protection level before the next rainy season. We assess that restoring the design level based upon the 1941 flood is achievable in the polder area but only if complemented by other rehabilitation measures and emergency preparedness (with temporary solutions, like sandbags and emergency pumping equipment).

It is important to communicate to the citizens and businesses, which level of protection they can expect. Emergency preparedness is needed as part of the short-term measures, but also needed on the long term as no flood protection system will guarantee full safety under all circumstances. Emergency preparedness needs always to be in line with the actually available level of flood protection.

Recommended actions for Emergency Response and Short Term Recovery

As part of the emergency preparedness the following recommendations are formulated and explained below in sub paragraphs:

For DMAE
- Ensure temporary pumping capacity
- Ensure monitoring capacity of the dikes
- Ensure capacity for raising temporary dikes

For the municipality of Porto Alegre
- Prepare a comprehensive multi-agency flood response plan

For the municipality of Porto Alegre, together with the state of RGdS
- Establish an early warning system

5.1. Ensure Temporary Pumping Capacity

Achieving a full rehabilitation of all pumping stations before the rainy season is doubtful. To supplement the available capacity, reserve capacity needs to be in place for this, as well as reserve capacity for malfunctioning of pumping stations during a new flood. This capacity needs partly to be 'owned' by DMAE and can partly be available through 'on call contracts'. Proposed is that DMAE should have itself the permanent capacity to 'replace' two pumping stations.

Temporary pumping equipment should include the procedures, manpower and equipment to place them and operate them during an emergency, as well as the capacity to store them. Preferably possible locations to position them during a flooding event should be pre-identified and assessed. Using the capacity on those locations should be trained.

5.2. Ensure Inspection of the Flood Protection before and during a Flood

Dike breaches occurred both due to overtopping and weaking of the dikes (for example, caused by irregulated building along the dikes). This can be prevented by regular inspection of the dikes, followed by repair works. It is advised to have a regular (yearly) visual inspection of the whole flood protection infrastructure, as well as for specific infrastructure (such as flood gates) a more thorough inspection by experts each 3-5 years.

A good inspection regime will heighten the chance that the flood protection infrastructure will be up to the design strength. However still failure is possible during a flood (for example due to weakening taking place after the inspection or weaknesses not visible during an inspection).

To overcome this, preventive inspection during a flood event is needed. This requires trained experts who visually inspect flood protection infrastructure during the flood event. This requires training of a group of persons on forehand and organising the inspections[2]. For inspection a good risk analysis of the flood protection system is needed to pre-identify weak spots.

Supportive for inspection of flood protection infrastructure is the use of drones with infra-red technology[3]. Drones are nowadays a cheap solution for an arial inspection of the flood protection infrastructure, especially when the camera is geo-referenced (giving the ability to upload footage in a GIS system) and if infra-red technology is added. Infra-red technology may identify weak spots in dikes based on slight temperature differences. These can be an indication for water saturation of a dike part. Inspection with drones needs less manpower while extra information is provided. To effectively use drones, people have to be trained thoroughly to operate these and interpret the images.

5.3. Ensure Capacity for temporary Dikes and Protection Infrastructure

Strengthening the existing dikes will most probably not be achievable before the next rainy season, while a next extreme flood might occur, which might overtop dikes with their design based on the 1941 flood. This implies that in order to achieve adequate flood protection, capacity for building temporary dikes is recommended.

The most common solution for temporary dikes is the use of sandbags. Sandbags are a cheap and flexible solution. Regular sandbags are the most flexible choice, however they need a large workforce to build a temporary reinforcement and are not practical for longer distances. Still, it is recommended that they are made available beforehand, including planning of the manpower needed for small repairs/reinforcements.

Big bags (filled with sand) overcome the disadvantages of smaller sandbags for a large part. However, they need heavy equipment (which may not be usable everywhere during a flood). It is recommended to make a stock of big bags available. The size of the stock should be based on an analysis of possible applications during a flood and the available capacity (personnel and equipment) to place them.

Besides sandbags and big bags, there are on the market different portable flood protection systems, most of them making use of water (several of them are pipes/bags/boxes, which fill with the flood water when it rises, while others need to be pre-filled). They are mostly manageable with less people and less heavy equipment than sandbags and big bags. They however mostly have requirements on

[2] In the Netherlands, waterboards may mobilize volunteers during a threat of flooding. These have been trained and each will inspect a section of a dike and report regularly on its state to the experts of the waterboard

[3] Infra red technology detects differences in heat, which is often an indication of higher water levels in a dike which implies that a weakening has occurred

the terrain to place them (mostly needs to be flat and solid) and need specific training to use them. They are more expensive to buy and some of them need to be manufactured for a specific length of dike. The water filled bags have a risk of shear, once water levels reach approximately half their height. However, under specific circumstances they may be a better solution in a built-up environment with low inundation depths, which can be estimated quite well in advance.

Beside strengthening of the existing dikes, temporary solutions can also by applied in specific situation such as:

- The harbour front where an acceptable solution is not achievable at reasonable costs or for other reasons
- Along the southern lake coast of the city, where no dikes are present and where seen the limited frequency and impact of flooding, investing in a permanent solution is not cost effective.

5.4. Prepare a comprehensive multi-agency flood response plan

The flood of May this year demonstrated that in Porto Alegre a large number of organisations is involved in flood response. The response to the flood was based on general plans and cooperation agreements, not on a scenario-based plan for flood management under emergency conditions.

The flood response worked in May rather well in the immediate response phase, but worked only very limited in the early action phase (period between the warning and the arrival of the high water level).

Through a good and specific plan, especially in the early action phase, the impact (damage and human suffering) of a flood can be reduced drastically. A good early warning (see Chapter 7) is a basis for such a plan. It is advised that the municipality of Porto Alegre shortly prepares a multi-agency flood response plan.

This plan should:

- Include flood forecasting and flood early warning
    - How to communicate the early warning with the public
    - Which early action can be taken based on the early warning
    - How will the warning be communicated with the public, at which levels and by whom.
- Be developed in discussion with all involved agencies (to ensure that the plan is ‘owned’ by all agencies and based on their possibilities and limitations)
- Be based on the existing flood protection system
- Be specific for the different parts of the city.

Regular evaluation of flood response plans is needed. In addition, it is recommended to create some form of flood awareness with the public. E.g. trainings should take place to test and evaluate the plan and can be input for the regular updating of the plan

Regular updating is needed due to:

- Results of training evaluations
- Further development of the flood protection system
- Further urban development in the city
- Impacts of climate change
- Changes within government agencies
- Changes in institutional arrangements (e.g. mandates).

6. Longer Term Recovery and System Adaptation

6.1. Introduction

The April-May 2024 flooding of Porto Alegre and the initial screening of its causes and impacts (Chapter 3) demonstrates the need for significant investments to reduce flood risks to an acceptable level. Common practice is to distinguish the following groups of measures:

1. Structural measures, dealing with the design of the flood protection infrastructure; and
2. Non-structural measures, dealing with knowledge development, planning and organisational and institutional arrangements.

The earlier discussion on causes and impacts of the floods reports on shortcomings on both aspects, providing ample space for improvements. It should be stated here again that the measures to be discussed focus on the Municipality of Porto Alegre as this was the objective of this mission. Where such measures may have either positive or negative impacts on neighbouring municipalities of the State of Rio Grand do Sul, this will be mentioned.

6.2. Structural Measures

It has been observed that during this emergency there were various locations where floods arrived at levels surpassing those of the protecting infrastructure, such as dikes. Although too early to conclude, this does not imply that the design level of the flood infrastructure was too low, as actual levels, such as dike levels, may have been lower than designed. In any case, for improved flood protection there are two approaches to provide more safety against flooding for an event similar to the one that occurred in May 2024:

1. Increase the levels of flood protection infrastructure; or
2. Take measures to lower the maximum flood levels around Porto Alegre.

It is too early to conclude on the most effective solution. It is recommended to make the evaluation part of a Flood and Drainage Master Plan Study for Porto Alegre, as detailed in this Chapter 6.

6.2.1 Increasing Levels of Protective Flood Infrastructure

The mission has doubts about the cost-effectiveness of bringing flood protection levels of dikes and associated infrastructure to a higher level than the 6 m +Ref, as adopted in the design of the current system, based upon a recorded level in 1941 of 4.75 m +Ref + a 1.25 m safety margin.

It is recommended to derive a new design level as part of the proposed Flood and Drainage Master Plan Study for Porto Alegre. Apart from levels of dike crests, this study shall also investigate the required level for other infrastructural components, such as safe levels for installations in pumping stations, levels of secondary dikes, such as those protecting passages underneath other roads and railways, airport protection, guaranteed access to hospitals, etc.

