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Hydraulic Capacity, Drainage Performance and Flood Risk of New Amsterdam, Guyana

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Abstract: New Amsterdam, the capital of Region 6, Guyana, experiences recurrent flooding during periods of intense rainfall despite the presence of gravity drainage sluices and recently installed drainage pumps. However, unlike Georgetown, no published study has quantitatively evaluated the hydraulic capacity and drainage performance of the municipality's drainage system. This study addresses that knowledge gap through field investigations, hydraulic analysis, and examination of historical rainfall and flood records. Field measurements were obtained at the town's five gravity sluices and two permanent drainage pumps, including sluice dimensions, water depths, operating conditions, and evidence of siltation. The hydraulic capacity of each sluice was calculated using a unified Sluice Drainage Coefficient Equation derived from the Chezy-Manning equation and the rainfall drainage coefficient relationship. The five sluices were estimated to provide a combined theoretical discharge of 7.06 m³/s, corresponding to a gravity drainage coefficient of 37.3 mm/day. The two 40-cusec pumps contribute an additional 2.26 m³/s, increasing the total theoretical drainage coefficient to 61.1 mm/day. Field observations indicated that the sluices were generally in good structural condition, functioning normally during low tide, and exhibited little or no significant siltation at their outfalls. The recently constructed additional sluice at Lot 31 increased the town's gravity drainage capacity by approximately 3.6 mm/day. Comparison with documented flood events shows that flooding continues to occur when rainfall exceeds the hydraulic capacity of the drainage system or when operational factors such as high tide, pump failures, blocked drains, vegetation, litter accumulation, or reduced canal conveyance restrict effective drainage. The study demonstrates that New Amsterdam's drainage performance has improved significantly following the installation of additional pumping capacity and the new sluice, but hydraulic capacity alone cannot eliminate flood risk during extreme rainfall. Recommendations are made for continued maintenance of drains, canals, sluices and river defences, together with future upgrades to pumping capacity and additional sluice infrastructure to enhance flood resilience. The study provides the first quantitative hydraulic assessment of New Amsterdam's municipal drainage system and establishes a baseline for future drainage planning and flood risk management in the municipality.

Keywords: *Urban Drainage; Drainage Coefficient, Sluice, Drainage Pumps, Flood Risk, Hydraulic Capacity.*

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I. INTRODUCTION

The municipality of New Amsterdam is located at the confluence of the Berbice and Canje Rivers, specifically on the east bank of the Berbice River, about 4.8 km from the river mouth, and directly on the south bank of the mouth of the Canje River. The Berbice River then drains into the Atlantic Ocean to the north. The township encompasses an area of 5.45 square kilometres and is the regional capital of the administrative region East Berbice-Corentyne (Region 6). The town is an urbanised area with paved streets and asphalt roads arranged in a grid pattern. Land use comprises commercial businesses, light industries, public buildings, the regional hospital, schools, residential neighbourhoods, recreational areas, and open green spaces. An extensive network of drains and canals criss-crosses the municipality, collecting and conveying stormwater and wastewater to the sluices and pumps.

Historically, New Amsterdam has experienced recurrent temporary flooding following periods of intense rainfall. During severe events, low-lying areas may be inundated by several centimetres to more than 0.6 m (approximately two feet) of water. The severity and spatial extent of flooding vary across the municipality. Although flooding rarely results in loss of life, it causes damage to homes, businesses, and public infrastructure, disrupts commercial activities and transportation, creates public-health concerns through the overflow of drains and canals, and imposes significant economic losses and inconvenience on residents.

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Despite periodic maintenance, the installation of two permanent drainage pumps, and the recent construction of an additional sluice, New Amsterdam continues to experience flooding following periods of intense rainfall.

This study evaluates the hydraulic capacity of the municipality's sluices and pumps, quantifies the drainage coefficient of the drainage system, and examines the relationship between drainage capacity and historical flood events.

II. REVIEW OF RELEVANT LITERATURE

Urban flooding, drainage engineering, and flood resilience in Guyana have received increasing research attention over the past three decades. Pelling (1997) examined social vulnerability to flooding in Georgetown, while subsequent engineering studies by the Dutch Risk Reduction Team (2016), Remmers et al. (2016), and Japan International Cooperation Agency (2017) evaluated the city's drainage infrastructure and recommended improvements to its hydraulic performance. More recently, Renville et al. (2026) developed an urban flood resilience index for Georgetown, and Hackett (2026) quantified the city's drainage capacity using hydraulic analyses of its sluices and pump stations.

Outside Georgetown, Mohabir et al. (2023) investigated the hydrodynamics and flood vulnerability of the Lower Canje River basin adjoining New Amsterdam. Their study examined river hydrodynamics and community flood vulnerability rather than the hydraulic capacity and operational performance of New Amsterdam's municipal drainage infrastructure.

Historical accounts by Ishmael (2005a, 2005b) describe the Dutch origins of New Amsterdam's drainage network and its reliance on gravity drainage through sluices and river embankments. However, these works are historical rather than engineering studies and do not evaluate the hydraulic performance of the drainage system.

To the author's knowledge, no published study has quantitatively evaluated the hydraulic capacity, drainage coefficient, sluice discharge capacity, pump performance, and overall drainage performance of New Amsterdam's municipal drainage system. This study addresses that gap by combining field measurements, hydraulic analysis, historical flood records, and rainfall data to assess the drainage performance and flood risk of New Amsterdam.

III. HISTORY AND DESCRIPTION OF THE NEW AMSTERDAM DRAINAGE SYSTEM

New Amsterdam began as a Dutch land settlement developed for trading and agriculture between 1733 and 1740. Later, it was established as the capital of the Dutch colony of Berbice in 1791. As the town expanded and later came under British rule, a commission was appointed in 1812 to plan and construct its roads, bridges and drainage system, establishing one of Guyana's earliest organised urban drainage networks (Ishmael, 2005a). The drainage system followed the Dutch system of coastal water management in which stormwater is conveyed through canals and discharged by gravity through sluices (locally known as kokers) during low tide while earthen embankments protect the town from tidal flooding (Ishmael, 2005b). After the British took control of Berbice in 1803, they maintained and expanded the Dutch drainage system which was inherited by Guyana when the nation became independent of British rule in 1966 (Kupi Travel Guide, 2026.)

