

Numerical Simulation of Dam-Break Flows Using Radial Basis Functions: Application to Urban Flood Inundation

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Abstract

Dam-break flows pose significant threats to urban areas due to their potential for causing rapid and extensive flooding. Traditional numerical methods for simulating these events struggle with complex urban landscapes. This paper presents an alternative approach using Radial Basis Functions to simulate dam-break flows and their impact on urban flood inundation. The proposed method adapts a new strategy based on Particle Swarm Optimization for variable shape parameter selection on meshfree formulation to enhance the numerical stability and convergence of the simulation. The method's accuracy and efficiency are demonstrated through numerical experiments, including well-known partial and circular dam-break problems and an idealized city with a single building, highlighting its potential as a valuable tool for urban flood risk management.

Keywords

Dam-Break Flows, Numerical Simulation, Shallow Water Equations, Radial Basis Functions, Urban Flood Inundation

1. Introduction

Climate change-induced natural disasters and increased rainfall intensities have become frequent over the past few decades [1] [2]. Among these disasters, floods and inundations have emerged as highly destructive in urban areas, causing significant human and economic losses [3] [4]. According to the United Nations International Strategy for Disaster Reduction report [5], between 1994 and 2013, the Emergency Events Database recorded 6873 natural disasters worldwide, resulting in the loss of 1.35 million lives, averaging nearly 68,000 lives per year.

Additionally, an average of 218 million people were affected by natural disasters annually during this period. The last report [6] reports that between 2000 and 2019, the number of major floods has more than doubled, rising from 1389 to 3254, while the incidence of storms increased from 1457 to 2034. Floods and storms were the most prevalent events during this period. This phenomenon has sparked worldwide public, political, and scientific interest, highlighting the need for improved flood risk awareness and prevention strategies [7]-[9]. Despite advances in forecasting, management, and defense technologies, floods remain a substantial global threat [10].

During the recent twenty years, the Comoros Islands have borne the brunt of impactful climate change and variable weather patterns. Notably, heavy rains adversely affected over 70% of the Mohelian population in April 2004 and April 2012, damaging primarily concentrated areas in the island's northern regions due to inundations and vegetation destruction [11]. These extreme climatic events also consistently devastate livestock, demolish homes, and decimate significant hectares of crops. In April 2012, the Comoros Interior Ministry declared a "National Disaster" in response to the flash floods and requested international assistance [12]. In April 2019, Tropical Cyclone Kenneth crossed the Comoros archipelago, primarily affecting Grand Comoros and causing subsequent flooding in the islands of Anjouan, Grande-Comore, and Moheli. The heavy rainfall associated with TC Kenneth led to widespread flooding. According to joint rapid assessments conducted by the government and partner agencies, the cyclone resulted in seven deaths, 200 injuries, and 20,000 displaced individuals. Additionally, 3818 houses were destroyed, 7013 houses were damaged, 96 water tanks were destroyed, 465 classrooms were damaged, and 213 of them were destroyed. Six health centers were damaged, and one hospital was flooded. Nearly 80% of crops were destroyed, leading to food shortages and inflation in the prices of staple foods [13]. Recently, between April and June 2024, heavy rainfall has been affecting Comoros, triggering landslides and causing floods that resulted in casualties and damage. According to media reports, a landslide occurred in Mut-samudu City on Anjouan Island, resulting in at least three deaths and two injuries. Additionally, on Grande-Comore Island in north-western Comoros, several houses have been affected by floods and landslides, and the village of Misoudje has been isolated. In the northwest of the small island of Moheli, the village of Hoani was severely impacted: houses were demolished, hectares of fields were damaged, a dike was destroyed, and a football field became part of the riverbed.

Numerical simulations are essential in engineering decision-making to understand flood situations and prevent catastrophes. A great number of works are conducted on understanding, modeling, simulating, describing, and assessing flood inundation situations. For more details, one can read [14] [15], among others. For example, an explicit description of land surface macrostructures of flood inundation is studied in [16], while an efficient flood inundation modeling based on a data-driven approach was conducted in [17]. Numerical studies are also conducted using shallow water equations [18] [19]. Mesh-based methods

have been widely proposed during the recent decades for urban flood modeling and dam-break flows. A finite volume method in a structured grid has been proposed in [20] to model urban flood situations in Ouagadougou, Burkina Faso, while in [21], a finite difference MacCormack method is adapted for numerical modeling of dam-break induced flow through multiple buildings in an idealized city. A discontinuous finite element Galerkin method was proposed for dam-break flood over natural rivers [22]. However, the accuracy of these methods is impacted by the quality of the meshes, stabilization techniques, and the solutions to Riemann problems. This limitation hinders their application to solving real-world problems with irregular domains and complex Riemann problems.

Meshfree Radial Basis Functions (RBFs) have gained significant attention in recent years as a powerful tool for solving complex problems in various fields, including fluid dynamics [23]-[25]. One such application addresses dam-break problems, which involve the sudden release of water due to the failure of a dam, leading to complex flow patterns that need to be accurately modeled for effective disaster management and infrastructure design. The advantages of using Radial Basis Functions in solving shallow water problems are manifold, making them an attractive choice for researchers and engineers [26]-[28]. RBFs offer excellent flexibility and adaptability in handling complex geometries and boundary conditions, which are common in dam-break scenarios. Moreover, the mesh-free nature of RBFs eliminates the need for mesh generation and refinement, a process that is often time-consuming and prone to errors in conventional numerical methods. This advantage significantly reduces the computational overhead and simplifies the implementation process, allowing for quicker and more efficient simulations. The lack of using mesh-free radial basis functions is how to choose a suitable shape parameter that leads the scheme to be high order accurate and stable [29]-[31]. The current paper proposes the use of a variable shape parameter selection based on particle swarm optimization tools [32].