Regarding rehabilitation and design of the future flood protection infrastructure this leads to the following recommended actions:

Recommended Actions Related to Designs Increasing the Level of Protective Flood Infrastructure

Short Term

- Determine the longitudinal profile of dike crests all along their 68 km extent, in the first instance by extracting these from the 2021 LiDAR survey DTM, complemented with ground surveys, where needed;
- Define a dike crest level to be adopted for rehabilitation/heightening of these dikes as temporary measure before the September 2024 rainy season starts;

- Inspect the quality of the dikes;
- Rehabilitate the dikes according to urgent needs in the period July-August 2024;
- Prepare for complementary temporary measures of dike rehabilitation/adaptation to bridge the period until medium and long term measures are in place. Establish a dike crest level serving this bridging period, not necessarily the 1941 design level or higher;
- Identify critical infrastructure that will require additional protection by dikes or guaranteed access, such as the airport, access to hospitals, etc.
- Prepare and commission the Flood and Drainage Master Plan Study for Porto Alegre.

6.2.2 Lowering Flood Levels around Porto Alegre

The mission is more optimistic about the cost-effectiveness of interventions that will reduce flood levels around Porto Alegre for an event similar to the one of May 2024. A pilar in this approach will be the concept of "Room for the River", which would lead to lower river water levels than the ones that occurred during the May 2024 flood, for the same rainfall and wind conditions. It must be stressed that such interventions are technically complex and will require detailed in-depth studies, partly defined as task in the proposed Flood and Drainage Master Plan Study for Porto Alegre and partly initiated as studies contracted beforehand in the short term.

The rationale for such interventions is based upon the following observation. Referring to Fig. 12 and the publication discussing this (Silveira et al., 2024), the runoff from the joint Jacuí, Caí, Sinos and Gravataí river basins faces 3 bottlenecks in its path from upstream of the Porto Alegre islands area (archipelago) until the ocean outlet:

1. Ponta da Cadeia, located near the former Usina do Gasômetro, where the river has a width of approximately 1000 m at a depth of 2 to 3 meters, with locally a deeper navigation channel dredged at a depth of the order of 6 meters. However, the bottleneck also includes the upstream river delta, with a length of approximately 11 kms (Fig. 11);
2. Ponta de Itapuã, approximately 40 kms further south along the Guaíba River, where its width reduces to approximately 3.7 kms at its transition to the Lagoa dos Patos;
3. Barra de Rio Grande, which has a severe constriction at the outlet from Lagoas dos Patos into the Atlantic Ocean.

Figure 11: Jacuí River Delta at the north-western side of Porto Alegre

During the floods, UFRGS has measured discharges at ***Ponta da Cadeia*** of nearly 40,000 m^3/s near the peak of the flow, using ADCP. Fig 12 shows the water levels along Porto Alegre on May 6, 2024, while flood levels are already falling. It is noted that from point D (Ponta da Cadeia) the water levels rise linearly upstream over a distance of 6 kms upstream around Niteroi and likely beyond. This clearly indicates that besides Ponta da Cadeia also its upstream braiding Jacuí River is a bottleneck in the flow conveyance system. This is confirmed by Fig. 11, providing the insight that the integrated width of the braiding Jacuí River in the river delta area is of the same order as the one at the Ponta da Cadeia bottleneck. The length of the delta along its shortest western branch of Jacuí River is 11 kms.

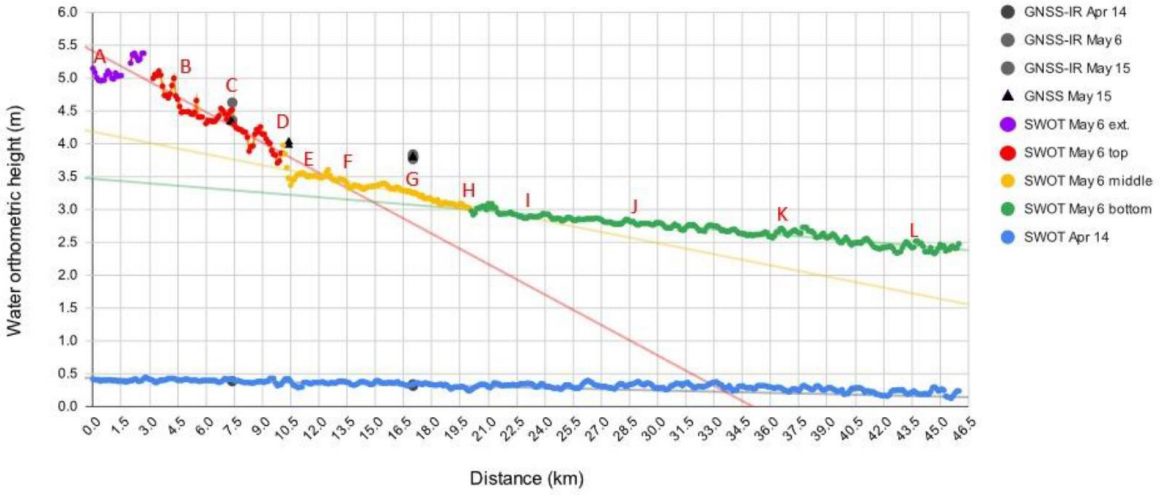

Figure 12: Flood levels around Porto Alegre on May 6, 2024, from Niteroi until going down to well into Rio Guaíba (courtesy UFRGS)

Increasing flow conveyance capacity at the Jacuí River Delta

UFRGS has recommended to widen the riverbeds in this constriction in order to increase the flow conveyance capacity and reduce the magnitude of the backwater upstream of Ponta da Cadeia. An alternative to widening the river is deepening it. In principle, this provides a more attractive solution as every m^3 of sediment dredged from the bed is at least twice as effective as the same quantity excavated from the riverbanks. Moreover, dredging the riverbed may have smaller negative social and environmental impacts.

At the request of the mission team, Prof. Rafael Manica of UFRGS has made a 2D model simulation demonstrating the impact of dredging a layer of 2 m at the Ponta da Cadeia constriction. This represents a sediment extraction quantity of the order of 10 million m^3. Although too early to present in this report, the first results are encouraging, indicating that it will be feasible to lower flood levels at Porto Alegre by an order of half a meter. Such intervention might have prevented most of the flooding of the Municipality of Porto Alegre during the May 2024 calamity. The sensitivity analysis also showed that a further reduction could be achieved by dredging the river bed at ***Ponta de Itapuã***. UFRGS is taking up this study further and has the intention to come up with a publication soon.

These observations lead to the conclusion that it is worth exploring this option further. However, there may easily be a number of complicating factors, such as:

- Encountering ***rock formations*** along the riverbeds. Such presence is most likely at the locations Ponta da Cadeia and Ponta de Itapuã. During the mission, the question of the nature of these constrictions could not be answered and will have to be investigated. Especially the formation of the Jacuí River Delta points at such presence of rocks at Ponta da Cadeia. Once again: no one could confirm such presence;
- The need for excessive ***maintenance dredging***. The overall morphological behaviour of the Jacuí River Delta is very complex and its disturbance may have unexpected consequences. Deepening of the riverbed may create a sediment trap. An intervention of this nature is only advised if there is an expectation that future maintenance dredging will remain acceptable. Apart from the creation of this sediment trap, also the continued flux of sediment along Guaíba River may not be guaranteed. A hopeful sign is that during the recent flood, large amounts of rather coarse sand were deposited along the Jacuí River banks at the Ilha da Pintada (Fig. 13). Most likely the extremely high flow velocities brought the usual riverbed loads in suspension. In any case, there

will be a need for an in-depth morphological study of this area with contributions from a world leading expert. It is highly recommended to analyse a sample of the sand deposited, to provide insight into size distribution as input for the expert judgement;

- ***Negative impacts*** for the settlements along Guaíba River. During the May 2024 flood various communities along Guaíba River got flooded and increasing the flow conveyance capacity along the Jacuí River Delta may worsen this situation. This impact will have to be investigated and most likely this would require some interventions further downstream as well. However, it is expected that interventions to increase the discharge capacity of the Jacuí River Delta will only have minor negative impacts on the flood levels along Guaíba River. The same applies to the banks of Lagoa dos Patos;
- The costs for dredging may be reduced if part of the ***dredge spoil can be used*** for the construction industry (see also Fig 13), either as sand for construction or as material for raising terrain levels. It is recommended to investigate such options shortly.

Figure 13: Flood deposited bed load (sand) along the Rio Jacuí banks at the Ilha da Pintada, May 2024

Increasing the flow conveyance capacity at Barra de Rio Grande

The recent flood event demonstrated that the Lagoa dos Patos acts as a retention basin for the flood water released by Rio Jacuí. The ocean outlet at Barra de Rio Grande has limited conveyance capacity to release this water. Even in June, Lagoa dos Patos did not return to its (dynamic) equilibrium water level. This slow decrease of Lagoa dos Patos water level has an impact on the water levels at Porto Alegre as well. With an increased flow capacity at Barra de Rio Grande, water levels at Porto Alegre would have decreased much quicker.