➢ *Description of the Catchment Area*

New Amsterdam is protected by a composite river defence system consisting of earthen embankments and timber revetments along the Berbice and Canje Rivers. The embankment forms the town's primary flood-protection against high river levels and tidal inundation, while five gravity sluices and two pumps convey stormwater through the embankment to the rivers. Vegetation growing on the embankments helps stabilise the slopes and reduce erosion. Three sluices are located along the east bank of the Berbice River (including the recently constructed sluice), while two are located along the south bank of the Canje River. The two pumps are each located on the banks of the rivers near two sluices. The sluices, pumps, drains and canals are maintained and operated by the Mayor and Town Council of New Amsterdam.

Unlike many coastal drainage systems that discharge directly into the Atlantic Ocean, New Amsterdam drains through sluices located on the Berbice and Canje Rivers. Atlantic coastal sluices are periodically affected by the migration of Amazon-derived mudbanks that migrate westward along the Guyana coast, altering coastal morphology and, in some locations, obstructing sluice outfalls and reducing gravity drainage efficiency (Khemraj, 2015; Best et al., 2025). In contrast, the riverine location of the New Amsterdam sluices makes them far less susceptible to blockage by the migrating mudbanks than the Atlantic coastal sluices, and field observations conducted during this study found little evidence of significant siltation at the sluices. Consequently, the principal limitations to drainage performance in New Amsterdam are more likely to arise from sluice capacity, internal drain maintenance, tidal operating windows and pump capacity than from blockage of the river outfalls by coastal mudbanks.

Figure 1 shows a map of the study area and the locations of the five sluices and two pump stations investigated during this study. The figure also illustrates the road network, and the layout of New Amsterdam. Most canals and internal drains run alongside the roads.

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Fig 1 Map of New Amsterdam Showing Locations of Sluices and Pump Stations Where Field Data Were Collected. Base Map from Google Earth Satellite Imagery (Google, 2026), October 17, 2020. Field Data and Annotations by the Author (2016–2026).

➢ *Structure and Operation of Sluice Gates*

The sluices in New Amsterdam consist of manually operated vertical lift sluice gates housed within reinforced concrete sluice structures. Each sluice comprises a reinforced concrete invert (bed), sidewalls or piers, and a reinforced concrete head beam supporting the gate from steel cables and pulleys with the winch mechanism at the base of a column. The gate itself is constructed from horizontally arranged timber planks reinforced by vertical members, although timber gates in some Guyanese sluices have been replaced by fabricated steel gates. The gate slides vertically within guide grooves cast into the concrete sidewalls to provide a watertight seal when closed.

Unlike many of the larger drainage sluices in Guyana, the five New Amsterdam sluices do not employ counterweights because of their relatively small gate dimensions. Instead, four of the sluices have gates raised and lowered manually using the cable-and-winch mechanism operated by the sluice attendant. The lower weight of the gates allows manual operation without mechanical balancing by counterweights. The fifth sluice, which was recently constructed, is raised and lowered by a vertical screw mechanism operated by a large turn wheel.

During low tide, the operator raises the gate, allowing the higher inland water level to discharge by gravity into the Berbice or Canje River. As the tide rises, the hydraulic head difference decreases and the discharge gradually reduces. Before the external river level exceeds the inland water level, the operator lowers the gate to prevent reverse flow and tidal inundation of the drainage system. The gates typically remain open for an average eight hours during each daily tidal cycle, although the actual operating duration depends on the prevailing tide and rainfall conditions.

Field observations of a typical sluice showed that the timber or steel gate is seated within recessed guide grooves approximately 100 mm deep along the sides and approximately 150 mm at the invert. When the river level exceeds the inland water level, the pressure differential forces the gate tightly against these recesses, producing a hydraulic seal. Cotton caulking placed between the timber planks helps reduce leakage through the gate.

Figure 2 shows the old gravity sluice, the newly constructed vertical-screw-operated sluice, and the nearby 40-cusec drainage pump with discharge pipeline installed at the Lot 31 site.

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Fig 2 Lot 31 Old (Right) and Newly Constructed (Left) Lot 31 Sluices and Pump Station in Background.

Figure 3 illustrates the Lot 51 sluice, where field observations showed free discharge under submerged-gate (orifice flow) conditions during low tide on one occasion and raised gate (free open channel flow) on another occasion.

Fig 3 Lot 51 Sluice Discharging by Gravity During Low Tide.

Figure 4 shows the Tucber sluice together with the adjacent 40-cusec drainage pump and discharge pipeline.

Fig 4 Tucber Sluice and Pump Station on the South Bank of the Canje River

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Figure 5 shows the NATI sluice, located approximately 160 m east of the New Amsterdam Technical Institute (NATI) on the south bank of the Canje River, from which the sluice derives its name.

Fig 5 NATI Sluice on the South Bank of the Canje River

- *Other Causes of Flooding*

In addition to flooding caused by intense rainfall, New Amsterdam is also vulnerable to flooding resulting from failures of its river defences. In September 2011, a breach in the earthen embankment along the Canje River, combined with high spring tides, inundated parts of Tucber, Nurseville and Winkel, highlighting the critical role of the river defences in protecting the municipality from tidal and river flooding (Kaieteur News, 2011). Then, in November 2025, the Tucber sluice gate was damaged during a high spring tide, allowing inflow of water that flooded Tucber and Vryman's Erven (Guyana Times, 2025c). These events were fundamentally different from pluvial flooding caused by insufficient drainage capacity, but demonstrates that effective flood management in New Amsterdam depends on both reliable drainage infrastructure and the structural integrity of the river defences.