This paper will be presented in the following order: the mathematical formulation of the shallow water equations is presented in their conservative form in Section 2. In contrast, the mesh-free radial basis method is presented and explained in Section 3. Numerical validations illustrating the accuracy and the stability of the proposed methods are presented in Section 4. Then a set of numerical simulations is conducted in Section 5. Finally, a summary and perspectives are drawn in Section 6.

2. Mathematical Formulation of the Shallow Water Equations

The 2D shallow water equations are utilized to model flood inundation. These equations are derived from the conservation of mass and momentum. They form a set of three equations that describe the behavior of the water depth and the horizontal velocities over time. These equations have been widely used to simulate urban flood modeling [3] [4] [20]. The continuity equation, obtained

from the equation of the mass conservation, is given by

$$\frac{\partial h}{\partial t} + \frac{\partial(hu)}{\partial x} + \frac{\partial(hv)}{\partial y} = 0, \quad (1)$$

where $h[\text{m}]$ is the water elevation, $u[\text{m} \cdot \text{s}^{-1}]$ is horizontal velocity in the x component and $v[\text{m} \cdot \text{s}^{-1}]$ is the horizontal velocity according to y coordinate. The momentum conservation equation gives two equations of velocities written by

$$\frac{\partial(hu)}{\partial t} + \frac{\partial}{\partial x} \left(hu^2 + \frac{1}{2}gh^2 \right) + \frac{\partial(huv)}{\partial y} = -gh \frac{\partial z}{\partial x} + S_{f_x} + \nu_t \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right), \quad (2)$$

$$\frac{\partial(hv)}{\partial t} + \frac{\partial(huv)}{\partial x} + \frac{\partial}{\partial y} \left(hv^2 + \frac{1}{2}gh^2 \right) = -gh \frac{\partial z}{\partial y} + S_{f_y} + \nu_t \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right), \quad (3)$$

where $g[\text{m} \cdot \text{s}^{-2}]$ represents the gravitational acceleration, $z[\text{m}]$ define the inner bed topography and ν_t is the horizontal viscosity coefficient. The friction terms S_{f_x} and S_{f_y} are computed using Manning's formula [20] [33]:

$$S_{f_x} = -gn_m^2 \frac{u\sqrt{u^2 + v^2}}{h^{4/3}} \quad \text{and} \quad S_{f_y} = -gn_m^2 \frac{v\sqrt{u^2 + v^2}}{h^{4/3}}, \quad (4)$$

where $n_m[\text{m}^{1/3} \cdot \text{s}^{-1}]$ is the Manning-Strickler roughness coefficient, which characterizes the roughness at the bed. Different values this coefficient can be determined by a GIS-based study and it depends on the characteristics of the material (buildings, trees, soil, ...). For more details, one can read for instance [34] and references therein.

Equations (1)-(3) can be written in a compact form as follows:

$$\frac{\partial \mathbf{U}}{\partial t} + \frac{\partial \mathbf{F}(\mathbf{U})}{\partial x} + \frac{\partial \mathbf{G}(\mathbf{U})}{\partial y} = \mathbf{Q}(\mathbf{U}), \quad (5)$$

where $\mathbf{U}$ represents the vector of conservative unknowns, $\mathbf{F}$ and $\mathbf{G}$ represent the advective and pressure fluxes in the x and y directions, and are given by:

$$\mathbf{U} = \begin{pmatrix} h \\ hu \\ hv \end{pmatrix}, \quad \mathbf{F}(\mathbf{U}) = \begin{pmatrix} hu \\ hu^2 + \frac{1}{2}gh^2 \\ huv \end{pmatrix}, \quad \mathbf{G}(\mathbf{U}) = \begin{pmatrix} hv \\ huv \\ hv^2 + \frac{1}{2}gh^2 \end{pmatrix}, \quad (6)$$

and $\mathbf{Q}(\mathbf{U})$, containing the diffusion terms and the friction terms, is expressed by:

$$\mathbf{Q}(\mathbf{U}) = \begin{pmatrix} 0 \\ -gh \frac{\partial z}{\partial x} + S_{f_x} + \nu_t \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) \\ -gh \frac{\partial z}{\partial y} + S_{f_y} + \nu_t \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) \end{pmatrix}. \quad (7)$$

3. Meshfree Radial Basis Functions Method

The numerical modeling of hyperbolic equations such as (1)-(3) requires the de-

sign of accurate and efficient tools to capture the fine solution features. Solving numerically these nonlinear equations in their conservative form is still a considerable task in nonlinear hyperbolic situations [35] [36]. Let us consider the compact formulation of the two-dimensional shallow water Equations (5) to be solved in set of $N = N_I + N_B$ collocation points $\mathbf{x}_i = (x_i, y_i)^T$ where N_I is the number of interior points while N_B is the number of boundary points. For each collocation point $\mathbf{x}_i$, the approximation of a solution $U_i(t)$ is defined as

$$U_i(t) \simeq \sum_{j=1}^N \lambda_j(t) \varphi(r_{ij}, \varepsilon), \quad (8)$$

where $r_{ij} = \|\mathbf{x}_i - \mathbf{x}_j\|$ is the Euclidean distance between the points $\mathbf{x}_i = (x_i, y_i)^T$ and $\mathbf{x}_j = (x_j, y_j)^T$, $\varepsilon \neq 0$ is a shape parameter that controls the fitting of a smooth surface to the data, and φ is a radial basis function. In the current study, we consider the infinitely smooth multiquadrics radial basis function defined as

$$\varphi(r, \varepsilon) = \sqrt{1 + (\varepsilon r)^2}. \quad (9)$$

The coefficients expansion $\lambda_i(t)$ in (8) are calculated by solving the following linear system of $N \times N$ algebraic equations

$$\mathbf{B}\boldsymbol{\Lambda} = \mathbf{u}, \quad (10)$$

where $\mathbf{B}$ is an $N \times N$ matrix with entries $\varphi(r_{ij}, \varepsilon)$, $\boldsymbol{\Lambda}$ and $\mathbf{u}$ are N -valued vectors with entries λ_i and u_i , respectively.