However, this does not guarantee that the peak flood levels at Porto Alegre would have been lower as well. Insight will have to be developed by hydrological/hydrodynamic model simulations for the complete river/lagoon system from the Rio Jacuí Delta to the Atlantic Ocean. Such simulation shall also include wind forcing on Lagoa dos Patos, as this caused significant water level differences, which have played a negative role in the May 2024 flooding of Porto Alegre.

Regarding the constriction at ***Barra de Rio Grande***, various proposals have been discussed in the past to increase its conveyance capacity or creating a shortcut to the ocean. For this study, the changes in the marine environment, as well as complications for the coastal morphology will require the input of high level expertise, supported by a modelling tool that integrates hydrodynamics, salt intrusion and morphology.

Decreasing flood peak levels at Porto Alegre by interventions in the upstream river basins

Flood levels around Porto Alegre could also be reduced by reducing the peak value of runoff from the 4 upstream river basins. Options will have to be explored as part of the Flood and Drainage Master Plan Study for Porto Alegre. Options to be considered are:

- Creating more storage by constructing reservoirs or enhancing infiltration of rainwater;
- Reducing the speed of runoff by planting obstructive vegetation in the (agricultural) fields.

However, it is not expected that, given the rain depth of 500 to 1000 mm in the basins for the May 2024 event, such measures will have much impact. This was also confirmed by various specialists met during the mission.

The investigations required for the study of intervention options mentioned above lead to a number of recommended actions, as follows:

Recommended Actions for Investigating the Option of the Lowering of Flood Levels

Short Term

- ***Analyse sand samples*** taken from deposits along the Rio Jacuí bank at Ilha da Pintada. A size distribution of this sand will provide highly valuable information on the morphological processes which have taken place in the Jacuí River Delta during the May 2024 flood;
- Commission a ***bathymetric survey*** of the Jacuí River Delta, Guaíba River and at least the northern part of Lagoa dos Patos. The outcome will serve as a necessary input for the development and calibration of an integrated hydrodynamic/morphological model of this system;
- Commission a ***sediment particle size and sediment depth*** survey for the same area to serve as a basis for morphological modelling of this system and provide information for potential dredging operations;
- Commission a ***study on the geological formations*** and the presence of sediments and rocks at critical locations along Jacuí River Delta, Guaíba River and at least the northern and ocean outlet parts of Lagoa dos Patos. The objective of this study is: (1) understanding how the delta has been formed and how it will continue to develop in the future; (2) provide basic information on sediment layers and their composition to inform possible dredging operation scenarios; and (3) provide the basis for understanding the morphological processes in the delta and how these would develop further in case “room for the river” options are being implemented. The sediment survey which will be part of this study shall provide information on the depth of the sediment layer above rocks and grain sizes along the vertical profile;
- At least for the coming wet season, commission the installation of ***temporary water level sensors*** (divers) at around 10 locations along the Jacuí River Delta, Guaíba River and Lagoa dos Patos. Installed at the latest August 2024, these sensors will provide important data for the calibration of the hydrodynamic model which will be an indispensable instrument for the Flood and Drainage Master Plan Study for Porto Alegre. In addition, the results will provide guidance for the installation of a permanent water level monitoring network in this same area, to serve continued data flows and serve the flood forecasting system discussed in Chapter 7. The temporary network will not require telemetry and therefore it will be a relatively low-cost investment.

6.2.3 Other Structural Flood Protection Measures for Porto Alegre

Pumping stations

Apart from the short-term actions on pumping stations described in Chapter 5, there is a need for a thorough investigation of the pumping needs for each individual polder in Porto Alegre. This analysis

shall be based on the day-to-day water management, with a focus on pluvial flooding, excluding scenarios of overtopping of dikes. It is recommended to include this activity in the Flood and Drainage Master Plan study for Porto Alegre.

The capacity needs will have to be based upon a selected allowable frequency of flooding of various categories of infrastructure, such as houses, commercial buildings, roads, critical infrastructure, etc. Given the climatic conditions of Porto Alegre, incidentally some inundation will have to be accepted in these polders. Rainfall intensities can simply be too high for economically feasible pump capacities installed. The limits set will be based on maximum flood depths, most likely for roads, and maximum flood duration. In many countries it is practice to impose that terrain levels for the construction of buildings are raised to a certain level above the existing access road. Better will be to use as a reference, road levels planned on the basis of flood hazard mapping.

The design of new pumps in these polders will have to be screened on their ability to continue functioning in case of overtopping of the surrounding flood defence system.

Flood gates or protective dikes as alternative

The flood defence system of Porto Alegre contains a number of flood gates that will be closed during a flood emergency situation. This typically relates to locations where roads are crossing underneath another road or railway, acting as dike. During the May 2024 flood a number of these gates buckled and collapsed due to high water pressures. Their design was inadequate.

An example visited during the mission was the Ponte da Porto Alegre, where an access road crosses underneath Road 290. Replacement of these gates on the short term has been discussed in Chapter 5. However, instead of replacing these, an alternative could be to create an overhead crossing or, smarter, build on one side a ring dike segment around the underneath crossing. This partial ring dike shall have the same level as the one of the protecting dike itself. At the location visited, such solution looks feasible, as there appeared to be sufficient space for such design. Such solution will be much more reliable and reduces the need for maintenance.

In other cases, these gates did not collapse, though led to concern about leaks. This was the situation at a location visited along Av. Portuária, giving access to the storage sheds. Leaks were reduced by placing sandbags. However, it should be considered to mount rubber slabs at the river side of these gates. It is also recommended to check all existing flood gates on their strength, as they have not been tested at maximum flood levels.

Apart from checks to be made on the short term (Chapter 5) a more extensive investigation of the functionality and reliability of flood gates shall be part of the Flood and Drainage Master Plan study for Porto Alegre.

Critical infrastructure

Critical infrastructure for Porto Alegre has also proven to be vulnerable. A striking example is the Airport, with nearly all its main structures completely flooded, including at least 80% of the runway. It was reported that the airport could remain out of operation for most of the remaining 2024. The economic loss is tremendous, as the number of flights arriving daily is reduced from around 100 to less than 10, diverted via the military airport of Canoas.

In addition, many roads were blocked for several weeks to one month. Chapter 5 points at the need to assure access to locations requiring temporary flood protection, particularly to people in urgent need at threatened locations.

Critical infrastructure will require careful attention in the recommended Flood and Drainage Master Plan study for Porto Alegre.

Temporary measures

An interesting application of combining a fixed and a temporary flood protection measure is the following. The Municipality has the intention to ***transform the storage sheds*** (armazens) along the Av. Portuaria into an entertainment and tourist attractive area, similar to successful transformations in Lisbon, Buenos Aires, Antwerp, etc. The problem in working out definite plans has always been the 3 m high wall protecting the historic centre from flooding from the Jacuí River. Placing a similar wall at the river side of the "armazens" is no option, as this will spoil the attractive visual connection to the river. The May 2024 flood will put these plans even more on hold.

However, there is a solution. This area could very well be protected with a combination of a ***fixed riverbank with a height of the order of 1 meter and an additional temporary protection*** with sand filled big bags raising the level to up to 3 meters, as the need arises. It is recommended to contract an urban designer to work out a plan with an approximately 1 m high river bank, in any case low enough to keep the visual connection between the restaurant and bar terraces with the river. The overtopping height of this fixed structure can be determined as part of the Flood and Drainage Master Plan for the city, deriving expected frequencies of flood levels at the quay in relation to adopted flood risk reduction measures. It is expected that the sand bags will have to be mobilized only once in 10 to 50 years.

Giving the crest of this wall a width of 2.5 meters, there is space for a double row of sand filled big bags, stacked up to 2 meters. With a quay with a length of 1.5 kms and supported by a flood early warning system this concept would provide a manageable flood protection for this area.

The investigations required for the study of intervention options mentioned above, lead to a number of recommended actions, as follows:

Recommended Actions Concerning other Structural Flood Protection Measures

Short Term

- Investigate the need for pump capacity in the polders as part of the Flood and Drainage Master Plan study
- Investigate all flood gates in Porto Alegre and analyse options to replace these by protecting partial ring dikes, reinforce existing gates, replace these completely, or take other measures needed
- List all critical infrastructure and check their flood protection, accessibility, etc.

6.3. Non-structural Measures

Non-structural measures in flood management provide a cost-effective and necessary way to complement the structural measures. It is generally acknowledged that there is a limit in investing in hydraulic structures that reduce flood risks, such as dikes, barriers, etc. For structural measures, most countries adopt a protection level against 1 in 100 year events for river induced floods and 1 in 200 years for coastal flooding. For pluvial flooding the accepted frequency is higher, depending on the nature of terrains and the way the inundation water can spread. For street inundations often a 1 in 2 year or somewhat lower frequency is applied.