IV. METHODOLOGY

Field visits were conducted between 2016 and 2026 to obtain measurements of sluice geometry, assess structural conditions, observe operational practices, and document drainage infrastructure through photographic records. Observations were made of drainage pumps present at sluice locations to determine their labelled discharge capacity which was confirmed later by the town engineer.

Sluice operating durations were estimated from local tidal predictions from the Guyana Tide Tables and List of Lights (2026). Pump operation was assumed during periods of sluice closure at high tide, providing approximately 14 – 16 hours of pumped drainage daily. Accordingly, the combined gravity-pumped drainage system is theoretically capable of continuous 24-hour operation during prolonged rainfall events.

- *Calculation of Sluice Drainage Coefficient*

Drainage coefficients of the sluices were calculated using the unified Sluice Drainage Coefficient Equation, given by:

$$\text{DC (mm)} = \frac{3.6\, t\, S^{1/2}}{A\, n} \frac{(b\, d)^{5/3}}{(b + 2d)^{2/3}} \quad \text{(Eq. 1)}$$

Daily operating time (hours) = t
Channel slope (no unit) = S
Catchment area (square km) = A
Manning coefficient (s/m$^{1/3}$) = n
Flow width at rectangular gate (m) = b
Flow depth at rectangular gate (m) = d

This equation was derived by combining the Chezy-Manning equation for open channel flow through a rectangular sluice gate with the rainfall drainage coefficient hydrology equation (Rowe 1970; Potter, 2009; Hackett, 2026).

The Chezy-Manning equation for uniform open-channel flow:

$$Q = \frac{A\, R^{2/3}\, S^{1/2}}{n} \quad \text{(Eq. 2)}$$

Volume flow rate or discharge capacity (m^3/s) = Q
Flow area of sluice gate (m^2) = $A = b\, d$
Hydraulic radius (m) = $R = \dfrac{b\, d}{b + 2d}$
Channel slope (no unit) = S

The drainage coefficient (depth of water drained from the catchment per day) equation:

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$$\text{DC (mm)} = \frac{3{,}600\,Q\,t}{1{,}000\,A} = \frac{3.6\,Q\,t}{A} \qquad \text{(Eq 3.)}$$

Catchment area (square km) = A

The other symbols have the same meanings as in the previous equations.

The unified equation (Eq. 1) makes for ease of calculation to obtain the theoretical daily drainage coefficient in mm directly from sluice geometry (b and d) and site parameters (t, S, A, and n).

➢ *Selection of Manning's Roughness Coefficient*

A Manning roughness coefficient of $n = 0.014$ s/m$^{1/3}$ was adopted for the sluices. This value is consistent with the range recommended for concrete channels (Potter, 2009) and is considered representative of the unfinished reinforced concrete surfaces observed during field inspections. Although the approach canals have greater roughness due to vegetation and earthen sections, the concrete sluices constitute the hydraulic control sections governing discharge; therefore, $n = 0.014$ s/m$^{1/3}$ was considered appropriate for estimating the drainage coefficients.

➢ *Selection of Channel Slope.*

A channel slope of $S = 0.0002$ was adopted for the hydraulic analysis. This value is representative of the low gradients characteristic of Guyana's coastal plain (Merrill, 1993; Naraine, 1971) and approximates the effective hydraulic gradient governing gravity drainage through the sluices during low tide.

➢ *New Amsterdam-Specific Form*

Substituting the parameters for the New Amsterdam sluices: $n = 0.014$ s/m$^{1/3}$, $S = 0.0002$, $t = 8$ hr, $A = 5.45$ km^2, the coefficient becomes a single empirical constant K:

$$K = \frac{3.6\,t\,S^{1/2}}{A\,n} = \frac{3.6 \times 8 \times 0.0002^{1/2}}{5.45 \times 0.014} = 5.338\ \text{m}^{-5/3} \qquad \text{(Eq. 4}$$

Hence, the per-sluice daily drainage coefficient equation for New Amsterdam becomes:

$$\text{DC (mm)} = 5.3388\,(b\,d)\left(\frac{b\,d}{b+2d}\right)^{2/3} = \frac{5.338\,(b\,d)^{5/3}}{(b+2d)^{2/3}} \qquad \text{(Eq. 5)}$$

➢ *Calculation of Pump Drainage Coefficient*

The drainage coefficient for the pumps is calculated by:

$$\text{DC (mm)} = \frac{3.6\,Q\,t}{A} \qquad \text{(Eq. 6)}$$

(Rowe, 1970)
Rated discharge capacity of pump (m^3/s) = Q
Daily operating time (hours) = t
Catchment area (square km) = A

➢ *Runoff and Flood Criteria*

New Amsterdam is a highly urbanised municipality comprising commercial, institutional, and residential areas interspersed with parks, open spaces, drains and canals. Rainfall on the town produces a combination of surface runoff from impermeable surfaces and infiltration into permeable areas.

The runoff coefficient (C) for urban catchments varies according to land use, surface cover and soil permeability, typically ranging from approximately 0.30 for open vegetated areas to 0.95 for paved commercial districts (Nathanson, 2008). A representative composite runoff coefficient of 0.75 was adopted for New Amsterdam to estimate storm runoff from recorded rainfall events. The adopted runoff coefficient of 0.75 represents an average value for the urban catchment. Actual runoff coefficients vary spatially and temporally with land use, soil moisture, and rainfall intensity, but the selected value provides a reasonable estimate for comparing runoff with the drainage capacity of the system.

For a rainfall event of depth R (mm), the estimated runoff = CR, where C is the runoff coefficient. If $CR \geq D$, where D is the effective drainage coefficient of the system, temporary flooding is expected because runoff exceeds drainage capacity. Conversely, where $CR < D$, flooding is unlikely under normal operating conditions.

V. RESULTS & ANALYSIS

Table 1 summarises the drainage coefficients of New Amsterdam's sluices calculated using the Unified Sluice Drainage Coefficient Equation (Eq. 1). The calculated values reflect the influence of sluice width and flow depth on discharge capacity, with a combined gravity drainage coefficient of 37.3 mm/day.