The first partial derivatives of (8) at point $\mathbf{x}_i$, according to x are obtained by the following equation

$$\frac{\partial U_i(t)}{\partial x} \simeq \sum_{j=1}^N \lambda_j(t) \frac{\partial}{\partial x} \varphi(r_{ij}, \varepsilon). \quad (11)$$

In the same manner, all the spatial derivatives can be expressed in a compact way as:

$$\frac{\partial \mathbf{U}}{\partial x} = \mathbf{H}_x \boldsymbol{\Lambda}, \quad \frac{\partial \mathbf{U}}{\partial y} = \mathbf{H}_y \boldsymbol{\Lambda}, \quad \frac{\partial^2 \mathbf{U}}{\partial x^2} = \mathbf{H}_{xx} \boldsymbol{\Lambda}, \quad \frac{\partial^2 \mathbf{U}}{\partial y^2} = \mathbf{H}_{yy} \boldsymbol{\Lambda}, \quad (12)$$

where $\mathbf{H}_x$, $\mathbf{H}_y$, $\mathbf{H}_{xx}$ and $\mathbf{H}_{yy}$ are $N \times N$ matrices with entries $\frac{\partial \varphi}{\partial x}(r_{ij}, \varepsilon)$, $\frac{\partial \varphi}{\partial y}(r_{ij}, \varepsilon)$, $\frac{\partial^2 \varphi}{\partial x^2}(r_{ij}, \varepsilon)$ and $\frac{\partial^2 \varphi}{\partial y^2}(r_{ij}, \varepsilon)$, respectively. The above partial derivatives can also be evaluated using a single matrix by vector multiplication as

$$\frac{\partial \mathbf{U}}{\partial x} = \mathbf{D}_x \mathbf{U}, \quad \frac{\partial \mathbf{U}}{\partial y} = \mathbf{D}_y \mathbf{U}, \quad \frac{\partial^2 \mathbf{U}}{\partial x^2} = \mathbf{D}_{xx} \mathbf{U}, \quad \frac{\partial^2 \mathbf{U}}{\partial y^2} = \mathbf{D}_{yy} \mathbf{U}, \quad (13)$$

where the derivative matrices $\mathbf{D}_x$, $\mathbf{D}_{xx}$, $\mathbf{D}_y$ and $\mathbf{D}_{yy}$ are $N \times N$ matrices given by

$$\mathbf{D}_x = \mathbf{H}_x \mathbf{B}^{-1}, \quad \mathbf{D}_y = \mathbf{H}_y \mathbf{B}^{-1}, \quad \mathbf{D}_{xx} = \mathbf{H}_{xx} \mathbf{B}^{-1}, \quad \mathbf{D}_{yy} = \mathbf{H}_{yy} \mathbf{B}^{-1}. \quad (14)$$

Hence, the RBF approximation of the problem (5) yields the following

semi-discrete system

$$\frac{\partial \mathbf{U}}{\partial t} + \mathbf{D}_x \mathbf{F}(\mathbf{U}) + \mathbf{D}_y \mathbf{G}(\mathbf{U}) = \mathbf{Q}(\mathbf{U}), \quad (15)$$

where $\mathbf{Q}(\mathbf{U})$ is discretized as

$$\mathbf{Q}(\mathbf{U}) = \begin{pmatrix} 0 \\ -gh\mathbf{D}_x \mathbf{Z} + S_{f_x} + v_t(\mathbf{D}_{xx} + \mathbf{D}_{yy})\mathbf{u} \\ -gh\mathbf{D}_y \mathbf{Z} + S_{f_y} + v_t(\mathbf{D}_{xx} + \mathbf{D}_{yy})\mathbf{v} \end{pmatrix}. \quad (16)$$

The semi-discrete system (15) can also be reformulated in a compact system of ordinary differential equations with the right-hand function

$$\frac{\partial \mathbf{U}}{\partial t} = \mathcal{F}(\mathbf{U}), \quad (17)$$

where $\mathcal{F}(\mathbf{U}) = -\mathbf{D}_x \mathbf{F}(\mathbf{U}) - \mathbf{D}_y \mathbf{G}(\mathbf{U}) + \mathbf{Q}(\mathbf{U})$. Forward Euler method has been mainly used as a time-stepping for RBF methods. However, this method is only first-order accurate in time and it may introduce excessive numerical dissipation in the computed RBF solutions. In the current study, we use an explicit Runge-Kutta method studied in [37]. Hence, to integrate the Equation (17), the time interval is divided into subintervals $[t_n, t_{n+1}]$ with duration $\Delta t = t_{n+1} - t_n$ for $n = 0, 1, \dots$. The notation $\mathbf{U}^n$ denotes the value of a generic function $\mathbf{U}$ at time t_n . The procedure to advance the solution from the time t_n to the next time t_{n+1} can be carried out as

$$\begin{aligned} \mathcal{U}^{(1)} &= \mathbf{U}^n + \Delta t \mathcal{F}(\mathbf{U}^n), \\ \mathcal{U}^{(2)} &= \frac{3}{4}\mathbf{U}^n + \frac{1}{4}\mathcal{U}^{(1)} + \frac{1}{4}\Delta t \mathcal{F}(\mathcal{U}^{(1)}), \\ \mathbf{U}^{n+1} &= \frac{1}{3}\mathbf{U}^n + \frac{2}{3}\mathcal{U}^{(2)} + \frac{2}{3}\Delta t \mathcal{F}(\mathcal{U}^{(2)}). \end{aligned} \quad (18)$$

The main feature of this method lies on the fact that the progression (18) is a convex combination of first-order Euler steps which exhibits strong stability properties. Therefore, the scheme (18) is TVD, third-order accurate in time, and stable under the usual Courant-Friedrichs-Lewy (CFL) condition.