It is not clear yet which frequency applies to the May 2024 flood event, though most likely its frequency is lower than 1 in 100 years. For this reason, some flooding of Porto Alegre could be expected, though not to the extent at which it happened. Pluvial flooding plays in the polders, though also here flooding was much worse than could be expected on the basis of handling pluvial flooding alone for polder areas. The overtopping and breaching of polder dikes heavily contributed to the damages that occurred. As a result, pumps failed or were disconnected from the grid, as

discussed in Section 4.2.3. The design of flood protection mechanisms for these polders require a dedicated study, to be taken up as part of the Flood and Drainage Master Plan Study for Porto Alegre, discussed in Section 4.3.2.

6.3.1 Surveying and Monitoring

There is an urgent need to commission a ***survey of the bathymetry*** of the Jacuí River Delta, Guaíba River, Lagoa dos Patos, including the Barra de Rio Grande. This survey will serve as a basis for:

1. Developing the hydrodynamic and morphological models for this area; and
2. Enabling the assessment of quantities of sediment to be dredged.

It is recommended to do this survey shortly and not wait until the Flood and Drainage Master Plan Study for Porto Alegre has been commissioned. The data collected may also provide useful insight into the formulation of the ToR for the Master Plan study.

Survey work is also needed for verifying dimensions of the ***existing dike system*** and its special attributes, such as flood gates. The survey should also address checks on the quality of the dikes. Part of this survey is short term work for damaged or obviously weak sections (Chapter 5). Other parts of the dikes may be surveyed as part of the Master Plan study.

There is also an urgent need for monitoring data for the development of hydrological, hydrodynamic, environmental and morphological models. The status of installed monitoring instruments is not fully known. The currently known status is the following:

1. ***Rainfall data*** is monitored by CEMADEN, who have installed approx. 20 weather stations in the joint Jacuí, Caí, Sinos and Gravataí river basins. These have been providing satisfactory information during the 2024 flood;
2. ANA, at federal level, is responsible for monitoring ***water levels*** along the main rivers of Brazil. It was reported that various originally installed stations in the joint Jacuí, Caí, Sinos and Gravataí river basins were no longer in operation. Some other stations failed, due to the unforeseen high flood levels, damaging the monitoring installations. Fortunately, at Ponta da Cadeia and two nearby locations the monitoring remained active, while Porto Alegre has a tidal station at the ocean side to provide data on tides and possible storm surges. The mandate for installing additional water level stations may be a complicating factor. For follow-up activities it is important to work this out in detail;
3. There is no systematic measuring of ***river discharges*** in place. Fortunately, during the flood, UFRGS has taken 6 discharge measurements with ADCP, on May 5, 6, 15, 22, 31 and June 6, respectively. This has provided very valuable information for follow-up studies. Regarding rating curves, Ponta da Cadeia is not a good location to establish such curve, as there are backwater effects from the Lagoa dos Patos. Rating curves may be available or will have to be established further upstream along Jacuí, Caí, Sinos and Gravataí rivers;
4. If it would turn out that increasing the discharge capacity at Barra de Rio Grande would be a feasible option to reduce flood levels in Porto Alegre, potential impacts will have to be studied further with water quality models, for which monitored ***salinity values*** will be essential for model calibration;
5. There is also a need for ***sediment data*** in the waterways, in particular in the Jacuí River Delta, in order to develop the morphological model. Data will have to be collected on sediment properties and on suspended and bed load transports.

Recently, UFRGS has proposed the installation of water level monitoring stations along the Lagoa dos Patos and Guaíba River. During the mission, it was observed that selected locations would need some further elaboration (Fig. 14). lFurther detailing of data needs and how these will be surveyed and monitored could be part of the follow-up DRRS Mission, tentatively planned for August 2024.

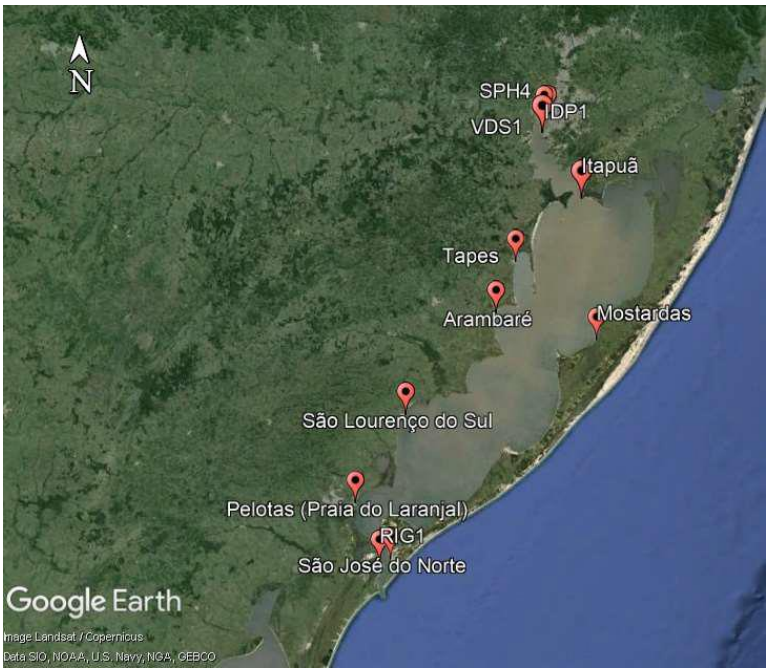

Figure 2: Water level monitoring station proposed by the UFRGS for installation along lagoon banks

6.3.2 *Development of modelling tools*

Various studies and services described in this mission report will require the (further) development of ***simulation modelling tools,*** describing hydrological, hydrodynamic, environmental and morphological processes, for the complete area or parts of this, from the upstream ends of river basins to the Atlantic Ocean. These tools have the following components:

a. ***Hydrological model*** for the Jacuí, Caí, Sinos and Gravataí river basins and the basins around Guaíba River and Lagoa dos Patos. Currently, for the river basins upstream of Ponta da Cadeia, UFRGS – IPH has a distributed hydrological model in place based upon their MGB-IPH (Modelo de Grandes Bacias – IPH) concepts. The May 2024 flood has shown that the calibration of this model needs improvement, in the first instance based upon measured discharges during that flood. In addition, based upon data to be collected through the proposed water level and discharge monitoring scheme. In addition, it is recommended to develop at least two other hydrological models for comparison. Given the fact that, compared with hydrodynamic models, hydrological models lack quite some accuracy in describing details of physical processes, such additional concepts allow for averaging out model results. Within the chain of models to be used for Porto Alegre, the hydrological model is simply the weakest (least accurate) link in the chain;
b. ***Rapid assessment hydrodynamic model*** describing the flow in Guaíba River and Lagoa dos Patos. This can be a 2D model with a very coarse grid with most cells having an area of the order of 100 km^2. This rapid assessment model is to be used in the flood forecasting system and for studies where large number of sensitivity analyses are to be made, requiring a very short turn-around time for rapid learning of system behaviour. It could also be a 1D network model, where particular attention will have to be given to the correct schematization of wind effects;
c. A ***detailed hydrodynamic model*** with a much smaller grid in 2D, which will be used for detailed designs, including wind scenarios;
d. A ***2D/3D*** hydrodynamic, water quality (including salt intrusion), ecological and morphological model. For this last application the modelling of the Jacuí River Delta will be a challenge, requiring a broadly tested tool. The water quality and ecological model would be needed in

case it turns out that the option of increasing outflow capacity to the Atlantic Ocean could be feasible. The morphological model will be needed for the area describing at least the Jacuí River Delta, Rio Guaíba and the southern part of Lagoa dos Patos.

A suitable tool for b), c) and d) would be ***Delft-3D***, a free and open source modelling system developed by Deltares in the Netherlands, which would enable . The system has been or is being used in 164 countries with a user community of 35,000 users (including students), with Brazil as the fourth largest community.

6.3.3 Flood and Drainage Master Plan Study for Porto Alegre

The flooding of Porto Alegre has demonstrated that planning investments in flood safety has had insufficient attention for years already. The city relied on designs made approximately 50 years ago and has not developed plans to update these designs at a pre-determined frequency. Neither has there been a systematic inspection to check whether the flood defence system still adhered to the originally applied criteria, despite extensive changes in the urban footprint and the first statistical signs that the climate is changing.

State of the art these days is that cities commission Drainage Master Plan studies and update these every 10 to 15 years. It is recommended that Porto Alegre commissions a Flood and Drainage Master Plan study immediately after survey and monitoring data are available, as described in Section 4.3.1.