Table 1 Drainage Coefficients of New Amsterdam's Sluices Using the Unified Sluice Drainage Coefficient Equation

	Sluices	Width (m)	Flow Depth (m)	DC (mm/day)
1	Lot 51	1.83	0.80	4.4
2	Lot 31 (old)	1.45	1.50	7.2
3	Lot 31 (new)	1.56	0.80	3.6
4	NATI	1.87	1.50	10.4
5	Tucber	2.34	1.30	11.7
			Avg = 1.18	**Tot = 37.3**

Table 2 summarises field measurements of bed depth, water depth, and siltation conditions at New Amsterdam's sluices. The observations indicate that the sluice channels are generally well maintained, with no significant siltation observed, suggesting that current drainage limitations are primarily related to hydraulic capacity rather than sediment blockage.

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Table 2 Field Measurements of Bed Depth, Water Depth and Siltation Conditions at New Amsterdam Sluices.

No.	**Sluice**	**Bed to Sluice Top (m)**	**Water Depth (m)**	**Conditions**
1	Lot 51	~ 3.1	0.80	No significant siltation
2	Lot 31 (old)	~ 3.0	1.50	No significant siltation
3	Lot 31 (new)	3.2	0.80	Hard bed. No siltation
4	NATI	3.8	1.50	Hard bed. No siltation
5	Tucber	3.02	1.30	No siltation

Table 3 shows the calculations for the discharge capacity and drainage coefficient of the Tucber sluice. These are incorporated into the Integrated Sluice Drainage Coefficient Equation for computational efficiency for each sluice.

Table 3 Discharge Capacity and Drainage Coefficient Calculations for Tucber Sluice

Parameter	**Value**	**Equations**
Width, W (m)	2.34	$Q = \frac{A(R^{2/3})(S^{1/2})}{n}$
Depth, D (m)	1.30	
Area, A (m^2)	3.04	$= \frac{3.04(0.615^{2/3})(0.0002^{1/2})}{0.014}$
Wetted perimeter, $P = W + 2D$ (m)	4.94	$= 4.96\ m^3/s$
Hydraulic radius, $R = A/P$ (m)	0.615	
Slope, S	0.0002	
Manning coefficient, n ($s/m^{1/3}$)	0.014	
Flow speed, v (m/s)	0.73	$D.C. = \frac{3{,}600\ Qt}{1{,}000A}$
Discharge capacity, Q (m^3/s)	2.22	
Duration of opening of sluice, t (hr)	8	$= \frac{3{,}600(2.22)(8)}{1{,}000(5.45)}$
Daily drainage volume, D (m^3)	63,936	
Drainage area of New Amsterdam, A (km^2)	5.45	= 5.0 mm
Drainage coefficient, DC (mm)	11.7	

Table 4 summarises the calculated hydraulic performance of New Amsterdam's sluices, including flow velocity, discharge capacity, and drainage coefficients. The results indicate that the five sluices collectively provide a discharge capacity of 7.06 m³/s, equivalent to a gravity drainage coefficient of 37.3 mm/day. These results confirm the values of drainage coefficients listed in Table 1.

Table 4 Calculated Discharge Capacity and Drainage Coefficients of New Amsterdam Sluices

No.	**Sluices**	**Breadth, b (m)**	**Depth, *d* (m)**	**Flow speed, *v* (m/s)**	**Discharge, Q (m^3/s)**	**Drainage Coefficient, DC (mm/day)**
1	Lot 51	1.83	0.80	0.57	0.84	4.4
2	Lot 31 (old)	1.45	1.50	0.63	1.36	7.2
3	Lot 31 (new)	1.56	0.80	0.54	0.68	3.6
4	NATI	1.87	1.50	0.70	1.96	10.4
5	Tucber	2.34	1.30	0.73	2.22	11.7
	Total	**-**	**-**	**-**	**7.06**	**37.3**

The sluice discharge estimates depend on assumed Manning's coefficient, channel slope, and average gate opening duration. Small variations in these parameters would produce corresponding changes in predicted drainage coefficients.

Table 5 summarises the calculation of the drainage coefficient contributed by the Lot 31 and Tucber pumps using Eq. 6. Based on a combined discharge capacity of 2.26 m³/s and 16 hours of daily operation, the pumps provide an additional drainage capacity of 23.8 mm/day over New Amsterdam's 5.45 km² drainage area.

Table 5 Calculations of Drainage Coefficient for Lot 31 and Tucber Pumps

Parameter	**Value**	**Drainage coefficient equation**
Discharge capacity for Lot 31 pump Q (m^3/s)	1.13	$D.C. = \frac{3.6\ Q_T\ t}{A}$
Discharge capacity for Tucber, Q (m^3/s)	1.13	
Duration of operation of pumps, t (hr)	16	$= \frac{3.6(2.26)(16)}{5.45}$
Daily drainage volume, D (m^3)	130,176	= 23.8 mm
Drainage area of New Amsterdam, A (km^2)	5.45	
Drainage coefficient (mm)	23.8	

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Table 6 presents the hydraulic contribution of the Lot 31 and Tucber pumps to New Amsterdam's drainage system. The two pumps collectively provide a discharge capacity of 2.26 m³/s, equivalent to an additional drainage coefficient of 23.8 mm/day over the town's drainage area.

Table 6 Pumps Discharge Capacity and Drainage Coefficients

No.	Pump	Discharge (ft^3/s)	Discharge, Q(m^3/s)	DC (mm/day)
1	Lot 31	40	1.13	11.9
2	Tucber	40	1.13	11.9
	Total	**80**	**2.26**	**23.8**

Total combined drainage coefficient of sluices and pumps is 61.1 mm/day. If the Lot 51 and Tucber sluices are de-silted to increase their flow depth to 1.5 m, the total sluice drainage coefficient would increase from 37.3 to 45.4 mm, bringing the town's total combined drainage coefficient to 69.2 mm/day, an increase of 13%.