For all problems involving matrices, solutions depend on the invertibility of the matrix. RBF-based meshless methods mainly rely on the invertibility of the RBF derivative matrix $\mathbf{B}$. It has been proven in the literature [23] that invertibility is ensured when using a constant shape parameter. However, this invertibility is lost if the matrix $\mathbf{B}$ becomes singular [38]. The shape parameter significantly impacts both the accuracy and stability of the method. When the domain is refined, global shape parameters can lead to ill-conditioned matrices, resulting in compromised accuracy and stability. Recently, techniques have been proposed to enhance the accuracy of the RBF method by using variable shape parameters. A well-known shape parameter in mathematical literature is the exponential shape parameter defined by [29]:

$$\varepsilon_i = \left[\varepsilon_{\min}^2 \left(\frac{\varepsilon_{\max}^2}{\varepsilon_{\min}^2} \right)^{\frac{i-1}{N-1}} \right]^{1/2}, \quad i = 1, \dots, N. \quad (19)$$

The random shape parameter defined by [30] is:

$$\varepsilon_i = \varepsilon_{\min} + (\varepsilon_{\max} - \varepsilon_{\min}) \times \text{rand}(), \quad (20)$$

where rand is the MATLAB function that returns uniformly distributed pseudo-random numbers on the unit interval. The trigonometric shape parameter given by [31] is:

$$\varepsilon_i = \varepsilon_{\min} + (\varepsilon_{\max} - \varepsilon_{\min}) \times \sin(i), \quad (21)$$

where $\varepsilon_{\min} = \frac{\sqrt{N}}{3}$ and $\varepsilon_{\max} = \sqrt{N}$, with N being the total number of collocation points. Genetic algorithms are used in [39] to find optimal variable shape parameters for one-dimensional boundary value problems. In the current study, we adopt variable shape parameters for Kansa's multiquadric using a heuristic optimization method based on particle swarm strategies [32].

4. Numerical Validations

In all the numerical examples considered in this section, the gravitational intensity is fixed to be $g = 9.81$; the bottom is assumed to be frictionless ($n_m = 0$), the Courant-Friedrichs-Lewy (CFL) number is taken with respect of the CFL condition $C = 0.45$ while time step Δt is varied according to the canonical stability condition [40]:

$$\Delta t = C \frac{d_{\min}}{\max(\sqrt{u \pm gh}, \sqrt{v \pm gh})}, \quad (22)$$

where $d_{\min}$ is the minimum distance between any two adjacent points in the collocation set. After a set of numerical simulations using different value of the viscosity coefficient, this one is taken to be $\nu_t = 0.0001$ which is suitable to stabilize the considered following examples without introducing notable numerical dissipation.

4.1. Partial Dam-Break Flows over a Flat Bottom

The performance of the developed numerical schemes is evaluated through partial dam break modeling. In this test case, the computational domain measures 200 meters in both width and length. Various authors have analyzed this scenario using a stabilized MacCormack scheme in [41] and a finite-element scheme in [42]. This simulation aims to assess the ability of the proposed RBF scheme to handle the discontinuity of the initial condition. The dam is located at the center of the domain where a breach at $y = 95 \text{ m} - 170 \text{ m}$ suddenly occurs in the dam. The upstream water level (hu) is 10 meters, while the downstream water levels (hd) are 5 meters, 0.1 meter, and 0.001 meters (dry). The bottom is assumed to be flat and frictionless, with all boundaries considered reflective.

Since no analytical solution exists for this case, the model is validated by comparing the simulation results with numerical results from previous studies. The computational domain and collocation points are depicted in **Figure 1**.

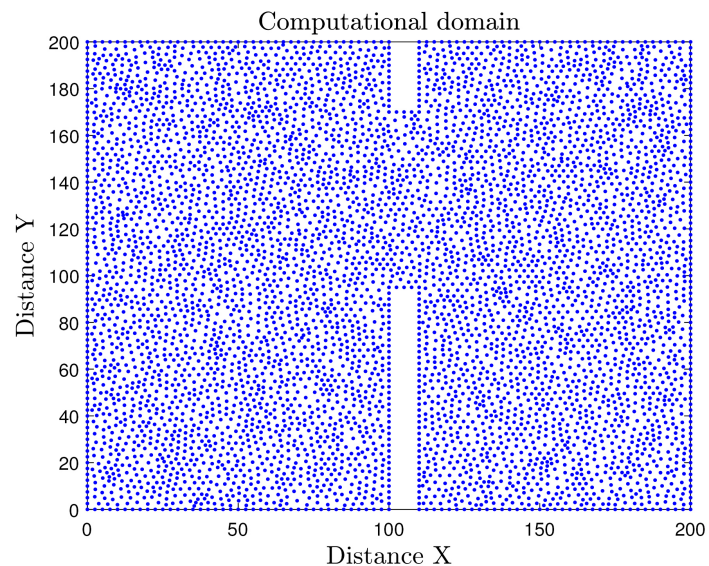


Figure 1. The computational geometry and the collocation points of the partial dam-break problem.