It is recommended that the Terms of References to be developed for this study contain at least the following components:

1. ***Developing understanding*** of the hydrological/hydrodynamic functioning of the river and lagoon system, listing also stakeholders and their mandates related to floods;
2. ***Data inventory*** and additional data surveying, monitoring and collection, including data consistency checking and archiving;
3. Selection of the ***most suitable modelling system(s)*** and the (further) development of numerical simulation models;
4. Determining a socially and economically justified ***flood risk protection standard*** for Porto Alegre, differentiated for the various neighbourhoods and (critical) infrastructure;
5. Producing ***flood hazard and flood risk maps*** for Porto Alegre;
6. Addressing ***critical infrastructure***;
7. Producing a ***prioritized flood risk reduction investment scheme***, for the near-, medium- and long term, based upon a developed and accepted vision on future needs and priorities, taking into account expected urban developments and climate change scenarios;
8. Defining additional ***non-structural measures*** to be implemented, including an early warning system and investigate preparedness operations;
9. Developing a ***maintenance and inspection*** scheme, including a material needs assessment;
10. Ways to create ***public awareness*** about flood risks, including a focus on municipal administrations;
11. Recommending on ***adaptations in the current institutional arrangements;***
12. A scheme of ***stakeholder consultation workshops.***

Much of what is specified also counts for a Flood and Drainage Master Plan Study for the complete Jacuí, Caí, Sinos and Gravataí river basins, or even partly for the complete State of Rio Grande do Sul. This first Master Plan study is also a priority for RGdS's Governor. However, Porto Alegre has its own responsibilities with respect to their flood risk reduction measures. A suitable way must be found to make sure that there will be a fruitful cooperation on both Master Plans.

6.3.4 Flood Early Warning System

Flood Forecasting and Early Warning are considered to be essential components of the non-structural flood risk reduction measures for Porto Alegre. This applies both to the maximum levels of dikes to be constructed in Porto Alegre, as well as to managing floods at the islands in the Jacuí River Delta and other unprotected areas.

During the mission, the ***delta area with its islands*** (archipelago) was visited. Despite the fact that this area has been designated as nature reserve, there are around 80 thousand people living there, primarily in illegal settlements. People there reported that the flood came as a complete surprise. They are used to get flood water into their houses each year and have adapted to living with floods. However, the magnitude of the May 2024 flood was beyond any experience and houses and goods were left behind in panic. Some of the inhabitants told us that if they had had any antecedent warning, their losses would have been significantly less. They had received none.

This case alone demonstrates already the ***need for having a good flood alert system in place***. Also for DMAE the sudden and exceptional rise of the flood water came as a surprise. This late information led to a far more complicated situation of handling the flood than in the situation where the flood had been forecasted with a lead time of a few days. Technically this would have been possible. UFRGS – IPH reported that while floods were already occurring, they developed a 1D hydrological/hydrodynamic forecasting model by extending their hydrological model for the joint Jacuí, Caí, Sinos and Gravataí river basins with a 1D hydrodynamic model for the Lagoa dos Patos. This provided some insight, though a good flood forecasting system will require a more fundamental approach.

It is recommended to develop a ***robust flood forecasting system for Porto Alegre***, or in fact for the complete Jacuí, Caí, Sinos and Gravataí river basins and lagoon system. This requires cooperation with the State of Rio Grande do Sul, who have a need for the same system. In addition, federal organizations such as ANA (National Water and Sanitation Agency) and CEMADEN (Centro Nacional de Monitoramento e Alertas de Desastres Naturais) play a role. Before defining the ToR for this development, it has to be investigated which authorities have mandates for flood forecasting at federal, state and municipal level. It is recommended to bring this issue on the agenda for the Conference planned for Porto Alegre. (see Chapter 8). Details on how the flood forecasting system could be configured are given in Chapter 7. It is recommended to develop one joint and integrated system for both municipality and the state.

With a good flood forecasting system in place, follow-up has to be arranged through the establishment of a ***Flood Emergency Centre*** from where Early Warnings for the population will be coordinated and disseminated. The mandate of this Centre can also be combined with other emergencies that may have to be handled at municipal (and possibly state) level. Apart from arranging a room that allows for the display of all relevant information, this room can be any municipal office space that will be transformed into the Emergency Centre whenever the need arises. Also here, the issue of mandates for early warnings has to be investigated and backed up by legal arrangements. Details on arrangements for setting up the Flood Emergency Centre are provided in Chapter 7.

6.3.5 Institutional Arrangements

The Porto Alegre flood protection system had been designed and implemented in the late 1960s and early 1970s by the federal 'National Department for Sanitation Works' (DNOS). As part of reforms of the federal government, DNOS was extinguished in the early 1990s, and the responsibility for the operation and maintenance of the existing flood protection systems was transferred to the

municipalities in which they were located. Thus, Porto Alegre municipality became the legal institutional entity to manage the flood protection system within its jurisdiction. After the adjudication of the responsibility to the municipality, the 'Drainage Department' (Departamento de Esgoto Pluvial) was the responsible entity. This institutional role passed to the water and sanitation department DMAE in 2019.

The current institutional and legal framework at municipal, state and federal levels is complex and its complete description goes beyond the scope of this DRRS mission. It is recommended to give particular attention to a revision of the institutional framework for flood protection systems, for a number of reasons:

i. Due to climate change the country will in the future be impacted by more intensive rainfall events and sea level rise;
ii. Effective flood protection systems will nearly always be of a nature that crosses municipal boundaries;
iii. In the case of the Porto Alegre flood protection system, the required investments in structural and non-structural (e.g. monitoring) measures may well be beyond the financial capacity of the municipality, thus warranting the involvement of other entities in the governance framework.

In particular the design phase of a new flood protection system, as well as the operation (and maintenance) of flood early warning systems, will require close cooperation with institutions of the State government.

The current flood protection system in Porto Alegre relies on a system of dikes, pumping stations and flood gates that protect the northern parts of the city. Now that the system has failed, a natural reaction would be to rebuild it with higher dikes, better pumping stations and stronger floodgates. However, an alternative might be found in taking measures in the Jacuí Delta to lower the water levels during floods, by creating more room for the river, for instance by dredging the river beds or creating a by-pass for high water discharges.

Such alternative solutions will require close cooperation with institutions that have responsibility over the wider river system. This cooperation is also essential for the realization of the monitoring and survey programs that serve as inputs for the Flood and Drainage Master Plan study for Porto Alegre and the joint Flood Early Warning System to be developed.

It is recommended to analyze the institutional implications of the rethinking of the flood protection system, in terms of mandates and in terms of financial flows for the investments that are required. The same can be recommended for the improved early warning system that would be an integral part of the flood protection system.

To investigate the scope of the required institutional arrangements, a Round Table dialogue with all involved institutions would be a valuable first step.

At the level of non-structural measures, a number of key recommendation can be provided:

Recommended Actions Concerning Non-Structural Measures

Short Term (2024 – 2025)

- Hold a Round Table Dialogue with all governance levels to explore the scope of change of institutional arrangement for the new flood protection system;
- Commission a study into the current and desired future institutional arrangements for designing, implementing and managing flood protection systems and infrastructure, as well as early

warning systems. The analysis should encompass, and be carried out in consultation and coordination with all governance levels (municipal, state, federal).

7. Flood Early Warning

Operational flood early warning systems are a cost-effective and reliable solution to protect lives and livelihoods from natural hazards such as floods and other weather related disasters. Early warning will not prevent flooding but if people, businesses and the government are timely informed on possible flooding, they are able to prepare and reduce the impact and diminish the human suffering and the costs of the flood.

An early warning system is seen as: An integrated system of hazard modelling and monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities and processes that enable individuals, communities, governments, businesses and other stakeholders to take timely action to reduce disaster risks in advance of hazardous events (as defined 1 December 2016 by resolution 69/284, United Nations General Assembly).

This description consists of four elements:

- *Disaster risk knowledge*
  Knowledge about floods: which water levels can be reached in the target area and what is the impact of a certain water level: what will be flooded at which level
- *Detection, observation, monitoring and forecasting*
  What detection do you need to have in place and how do you configure a flood forecasting system to assure that you are able to forecast a possible water level/flood
- *Warning dissemination and communication*
  To assure that the forecast/warning is communicated both to the relevant authorities as well as to the citizens and enterprises. All in a way that all possibly affected people are informed timely; and
- *Preparation and response*
  Arranging that government, people and enterprises are prepared to act, based on the warning received.

Figure15: The four elements of Early Warning, as presented in the "Early Warnings for All" initiative of the United Nations Secretary General

Even in a situation of an optimal protection, an early warning system is essential as each protective system is designed on the basis of a certain water level return period, while higher water levels can still occur, be it with a low chance.

As stated in Chapter 3, during the May 2024 flood, a basic level of flood forecasting was in place. Weather warnings were given, while the meteorological institute also warned for a severe flood risk. The warnings were not specific and did not guide people on how to act. As we spoke with affected people on the islands, they did not receive warnings, while other people (for example, the people along the Guaíba River banks) were not aware of a risk of flooding, as they did not receive a warning.