The relative contributions of each sluice and pump to the total drainage capacity are shown in Figure 6.

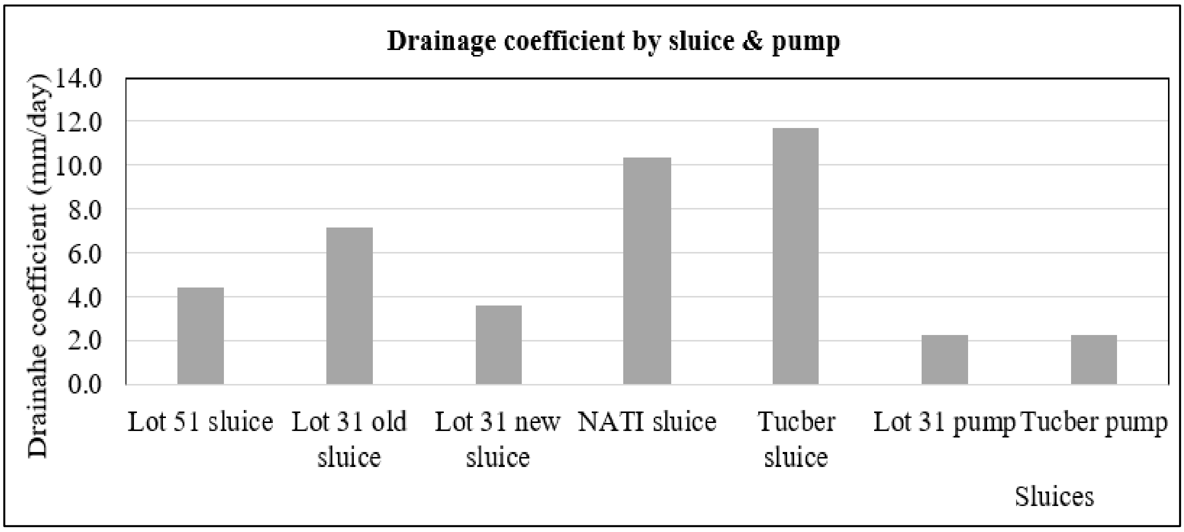

Fig 6 Drainage Coefficient by Sluice and Pump

The Tucber sluice provides the greatest gravity-drainage capacity, followed by the NATI sluice. The recently constructed Lot 31 sluice contributes additional drainage capacity and operational redundancy. Each 40-cusec pump contributes approximately 11.9 mm/day, demonstrating the enhancement provided by mechanical pumping.

Table 7 summarises some historical rainfall events linked to flooding in New Amsterdam and surrounding areas. Rainfall records were unavailable for some reported flood events in New Amsterdam. Therefore, the highest daily rainfall reported by Hydromet for the nearest available location on the corresponding date was used as a proxy for the event magnitude. This approach provides an approximate indication of rainfall severity but does not necessarily represent the actual rainfall received in New Amsterdam. The recorded rainfall totals demonstrate the occurrence of both moderate and extreme rainfall events, highlighting the need to assess the adequacy of the town's drainage infrastructure under high rainfall conditions.

Table 7 Some Historical Rainfall Events Associated with Flooding in New Amsterdam

Date	Rainfall (mm)	Nearest location	Source
Jul 6, 2012	254 .0	Region 6	Stabroek News, 2012
Dec 23, 2016	138.2	John's	Stabroek News, 2016
Jun 24, 2017	188.7 78.7	John's – Jun 22 John's – Jun 23	Hydromet, 2017a; Guyana Times, 2017; INews Guyana, 2017
Sep 1, 2017	42.0	New Amsterdam	Hydromet, 2017b
Mar 29, 2020	83.7 92.6	Yakusari – Mar 28 No. 63 – Mar 29	Guyana Times, 2020; Hydromet, 2020
Apr 25, 2023	175.5	Blairmont	Guyana Times, 2023a
May 17, 2023	20 – 50	Region 6	Guyana Times, 2023b; Stabroek News, 2023
Jul 17, 2024	113.2	New Amsterdam	Hydromet, 2024
Apr 16, 2025	205	Bath Waterloo	Hydromet, 2025; Guyana Times, 2025a
Apr 20, 2025	20 – 50	Region 6	Guyana Times, 2025b

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➤ *Analysis of Selected Flood Events in New Amsterdam*

Contemporary news reports documented widespread flooding in New Amsterdam and other East Berbice communities following the intense rainfall of 22–23 June 2017, despite the continued operation of gravity drainage and pump systems. Field observations conducted on June 24, 2017 confirmed that the Everton and Edinburgh–Heathburn sluices on the East Bank of the Berbice River, approximately 3 km south of New Amsterdam, remained open and discharged continuously during the low-tide period of approximately eight hours. Outflow gradually diminished as the tide rose and ceased once the sluice gates were closed. These observations demonstrate the strong dependence of gravity drainage on the available tidal discharge window.

On September 1, 2017, New Amsterdam received 42 mm of rainfall (Hydromet, 2017b) and experienced temporary flooding. Assuming a runoff coefficient of 0.75, the estimated runoff was approximately 32 mm. At that time, the drainage system comprised only four gravity sluices with a theoretical drainage coefficient of 33.7 mm/day. Because the estimated runoff was comparable to the theoretical drainage capacity, the occurrence of flooding indicates that the effective drainage performance during the event was below its theoretical maximum. This reduction was likely due to tidal constraints, operational limitations, partial blockages within the drainage network, or other hydraulic losses. The recession of floodwaters within approximately 24 hours suggests that the effective drainage capacity during the event was of the order of 30 mm/day, slightly below the calculated theoretical capacity and close to the traditional colonial drainage coefficient of approximately 38 mm/day for gravity drainage systems (Lacey, 1953).