Figure 2 presents the water surface elevation at $t = 7.2$ s following the instantaneous dam break for downstream water levels of 5 meters (left), 0.1 meters (middle), and 0.001 meters (right). The results demonstrate that the proposed model produces outcomes consistent with those from previous studies. Following the dam failure, water is released through the breach, generating forward-propagating waves. According to the RBF model, the flood wave propagates faster as the downstream water depth decreases.

4.2. Circular Dam-Break Problem

Next, the RBF scheme is applied to solve a circular dam-break problem, as detailed in [42] [43]. This case involves the breaking of a cylindrical dam to evaluate the model's ability to preserve symmetry. The initial condition consists of two stationary water bodies separated by a thin-walled cylinder with a diameter of 22 meters, located at the center of a 50×50 m² horizontal, frictionless channel. The domain is discretized using 2931 collocation points. The water depth inside the wall is 10 meters as in [42]. In previous studies where the test case is considered, the depth outside was fixed to be 1 m. In the current study, we consider two more values 5 and 0.001 to see the effect of the depth ratio on the flow regime in the channel. It should also be pointed out that the flow regime in the channel is subcritical for a depth ratio greater than 0.5 (case where the depths outside is equal to 5 m), and it is supercritical for a depth ratio smaller than 0.5. **Figure 3** illustrates the considered computational geometry and the distribution of collocation points in the domain.

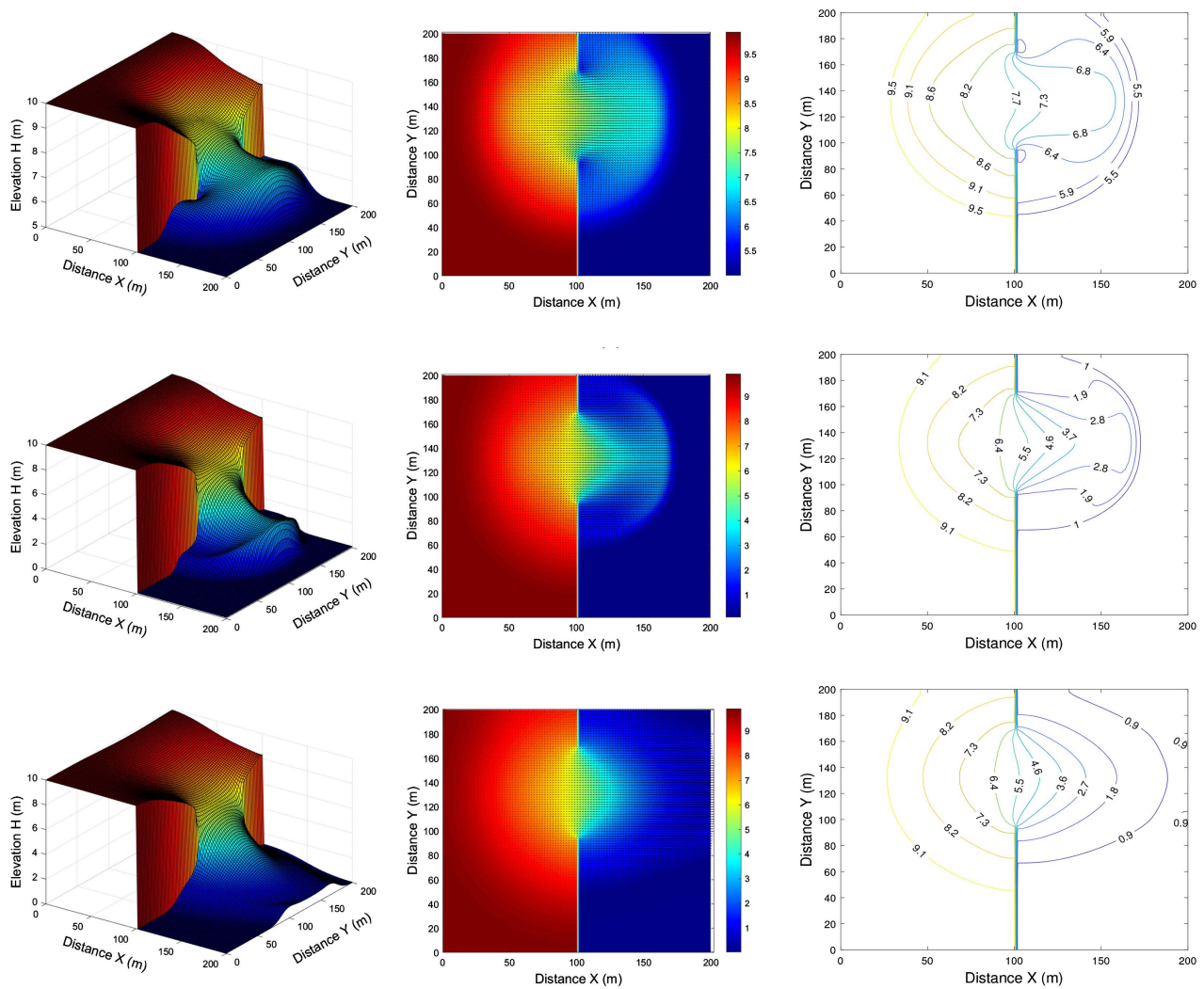


Figure 2. Dam-break flow at time $t = 7.2$ s for downstream flow $hd = 5$ (first line), $hd = 0.1$ (second line) and $hd = 0.001$ (third line).