For a good early warning system, all four elements, as given in Figure 15, need to be in place. In the current situation, Porte Alegre receives general early warning information on water levels, but not based on a well-designed and operational flood forecasting system. Neither is a protocol in place to take mitigation actions based on the warnings.

Work is needed in Porto Alegre to improve each of the four components of early warning. The first two steps (disaster risk knowledge and monitoring and forecasting) shall focus mainly on improving the accuracy of forecasted water levels and the available warning time, while the third and fourth step shall focus on improved mitigation of the impacts of a flood event.

In the following sub paragraphs, each of the four elements will be further described and recommendations for improvement will be formulated.

7.1. Disaster Risk knowledge

Disaster risk knowledge is an essential component of a flood forecasting and early warning system, as this will provide additional insight into what may happen in case of a new calamity. The following knowledge components are important for the development of an early warning system:

1. Understanding of causes and impacts of previous floods. The recent 2024 floods have demonstrated that such knowledge fell outside earlier experiences and the extent of failures was not anticipated. For the future, the May 2024 event has generated a lot of new insight, which will have to be consolidated. It is recommended to register this experience as much as possible, for example by creating observed flood maps based on flood marks, while these are still visible.
2. Disaster risk knowledge will further be developed through the Flood and Drainage Master Plan, which will generate a better understanding through the development of numerical simulation models and the production of flood hazard and risk maps. Part of the products generated shall be catalogued to inform authorities about potential flood hazards under combinations of a variety of flood forcing factors, such as possible rainfall distributions and wind conditions.
3. Insight into vulnerable infrastructure and communities, to transform flood forecasts into early warnings for stakeholders. Setting up a successful early warning system also requires insight into institutional arrangements and mandates.

7.2. Detection, observation, monitoring and forecasting

It is recommended to install in Porto Alegre a flood forecasting system, based upon the following (improved or completed) components:

1. An on-line monitoring system for the collection of information on rainfall, river and lagoon water levels, water levels provided by the tidal gauge of Porto Alegre, as well as predicted tidal levels;
2. A hydrological/hydrodynamic model describing flows and water levels in the Jacuí, Caí, Sinos and Gravataí river basins, Guaíba River and the Lagoa dos Patos;

3. All other data sources that may contribute to increasing the reliability and lead time of the forecasts, such as data from numerical weather models and weather radar and satellite images;
4. A platform for the processing of all sources of information, to provide a forecast of water levels in Porto Alegre with a maximum achievable lead time.

Although subject to assessment, it is expected that the ***rainfall*** stations of CEMADEN provide sufficient information on ground-recorded rainfall data. Data shall be transmitted with a frequency of at least each 15 minutes. Porto Alegre will receive a new weather radar, which will provide additional information on the spatial distribution of rainfall.

The network of ***water level monitoring stations*** will, most likely, require upgrading, as various stations installed by ANA have been damaged, or were already no longer in operation (status to be verified). In addition, UFRGS has proposed to install a network of water level gauges along the banks of Guaíba River and the Lagoa dos Patos (Figure 14). Their installation is highly recommended, though an assessment of their number and most effective locations is recommended, taking into account the recording of wind impacts and flow head losses at flow constrictions. In addition, the Rio Jacuí Delta area will have to be served better.

Recommendations for the (further) development of ***hydrological and hydrodynamic models*** have been specified extensively in Section 4.3.2. It is emphasized again that it is important that the hydrological/hydrodynamic model implemented as part of the flood forecasting system returns results within at most 15 minutes. This requires a schematization based either on a 1D grid or on, for the lagoons, a coarse 2D grid. In case of using a 1D grid, a special schematization will be required to capture wind impacts in a physically correct way. This is doable.

The ***flood forecasting platform*** requires options to connect all possible sources of weather information, such as ground stations, weather radar, numerical weather models and satellite images, as well as outputs of all accepted models providing information on water levels and flows. In addition, the platform shall trigger the activation of model simulations. It is recommended to use a broadly accepted platform to assure robustness of the system and minimize the need for maintenance.

A good choice would be the ***Delft-FEWS system***, which has a large user community, including users from Brazil. The software itself is open source and license free (https://www.deltares.nl/en/software-and-data/products/delft-fews-platform). Delft-FEWS has also been installed for a wide range of other applications, including the forecasting of salt intrusion in lagoons.

7.3. Warning dissemination and communication

Warnings should be issued based on the forecast of reaching pre-agreed alert levels. Critical is that the warnings reach the target group in a timely manner. Warnings should always contain a very clear action perspective (i.e. how should people act upon receiving the warning).

Warnings should be specified for the different areas in Porto Alegre as the risk differs between the southern lake coast, the harbor area, the northern polders and the islands in the Archipelago. Warnings should be addressed to specific groups, groups which most probably will need different communication channels and different warning information. The information for each group needs to be based on the prepared response plans (see preparation and response).

Four specific groups are identified:

- The departments within the municipality of Porto Alegre as well as other government agencies involved in the flood response management;

- The critical infrastructure administrators of Porto Alegre. Besides DMAE for drinking water also the electrical power utility, the telecom company, the road authority, the port authority and the airport authority[4] need to receive specific warnings to give them the ability to take the needed measures to assure as much as possible continuation of services and/or prepare for specific emergency measures;
- The citizens of Porto Alegre;
- The business community of Porto Alegre.

Messaging needs to use the appropriate channels to reach the target groups.

For information to the municipality and critical infrastructure , emails, sms, and app messages can be used. Considering the criticality of this information it is important that checks be made by the issuer of the warning on receiving the warning by the target groups.

Information to businesses and citizens can be provided through sms alerting and news broadcasts. This however can have limitations, e.g. if people need to be registered for the sms-alerting, and when they listen to the news broadcast. For high risk areas (for example the archipelago) an option could be to disseminate through delivering the messages directly on the neighborhood level by government officials or by megaphones (police cars for example).

As follow-up on the warning, information should be available on official websites and social media and be accessible on mobile phones. For very specific information, especially in case that mobile phones are not available, leaflets could be made available.

The Centro Nacional de Gerenciamento de Riscos e Desastres – CENAD has a cell broadcast system under development. This is a system which gives a message to every mobile telephone located in a specific area. This system is very promising for alerting businesses and citizens however not yet available. This system could very well replace sms-alerting.

The choices made for channels to alert the citizens and businesses need to be communicated beforehand to the target groups. Such information needs to be repeated regularly (at least yearly) to ensure that citizens stay aware. Attention needs to be given to the formulation of messages. A warning should always be actionable.

7.4. Preparation and response

Receiving an early warning implies that the persons and organizations warned can actually anticipate the possible flood and act. This should be a coordinated anticipation of government, citizens and businesses and should be pre-planned into a flood response plan.

Based on risk scenarios a flood response plan can be made. This should contain the tasks and responsibility of each of the involved actors (including citizens) before, during and after a flood. This plan needs to be based on the actual situation and updated after each change of scenarios and prevention level as well as in the case of changes within the organization of the involved key actors. A yearly update is advisable.

Preparation implies that businesses and citizens are aware of what they can expect from the government (for example: is a possible evacuation part of the plan?; if so, what can people take with them?) as well as what they need to do themselves to be prepared. This awareness needs to be regularly communicated and should also be integrated in the warning messages.

Preparation at the government and critical infrastructure side also implies assessing the availability of means ((temporary) Flood Emergency Centre**,** personnel, equipment and finance) especially to

[4] This list of critical infrastructure can be enlarged if needed: the given list is only indicative

execute the tasks to be executed within the available time between the warning and the possible occurrence of the flood.

Recommended Actions Concerning Flood Early Warning

Short Term (2024 – 2025)

- Decide on the institutional setting, including financing, housing and staffing arrangements, of the Flood Early Warning System. Shall it be a system developed specifically for Porto Alegre or a system integrated with the needs for the RdS state
- Define the links and necessary joint arrangements with the Flood and Drainage Master Plan study for Porto Alegre
- Develop the ToR for and commission the study, specifying all components of the Flood Early Warning System

8. Follow-up Action DRRS: Three-Day Cocreation Conference

Theme: Rethinking the Flood Management System of the Porto Alegre Metropolitan Area

Concept Note DRRS

Background

In May of 2024 the State of Rio Grande do Sul suffered its worst flood in living memory. The Porto Alegre Metropolitan Area was badly affected in terms of human suffering and loss of livelihoods and economic damage. At the moment of writing, the efforts towards recovery are ongoing, and will be so for a considerable time. Also, the thinking about the causes of the flood and about potential interventions to avoid future floods have begun, with municipal, state and federal governments analyzing their role in improving flood prevention and impact mitigation.