The installation of two mobile drainage pumps in 2023 increased the town's theoretical drainage coefficient from 33.7 mm/day under gravity drainage alone to approximately 57.5 mm/day (Guyana Chronicle, 2023). Following construction of the new Lot 31 sluice, the total combined theoretical drainage coefficient is now 61.1 mm/day.

On July 17, 2024, New Amsterdam received 113.2 mm of rainfall (Hydromet, 2024), corresponding to an estimated runoff of approximately 85 mm. This runoff substantially exceeded the town's theoretical drainage capacity, indicating that temporary flooding would be expected even if the drainage system had been operating near its maximum hydraulic efficiency. Contemporary reports indicated that floodwaters required more than 24 hours to recede, consistent with runoff exceeding the hydraulic capacity of the drainage system.

Table 8 presents the comparison between rainfall-generated runoff and the estimated drainage capacity of New Amsterdam for two flood events. The results show that flooding occurred despite the calculated drainage capacity, suggesting that flood risk is influenced not only by total rainfall volume but also by rainfall intensity, timing, tidal conditions, and drainage system performance.

Table 8 Comparison of Estimated Runoff and Drainage Capacity for Selected Flooding Events in New Amsterdam

Date	Rainfall (mm)	Estimated runoff (mm)	Drainage capacity (mm/day)	Flooding
Sept. 1, 2017	42.0	31.5	33.7	Yes
July 17, 2024	113.2	84.9	57.5	Yes

VI. DISCUSSION

The drainage coefficients calculated in this study represent the theoretical maximum hydraulic capacity of the drainage system assuming unobstructed flow and full operation of the sluices and pumps. In practice, the effective drainage coefficient experienced during actual storm events may be substantially lower because of tidal constraints, pump failures, siltation, vegetation, litter accumulation, partial blockage of canals, operational delays, and encroachment upon drainage reserves.

If the two current pumps are replaced with ones of twice their discharge capacity, the town's overall drainage coefficient would be boosted to 84.9 mm/day, a significant increase of 39% over the current drainage performance. This will reduce the frequency, duration, and severity of flooding in the township during intense rainfall events. It should be borne in mind, however, that once runoff exceeds this maximum drainage coefficient, temporary flooding is likely to happen. Therefore, it is imperative that the Council maintains the town's internal drains and canals to keep them clear and clean of all obstacles to ensure maximum conveyance of the network to the sluices and pumps to reduce the duration of temporary flooding.

To further improve gravity drainage, the Lot 51, NATI and Tucber sluices should ideally be supplemented by vertical screw mechanism sluices as was done at the Lot 31 sluice site. This would bring to eight the total number of sluices serving the town and create redundancy in the event of repair or failure of any of the sluices. However, such an undertaking would involve substantial capital expenditure, likely beyond the financial capacity of the Town Council unless funded and executed by the National Drainage and Irrigation Authority (NDIA). Furthermore, from a maintenance perspective, retaining and rehabilitating the existing smaller sluices is likely to be more practical and less costly for the Council.

The installation of two mobile drainage pumps in 2023 increased New Amsterdam's theoretical drainage coefficient from 33.7 mm/day under gravity drainage alone to a combined capacity of approximately 57.6 mm/day. With the recently constructed sluice at Lot 31, the total combined drainage capacity is now 61.1 mm/day. Contemporary reports indicate that this investment, together with canal cleaning and improved maintenance by the Town Council, the Regional Democratic Council and the NDIA, substantially reduced flooding during the 2024 rainy season (Stabroek News, 2024). These observations provide practical evidence that

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improving both pumping capacity and canal maintenance can significantly enhance drainage performance.

However, subsequent flood events demonstrate that hydraulic capacity alone does not eliminate flood risk. On July 17, 2024, Hydrometeorological Service (Hydromet) records showed 113.2 mm of rainfall at New Amsterdam, almost twice the town's calculated drainage capacity of 57.5 mm/day. Temporary flooding under such rainfall conditions would therefore be expected even if the drainage network were operating at maximum efficiency.

Likewise, flooding on April 16, 2025 occurred during high tide when sluices were closed, while contemporary reports indicated that both mobile pumps were not operating and that extensive littering, silted drains and encroachment on drainage reserves had reduced the storage and conveyance capacity of the drainage network. These operational and maintenance deficiencies compounded the effects of the intense rainfall.

The present study evaluates only the hydraulic capacity of the drainage system. However, overall flood resilience in New Amsterdam also depends on maintaining the integrity of the river embankments. Failure of the river defence can permit direct inflow of river water into the protected area irrespective of the capacity of the sluices and pumps. Consequently, drainage improvements should be complemented by regular inspection and maintenance of the river defences.

➢ *Study Limitations*

The hydraulic capacities presented represent theoretical maximum values calculated from field measurements and hydraulic equations under assumed operating conditions. Actual drainage performance during storm events may differ because of temporal variations in tidal levels, rainfall intensity, pump reliability, gate operation, vegetation, litter accumulation, canal roughness, and other operational constraints. Future studies incorporating continuous rainfall, tide, and water-level monitoring would permit more detailed hydraulic modelling of drainage system performance.

VII. RECOMMENDATIONS

➢ *Upgrade Pumping Capacity*

The two existing 40 cusec pumps should be replaced, or supplemented, with higher-capacity pumps. Hydraulic analysis indicates that doubling the pump capacity would increase the municipal drainage coefficient from approximately 61.1 mm/day to 84.9 mm/day, substantially reducing the frequency, depth and duration of flooding during moderate to heavy rainfall events.

➢ *Construct Supplementary Sluice*

An additional gravity sluice should be constructed adjacent either to the NATI or Tucber sluices using a modern vertical-screw-operated gate similar to the recently completed Lot 31 sluice. Providing duplicate sluices would increase total gravity discharge, reduce drainage time, provide redundancy during maintenance, and improve operational reliability. The recent Lot 31 project demonstrates that this approach is technically feasible.