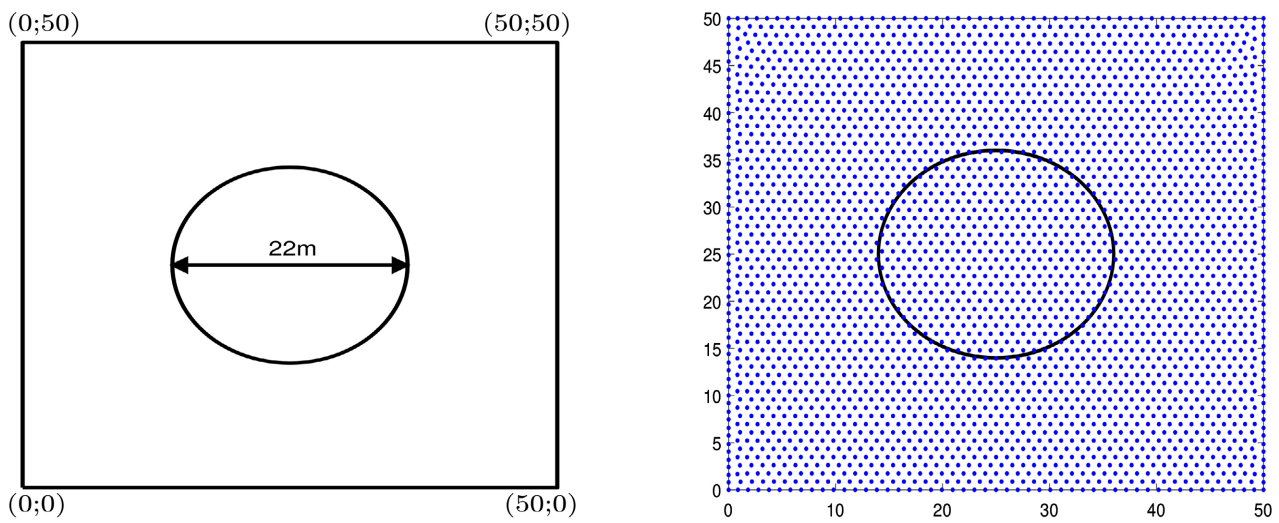


Figure 3. The computational geometry (left) and the collocation points (right) of the circular partial dam-break problem.

Figure 4 shows the resulting depth contours and velocity vectors. The considered RBF scheme demonstrates symmetry preservation and shock-capturing capabilities. The results are comparable to those from [42], where the outer wall water depth was fixed at 1 meter.