The DRRS team, financed by the Government of the Netherlands, worked in Porto Alegre from 5 to 11 June to assess the floods, analyze the failure of the flood protection system in the city, and present some ways forward, for the short, medium and long term. The team's contacts with stakeholders have created a clear picture of the need to improve monitoring, early warning, preparedness and flood prevention interventions. With the failure of the existing flood protection system, a rethink of the approach towards floods has become necessary. Given a number of bottlenecks in the passage of the flood flow to the ocean, it is recommended to explore the potential of applying the concept of "Room for the River", as part of a Flood and Drainage Master Plan study for Porto Alegre.

Objectives and Deliverables

To bring together all governance levels and stakeholders to rethink the flood management system, a knowledge exchange between Brazilian and Dutch experts is expected to be able to deliver a practical and intermediate result. A two-day conference focused on co-creation of specific key elements of – still to be developed – integrated master plans is a good format to achieve this.

The **objective of the conference** would be to bring together knowledge parties from Brazil (UFRGS institutes IPH and Instituto de Geociências) and the Netherlands (Deltares, TU Delft, IHE Delft), with the water sector governance bodies at state (RGS), municipal (PA, Canoas, …) and federal (ANA, …) levels, to discuss the future flood protection of the larger metropolitan area (*boundaries to be defined*).

The **main deliverable of the conference** would be a specified vision for the future flood management system of the metropolitan area. Specific topics, developed in separate workshops or hackathons, would include:

i. *the monitoring and modelling system, the early warning system*
ii. *the future protection level, flood management structural and non-structural options*
iii. *institutional framework and financing*

The specified vision document that would be the main deliverable of the conference can be used as a starting point for master planning and project development at the various governance levels.

Organization

NL side: DRRS as organizer on behalf of the Netherlands as host, with NBSO PA and active support and involvement of the SP consulate and Brasília Embassy.

BR side: UFRGS as co-organizer, with support and involvement of RGS State, Federal Agencies, and PA/DMAE.

Participation of BID, World Bank and other finance partners in the Conference would be very welcome, in a format to be discussed.

The main perspective of the conference is on knowledge exchange and to make this practical for the rethinking and rebuilding of the flood management system of the larger metropolitan area.

Program and Participants

Program outline (components to be detailed further):

Prior to the Conference: preparation meetings with key participants

<table>
<tr><th>Day 1
morning</th><th>Day 1
afternoon</th><th>Day 2
morning</th><th>Day 2
afternoon</th><th>Day 3
morning</th><th>Day 3
afternoon</th><th>Day 3
Evening</th></tr>
<tr><td rowspan="3">Opening and key note lectures*</td><td rowspan="3">Field visits to Affected Areas in the Greater Metro Area</td><td colspan="2">Hackathon on Flood Monitoring, Modelling and Early Warning</td><td></td><td></td><td rowspan="2">Closing Session with Results and Vision Document</td></tr>
<tr><td></td><td></td><td colspan="2">Hackathon on Protection Levels and Flood Management Structural / Non-Structural Options</td></tr>
<tr><td colspan="2">Round Table Dialogue on Finance and Institutional Framework for Action</td><td colspan="3"></td></tr>
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* Opening with NL Ambassador, RGS Governor, Mayors of PA+ Municipalities, Federal Government representatives; Key note lectures, including findings of IADB;

Following the conference a working group will compile the results into a vision document.

Participants (list to be completed):

- Experts from the Dutch water sector, Embassy
- UFRGS IPH Institute, Geosciences Institute, other universities
- Federal representatives from ANA, Minister Pimenta (temp. federal support)
- RGS State technical team
- PA and other municipalities technical teams
- IADB, World Bank, KfW, CAF, Invest International, FMO, other finance institutions

Planning

Proposed dates: August of 2024

Location: UFRGS conference center, or alternative location, to be decided

Annex I: Official Request from DMAE to DRRS

From: Mauricio Loss <mauricio.loss@dmae.prefpoa.com.br>
Sent: woensdag 15 mei 2024 19:53
To: Ben Lamoree <info@lamoreeconsult.com>; Lucila Almeida <lucila.almeida@nbso-brazil.com.br>; Caspar van Rijnbach <caspar.vanrijnbach@nbso-brazil.com.br>
Subject: Pedido de apoio

Ao Dutch Reduction Risk (DRR)

O evento climático que atingiu o Estado do Rio Grande do Sul nos últimos dias gerou a maior catástrofe natural da história do sul do Brasil, e a cidade de Porto Alegre encontra-se em estado de calamidade pública.

Conforme amplamente noticiado pelos diversos veículos de comunicação, o Município de Porto Alegre foi atingido por grandes volumes de água que causaram enorme elevação no nível do Lago Rio Guaíba, que alcançou a marca 2,35Cm acima da sua quota de inundação que é de 3,00m, totalizando a marca histórica de 5,35cm no dia 05 de maio. Tal fato gerou inundações em inúmeros bairros da cidade, tendo em vista que o sistema de proteção contra cheias não se mostrou eficiente em sua plenitude para resguardar a cidade.

Lamentavelmente, esse episódio afetou de forma drástica comunidades inteiras que são residentes em áreas de risco e em vulnerabilidade social, a exemplo dos moradores das ilhas que compõe o arquipélago da cidade e os bairros localizados na região do 4º Distrito do Município, com muitas famílias desabrigadas perdendo suas residências e todos os seus pertences.

O Município, em conjunto de esforços com órgãos públicos, inciativa privada, e voluntários, está disponibilizando todo o seu aparato para minimizar os efeitos do desastre, bem como para promover assistência e socorro das pessoas. Contudo, considerando que as consequências deste desastre resultaram danos materiais e prejuízos econômicos e sociais que precisam ser evitados que se repitam no futuro, solicitamos a visita da equipe da DRR em Porto Alegre para que juntos possamos buscar novas soluções, sugestões, propostas, visando o aperfeiçoamento e melhorias do sistema de proteção contra cheias e do sistema de drenagem de águas pluviais do Município.

Certo de vossa colaboração.

dmae
Essencial para todos

Maurício Loss
Diretor-Geral
(51) 3289.9201
Dmae - Departamento Municipal de Água e Esgotos
Prefeitura Municipal de Porto Alegre

Annex II: Mission Program

Date and time	Activity	Remarks
WEDNESDAY 5 June		
Early afternoon	Arrival in Porto Alegre of the DRRS team and Consul General Mrs. Wieneke Vullings	
16.00	Meeting with Prefeitura and DMAE to discuss program and scope of visit Address: Gabinete DG – Rua 24 de Outubro, 200 – Moinhos de Vento	Participants: DMAE (Municipal Department of Water and Sewage) • Maurício Loss (Director of DMAE) • Darcy Nunes (Deputy director of DMAE) • Marco Faccin (Engineer at DMAE) • Marcus Caberlon (Technical Consultant Engineer) • Sebastião Melo (Mayor of Porto Alegre) • Cláudia Silber (Director of International Relations) SMAMUS (Municipal Secretariat for the Environment, Urban Planning and Sustainability of Porto Alegre) • Germano Bremm (Municipal Secretary of the Environment, Urbanism and Sustainability) • Patrícia Tschopke (Architect) • Rovana Bertolini • Vaneska Paiva SMPAE (Municipal Secretariat for Planning and Strategic Affairs) • Márcia Rodrigues UFRGS (Federal University of Rio Grande do Sul) • Professor Carlos Bulhões (Dean)
17.00	Technical briefing at DMAE, maps, data availability, failure sequence, current challenges	DMAE team, DRRS team
THURSDAY 6 June		
08.30 – 09.50h DMAE 10.00h – 11.30h field	Continue technical briefing at DMAE; short field visit to critical points	DMAE team, DRRS team
14.00 – 15.45	Meeting State Government	Participants:

	Address: Centro Administrativo de Contingência – Av. Joaquim Porto Vilanova, 201 – Jardim Carvalho	• Eduardo Leite (Governor of Rio Grande do Sul) • Marjorie Kauffmann (SEMA - Environment and Infrastructure State Secretary) • Marcelo Camardelli (SEMA - Deputy Environment and Infrastructure State Secretary) • Artur Lemos (Civil House State Secretary) • Gustavo Paim (Civil House Deputy State Secretary) • Juvir Costella (Transport and Logistic State Secretary) • Pedro Capeluppi (Extraordinary Secretariat to Support the Reconstruction of Rio Grande do Sul State Secretary)
18.00	Meeting Federal Government Address: Banco do Brasil - Rua Honório Silveira Dias, 1830 – Higienópolis	Participants: • Ronaldo Zulke (Director of Economic Articulation of the Extraordinary Secretariat to Support the Reconstruction of Rio Grande do Sul • Marcelo Baumbach (diplomat responsible for the Ministry of Foreign Affairs Office in RS) • João Ferrer (Head of Staff)
FRIDAY 7 June		
08:00 – 10:45	Meetings with IPH, Prof. Tucci Address: Gabinete DG – Rua 24 de Outubro, 200 – Moinhos de Vento	Participants: DMAE • Maurício Loss (Director of DMAE) • Darcy Nunes (Deputy director of DMAE) • Marco Faccin (Engineer at DMAE) • Marcus Caberlon (Technical Consultant Engineer) • Airana R Canto • Felipe Malacarne • Bruno Schneider • Caetano Fraga • Cláudia Silber (Director of International Relations) SMAMUS • Tiago Salomoni • Alexandre dal Pizzol