➢ *Maintain Internal Canals*

Routine desilting and vegetation removal should continue throughout the municipal drainage network. Field observations showed that although the major canals were generally in good condition, several secondary canals contained dense vegetation, floating debris, and plastic waste. These reduce conveyance long before water reaches the sluices.

➢ *Prevent Encroachment*

The municipality should prevent construction on drainage reserves, filling of canals, narrowing of waterways, and illegal structures adjacent to drains. Maintaining the original hydraulic cross-sections is essential to preserve conveyance capacity.

➢ *Improve Pump Reliability*

The permanent pumps should receive preventive maintenance and standby equipment should be available during the rainy seasons. Historical flood events demonstrate that pump failures during storms significantly reduce drainage performance.

➢ *Improve Sluice Operation*

Standard operating procedures should be established to ensure sluices are opened promptly during falling tides and closed before reverse flow occurs. Where feasible, installation of water-level gauges, tide gauges, and automated monitoring would improve operational efficiency.

➢ *Continue River Defence Maintenance*

The earthen embankments and timber revetments along the Berbice and Canje Rivers should be inspected regularly for erosion, settlement, seepage, burrowing animals, and deterioration of the revetments, particularly before the spring-tide season. Since the integrity of these river defences is essential for protecting New Amsterdam from tidal and river flooding, any defects or breaches should be repaired promptly using properly engineered materials and construction methods rather than temporary mud fills, which may fail during subsequent high tides.

➢ *Install A Municipal Rainfall Gauge Network*

A permanent rainfall monitoring programme should be established within New Amsterdam by partnering with the Hydromet Service of the Ministry of Agriculture. Continuous rainfall records would allow rainfall intensity analysis, calibration of hydraulic models, better estimation of runoff, improved flood forecasting. This would greatly strengthen future engineering studies.

➢ *Install Water-Level Recorders*

Automatic level loggers should be installed upstream of sluices, downstream of sluices, at selected canals. These data would quantify drawdown, drainage rates, tidal effects, storage characteristics, and actual rather than theoretical hydraulic performance.

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- *Develop Design Standards*

The Town Council and NDIA should develop minimum drainage performance targets for urban drainage systems. For example, future upgrades could be designed to provide a drainage coefficient of at least 90 – 100 mm/day, similar to Georgetown's, which would accommodate most intense rainfall events recorded over the past decade while reducing flood frequency.

- *Drainage Management Plan*

Develop an Integrated Urban Drainage Management Plan. The Mayor and Town Council, in collaboration with the NDIA and Hydromet, should establish an integrated drainage management programme combining regular canal maintenance, preventive pump servicing, optimised sluice operation based on tide forecasts, routine rainfall and water-level monitoring, and public education on preventing littering and drainage obstruction. Such an integrated approach would improve the effectiveness of existing infrastructure and reduce flood risk without relying solely on major capital investments.

- *Future Research*

Further investigations should include detailed rainfall intensity-duration-frequency (IDF) analysis, runoff modelling, hydraulic modelling of the canal network, tidal interaction with sluice operation, climate change impacts on future rainfall, economic cost-benefit analyses of drainage upgrades. These studies would provide a stronger basis for long-term flood management planning.

VIII. CONCLUSION

This study presents the first quantitative hydraulic assessment of the drainage system of New Amsterdam, Guyana. Field measurements, hydraulic analyses, and historical rainfall and flood records were used to evaluate the discharge capacity and drainage performance of the municipality's five gravity sluices and two mobile pump stations. By quantifying the hydraulic performance of the drainage network, the study addresses an important gap in the published literature on urban drainage in Guyana and establishes a scientific baseline against which future improvements can be evaluated.

The results indicate that the five gravity sluices provide a combined theoretical drainage coefficient of approximately 37.3 mm/day, while the two 40-cusec drainage pumps contribute an additional 23.8 mm/day, giving a total theoretical drainage coefficient of approximately 61.1 mm/day. The recently constructed Lot 31 sluice has increased the town's gravity drainage capacity and provides additional operational redundancy. Field investigations further showed that the sluice outfalls were generally free of significant siltation, reflecting the riverine location of New Amsterdam where the Berbice and Canje Rivers are largely unaffected by the migrating Amazon-derived mudbanks that periodically obstruct many Atlantic coastal sluices.

Comparison of the calculated drainage capacity with documented rainfall events demonstrates that flooding in New Amsterdam results from both hydraulic and operational factors. The September 2017 flood occurred when estimated runoff was comparable to the theoretical drainage capacity, indicating that tidal constraints, operational limitations, or reduced conveyance within the drainage network lowered the effective performance of the system below its theoretical capacity. In contrast, the July 2024 flood resulted from storm runoff that substantially exceeded the calculated drainage capacity, indicating that temporary flooding would have been expected even under efficient operating conditions. These findings demonstrate that flooding may occur either because rainfall exceeds the hydraulic capacity of the drainage system or because maintenance and operational deficiencies reduce its effective performance.

Although the principal sluices and pump stations were found to be generally in good structural condition, effective flood management depends equally on maintaining clear internal drains and canals, reliable pump operation, efficient sluice management during tidal cycles, and the continued integrity of the Berbice and Canje River embankments. Improvements in pumping capacity, construction of additional sluices at existing sites, and routine maintenance of the drainage network would further enhance the town's resilience to intense rainfall. Nevertheless, no practical drainage system can completely eliminate temporary flooding during exceptionally severe rainfall events.

The unified Sluice Drainage Coefficient Equation proved to be an effective engineering tool for quantifying the hydraulic capacity of New Amsterdam's drainage system and provides a practical framework for evaluating similar gravity drainage systems elsewhere in Guyana. Future studies should incorporate high-resolution rainfall intensity records, continuous water-level monitoring, and hydraulic modelling of the canal network to refine estimates of effective drainage capacity and improve flood prediction. Overall, this study provides the first scientific benchmark for assessing the drainage performance of New Amsterdam and offers an engineering basis for evidence-based planning, investment, and long-term flood risk reduction.