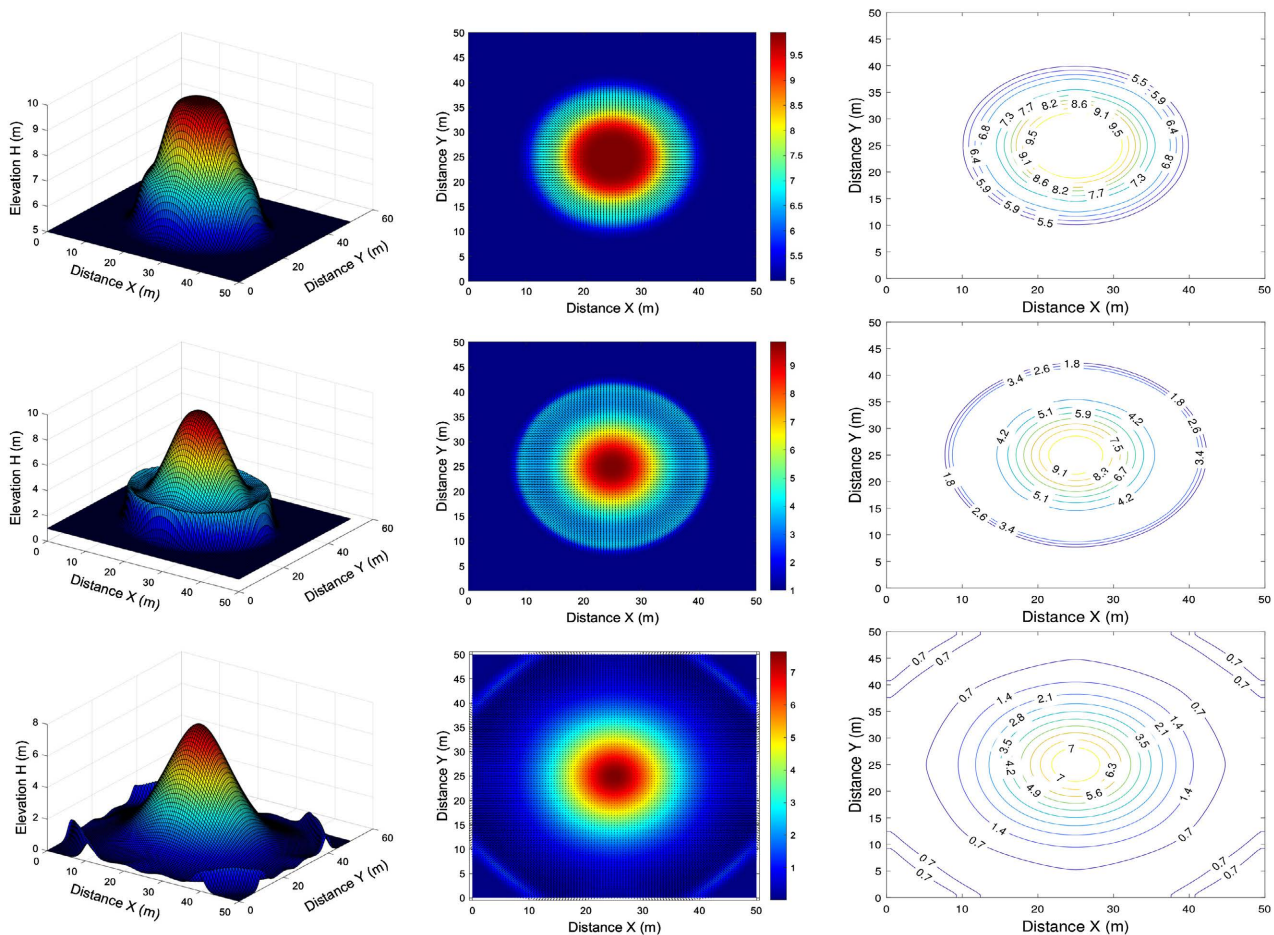


Figure 4. Circular dam-break flow at time $t=0.69\text{ s}$ for downstream flow $hd=5$ (first line), $hd=1$ (second line) and $hd=0.001$ (third line).

5. Application to Urban Flood Inundations

The case study under consideration was previously examined in [44] for the experimental measurement of dam-break flow against a single isolated obstacle. This case was chosen due to its simplicity, involving only a single building, which facilitates the analysis of the flow behavior around the structure. The experiment was conducted in a flume measuring 35.80 m in length and 3.6 m in width, with a single building positioned in the downstream reservoir. From this study, the Manning coefficient was determined to be $n_m = 0.010\text{ s}\cdot\text{m}^{-1/3}$. The initial conditions of the experiment included a water depth of 0.40 m in the upstream reservoir and 0.02 m in the downstream reservoir. Water depth was monitored at six control points, labeled $G1$ to $G6$. This model is solved in [21] using a predictor-corrector MacCormack method coupled with the Hansen nu-

merical Filter. The authors used a comparison of three building approaches to define the buildings and the dam wall (Manning approach, contour approach and wall Boundary approach). Based on the calculation of the Median Absolute Percentage Error (MDAPE) value, their study tried to determine the approach with the highest accuracy. And it has been proved that the wall boundary approach had the highest accuracy. This approach is selected in the current study and only results from [21] using this approach will be used for comparison. To define the building with the wall boundary approach, the velocity perpendicular to the buildings is restricted to zero. The model setup is depicted in **Figure 5**. For more details on the position of the Gauges, the Gape, and the building, readers can refer to [44].

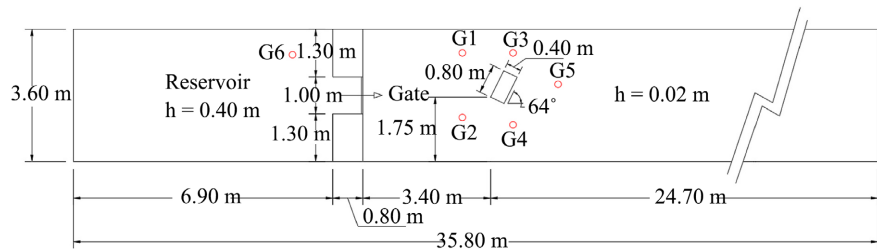
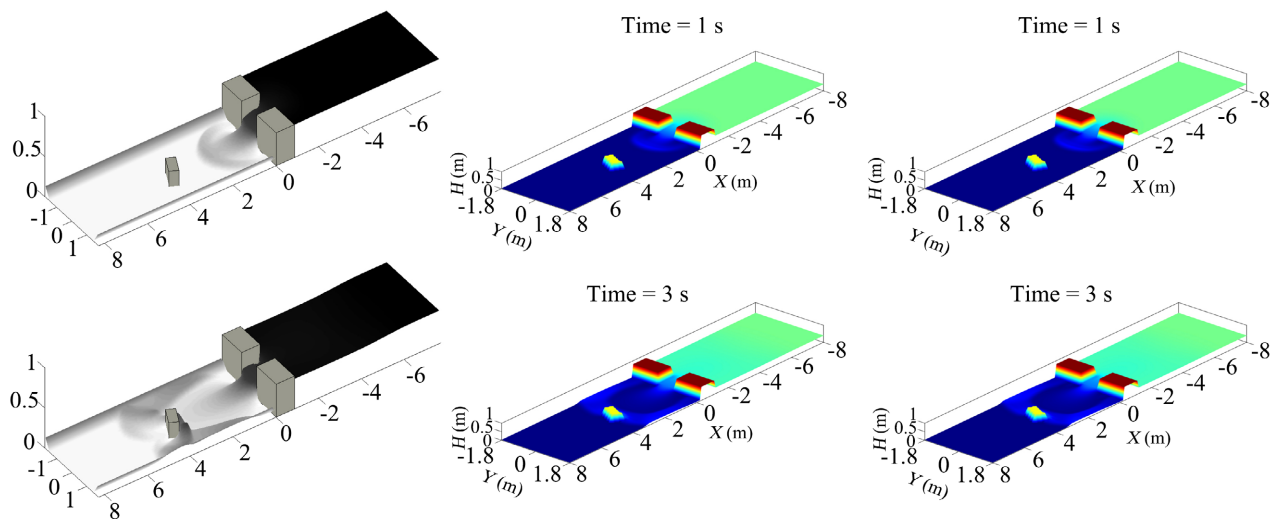


Figure 5. Geometry and model set-up for the considered inundation propagation flow (see [21] [44]).