		IPH • Joel Goldenfum (Director of IPH) • Carlos Tucci (Emeritus professor UFRGS) and Rhama Consulting) • Ricardo Locatelli (Consultant)
11:30 – 14:00	Meeting Port Authorities Port of Porto Alegre and UFRGS Address: Av. Bento Gonçalves, 9500 – Agronomia Prédio 43130, segundo andar, LabModel em frente a Prefeitura Universitária	Participants: UFRGS • Dra. Tathiana Silva (Deputy director of the UFRGS Geosciences Institute) **other participants below* Portos RS • Henrique Ilha (Environment Director at Portos RS, also ICmBio career server, linked to IBAMA)
15.00	Dean office UFRGS Address: Av. Paulo Gama, 110 – Farroupilha	Participants: • Dr. Carlos Bulhões (Dean)
17.00	Meeting with Alvarez e Marsal Address: Av. Carlos Gomes, 2120 - Auxiliadora	Participants: • Germano Bremm (Secretary of the Environment, Urban Planning and Sustainability of Porto Alegre) • Juan Ladeira (Director Alvarez e Marsal) • Adriano Moura (Alvarez e Marsal)
18.00	Meeting with Municipal Secretary of Finance Mr. Schirmer and his team	Review and discussion about existing projects, including international financing
SATURDAY 8 June		
	Further field visits POA	Organized by DMAE. Freway - EBAP 5; Sarandi - EBAP 10; Dique - Vila Dique / Portão 14; Lunch; Guarujá - Zona Sul; Ilhas Marinheiros e Pintada
SUNDAY 9 June		
	Team discussions and reporting	At the hotel
MONDAY 10 June		
09.00	Meeting to discuss outline recommendation with DMAE Address: Gabinete DG – Rua 24 de Outubro, 200 – Moinhos de Vento	Participants: • Maurício Loss (Director) • Darcy Nunes (Deputy Director) • Marco Faccin (Director of development at the Municipal Department of Water and Sewage) • Lisiane Menezes Pacheco (Drainage Works Inspector) • Cláudia Silber (Director of International Relations)
11.00	Meeting IADB/WB (online)	Participants:

		• Gines Suarez Vazquez • Maria Alejandra Escovar Bernal
14.00 – 15.30	Meeting State Secretary of Environment and Infrastructure Address: Rua Dr. Salvador França, 1427 – Jardim Botânico	Participants: • Marjorie Kauffmann (SEMA -State Secretary of Environment and Infrastructure) • Marcelo Camardelli (SEMA - Deputy State Secretary of of Environment and Infrastructure) • Gabriel Fajardo (Extraordinary Secretariat to Support the Reconstruction of Rio Grande do Sul Deputy State Secretary) • Daniela de Lara (Coordinator of the Climate Advisory Department of the State Secretariat for the Environment and Infrastructure at SEMA) • Carlos Silveira (Department of Water Resources and Sanitation Management - geologist) • Diego Carrillo (Head of Meteorology, Climate Change and Critical Events Division) • Adriano Schneider (Communication advisor and translator)
16.00	Wrap up with DMAE & final meeting with Mayor	Participants: • Maurício Loss (Director) • Darcy Nunes (Deputy Director) • Marco Faccin (Director of development at the Municipal Department of Water and Sewage) • Cláudia Silber (Director of International Relations) → Consul to join online • Sebastiao Melo (Mayor)
18.30	Meeting at Manhattan hotel	Participants: • Ingrid de Kroes (Dutch Honorary Consul of Rio Grande do Sul) • Mike Janse (Group COO and Member of the Executive Board DLL) • José Campos (CEO LATAM DLL)
TUESDAY 11 June		
Morning	Departure of the DRRS team	

Annex III: Advice on the Early Recovery (Phase I Activities) in Porto Alegre

Dutch Disaster Risk Reduction and Surge Support (DRRS) Programme

May 21, 2024

In the early recovery phase, the focus will be on restoring a functioning society. This implies that citizens should be able to pick up their normal live and businesses should start functioning again.

To achieve this, cleaning of the area, houses and businesses is needed as well as the restoration of services and infrastructure. In the early recovery phase, the focus is on restoring the situation as it was before the flood. Improvements will still be limited. However, in situations where huge investments are needed for restoration, an assessment of the cost-effectiveness of building back better needs to be taken into account.

Besides this, there needs to be attention to assure that the area is prepared for a possible next flood.

Especially for the preparation of a possible next flood a 'whole of society approach' is advised: Structural measures to prevent flooding will not be in place in the case of a next threat of flooding, as structural measures will take at least 5-10 year for implementation. **This implies that citizens and businesses need to be informed that they need to prepare for a next flood themselves. By giving them this responsibility they often can reduce or mitigate the impact of a next flood by measures taken at their own premises**.

During the early recovery phase[5], points of attention are:

- Public health.
    - Safe drinking water:
        - Water delivery infrastructure in a flooded area is often damaged and needs to be restored;
        - Contamination of existing water delivery infrastructure is to be expected;
            - Citizens need to be informed on this and get instruction (what water can be used for which purpose / treatment advice, e.g. boiling);
            - Testing of drinking water needs to take place, both at the sources and in distribution systems of drinking water;
        - Bottled water, boiled water and mobile water treatment facilities needs to be provided as long as the regular provision of drinking water has not been restored;
    - Vector borne diseases:
        - Every spot of stagnant water can become a breeding ground for mosquitos that can spread disease;
        - Proper cleaning up and removing all pools of stagnant water is important;
        - Monitoring of the mosquito development should be organised;
        - Consider spraying areas with insecticide to prevent development of mosquitos;
        - Give instruction to the population on removing pools of stagnant water and on protection against mosquito bites;
    - Contamination and diseases:
        - Sewage systems will be damaged whereby faeces and other contagious material will be spread over the area; cleaning up is important;

[5] here defined as starting at the moment that the water starts to recede and areas become dry until the period that all emergency work has ended

        - Strict hygiene protocols need to be established for persons involved in the cleaning up work;
        - Give instructions to the population on hygiene during their cleaning operations;
        - Health monitoring of infectious diseases needs to take place;
- Debris and mud/sediment removal
    - After the water has started receding debris and mud/sediment will be present in the area:
        - Removal is needed;
        - Assessment is needed:
            - to check if contamination/pollution) is present in the area;
            - for agricultural areas to assess the impact of the mud for the usability of the land;
- Waste management
    - In flooded areas household equipment and business equipment which has been under water is in the most cases not recoverably which will lead to a vast amount of waste:
        - Management of the waste is needed: how to collect it, where to dispose of it;
        - Citizens and companies need to be informed on how the waste management will be organised;
- Restoring of infrastructure

Quick restoration of essential infrastructure is a requirement for getting society back to 'normal functioning'. Priority: areas with high concentration of people.

    - Roads need to be cleaned and restored:
        - if huge investments are needed for a specific situation, then assessment needs to be done if reconstruction the existing situation is wise (building back better needs to be taken into account);
    - Drinking water (see public health);
    - Electricity:
        - before reconnecting premises to the electricity grid a safety check of the installations need to take place to prevent dangerous situations;
    - Airport:
        - after re-opening preparation for a next flooding and taking measure to minimize the impact of a flooding will key;
- Damage assessment
    - This needs to be organised as early as possible. As damage assessment is the basis for financial compensation of citizens and businesses as well as the basis for federal or international financial support:
        - Make use of a standardised approach;
        - Assure as much as possible documenting situations on object level;
- Financial support
    - Affected people often have no income, while damage compensation (through government or insurance) will take time:
        - Temporary financial support needs to be in place both for citizen and businesses;
        - Specific attention is needed for farmers who have often lost a crop, which implies that they could need support at least until the next growing season;

- Preparing for the next flooding:
    - All flood defences and other relevant infrastructure (such as pumping stations) need to be inspected, serviced, maintained and restored;
        - As much as possible lessons of failure mechanisms need to be taken into account;
    - When significant investments are needed building back better needs to be taken into account;
    - Citizen and Businesses need to be prepared for the next flooding:
        - they have experienced flooding and can take measures to diminish the impact of flooding;
    - Early warning should be evaluated and if needed be improved:
        - Focus on warning with impact information and action perspective for populations;
    - Emergency plans need to be evaluated and improved:
        - how to inform citizens and businesses to prepare in the case of an imminent flood thread ;
        - Assure availability of emergency equipment (pumps, flood protection etc.) to assure direct measure in the case of an imminent flood thread;
        - Communicate with citizens and businesses what the government focus will be and what kind of measures they need to take themselves.