To perform a comparison between the RBF scheme and the MacCormack method, we prefer to use the same uniform grid as in [21] where $\Delta x = 0.1$ and $\Delta y = 0.1$. The maximum simulation time is set to 30 s with a fixed time step $\Delta t = 0.001$. Numerical results are given in **Figure 6** where height elevation is shown at different times of simulations. Experimental results and those from [21] are also depicted for view comparison. From a bird's-eye view, we remark that both RBF and MacCormack methods give similar results for the considered problem. Both capture attentive chocks at the upstream and the downstream of the gate and around the building.



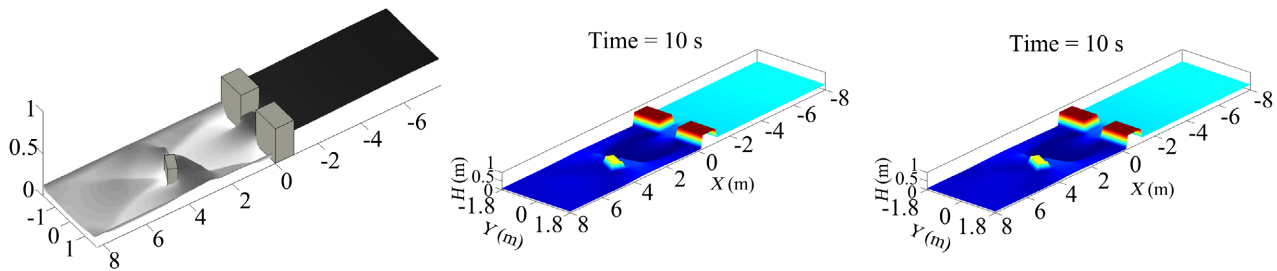


Figure 6. Dam-break inundation flow around a single building at time $t=1s$ (first row), $t=3s$ (second row) and $t=10s$ (third row) using the experimental results (first column), RBF results (second column) and MacCormack method (third column).

For more comparison, two-dimensional profiles of the instantaneous water elevation at the six gauges are plotted in **Figure 7**. The experiment, the RBF, and the MacCormack profiles are provided. Once more, obtained results underline the powerful of the RBF scheme to detect correctly dam-breaks and building inundations, as does the stabilized MacCormack method.

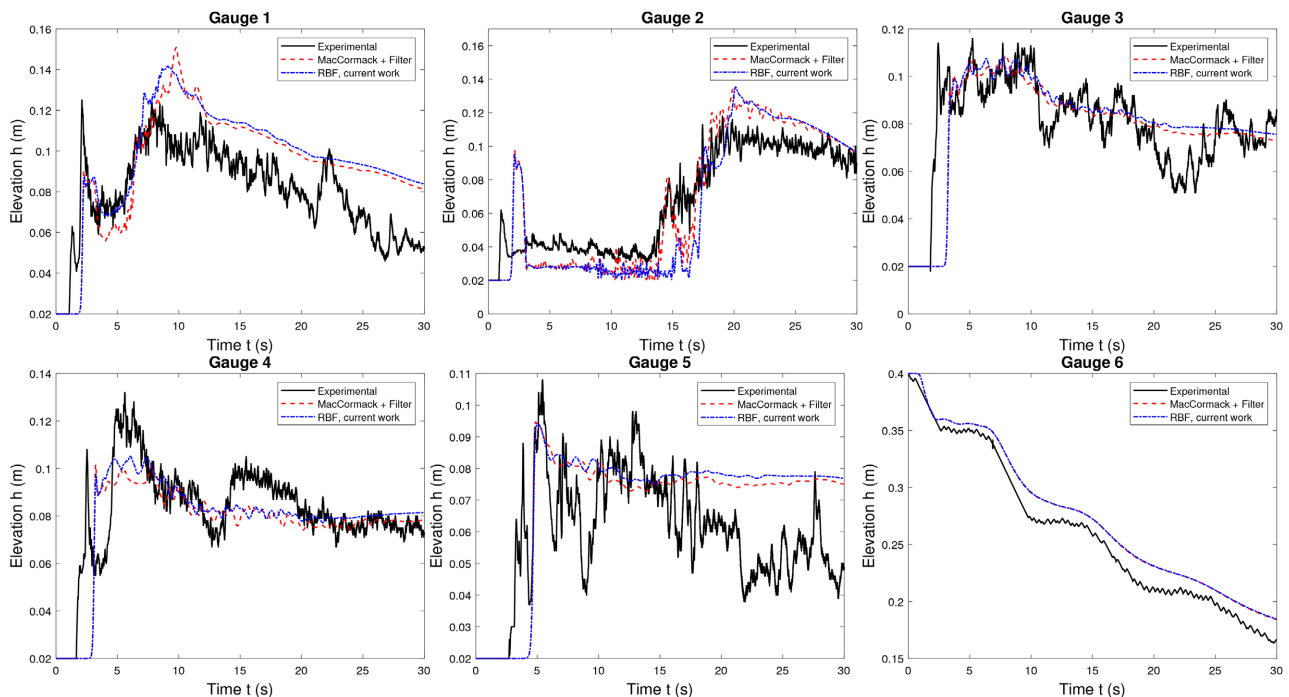


Figure 7. Instantaneous water elevation for the dam-break inundation flow around a single building at the different six gauges.

6. Conclusion

This study presents a novel application of Radial Basis Functions in simulating dam-break flows and urban flood inundation. The RBF-based method offers significant advantages in handling complex geometries and provides accurate and efficient simulations. Furthermore, the results of the water inundation case demonstrate that the RBF method is highly reliable in modeling a more complex 2D scenario, yielding results that closely match the experimental data. The results demonstrate its potential as a valuable tool for urban flood risk manage-

ment, aiding in the development of effective emergency response strategies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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