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The original printed copy of Lacey (1953) consulted in this study is held in the University of Guyana Library, Turkeyen Campus.

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APPENDIX: HYDROMET'S WEATHER BRIEF FOR JULY 18, 2024

HYDROMETEOROLOGICAL SERVICE
MINISTRY OF AGRICULTURE

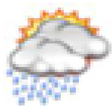
WEATHER BRIEF for Thursday, 18 July 2024, from the Hydrometeorological Service, Guyana-

Rainfall records for the past 24 hours, measured at 08:00hrs Thursday, 18 July 2024, were available for most stations. New Amsterdam in Region 6 recorded the highest rainfall of 113.2mm

Synopsis: Today The atmosphere over the forecast area continues to be moderately unstable due to the Inter Tropical Convergence Zone (ITCZ), and a tropical wave to the North of Guyana. Atmospheric moisture is not expected to have any significant, change for the remainder of the week, and early in the new week.

Today's Weather review: Partly cloudy to cloudy with occasional showers over regions 1, 10, and inland areas of region 4. In the other areas mostly sunny skies.

Table # 1 Weather forecast for the next Twenty-four hours

Thursday, July 18, 2024 (19:00 hrs. – 07:00 hrs.)			Friday, July 19, 2024 (07:00 hrs. – 19:00 hrs.)		
Regions	Not significant	**Cloudy to overcast skies with occasional to frequent showers, and rain over all regions.** **Winds: Light to Gentle Easterly-Southeasterly breeze.** **<u>Minimum temperatures:</u>** **Coast: 23 °C – 25°C** **Hinterland: 19 °C – 24 °C**	Regions	Weather Conditions	**Mostly cloudy skies with occasional to frequent showers and intermittent rain over all regions.** **Winds: Gentle to moderate Easterly to -Southeasterly breeze.** **<u>Maximum temperatures:</u>** **Coast: 29 °C – 32°C** **Hinterland: 29 °C – 33 °C**
Regions 1 to 10,	 **Rainfall is between 15.0 and 30.0 mm, the maximum over Region 7 and coastal areas**		**Region 1, 7, and 10, and Central Region 6**	 **Rainfall is between 20.0 and 40.0 mm, over.**	
			Elsewhere.	 **between 15.0 and 20.0 mm.**	

Georgetown's long-term daily average rainfall for the next 10 days, July 18 to July 27, 2024, is 7.5 mm per day.e

<u>Weather Warnings: None at this time.</u>

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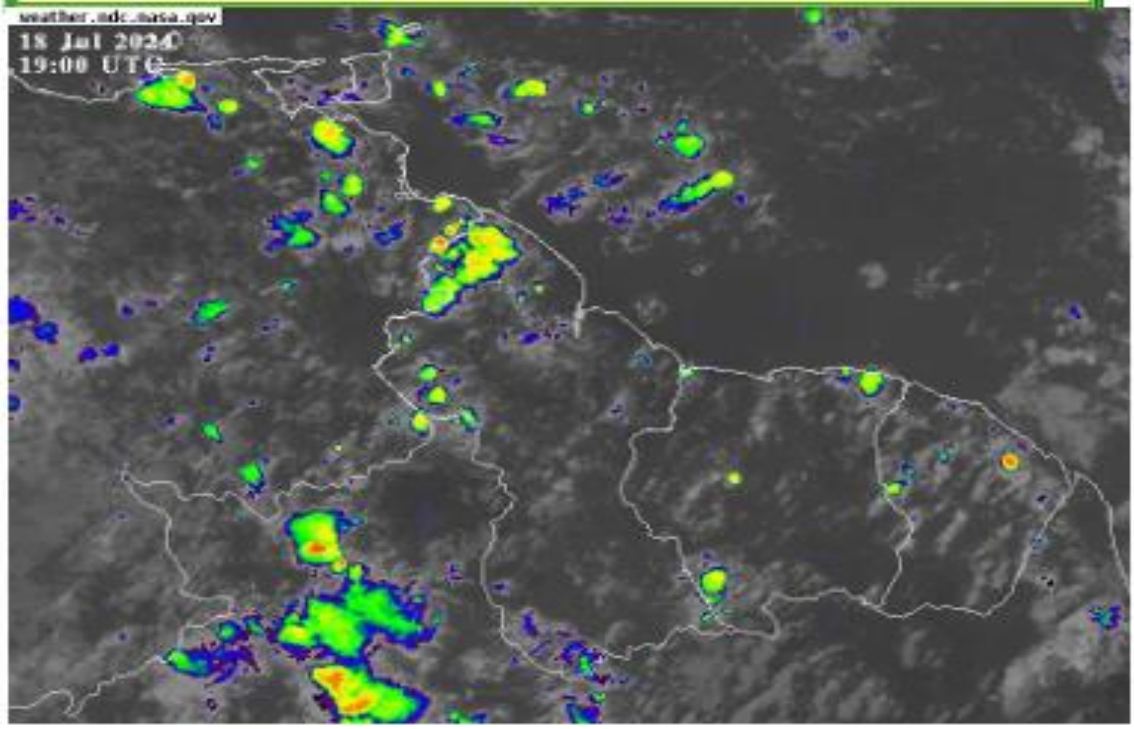

Infrared Satellite and Radar images are valid at 19:00 UTC (15:00hrs) on Thursday 18 July 2024.

Radar-generated precipitation estimates for 24 hours. Rainfall is valid for 08:00 hrs and 15:00 hrs. Thursday 18, July 2024. Not Available

Table # 2 Occurrences of high and low tides for the next 24 hours and the times for sunrise and sunset.

Tonight (July 18, 2024)	Tomorrow Morning (July 19, 2024)	Tomorrow Afternoon (July 19, 2024)
Low Tide: 20:01 Height 1.22 m	*High Tide 02:12 hrs Height 2.72 m SPRING TIDE IS NOT IN EFFECT* *Low Tide: 08:39 Height 0.67 m*	*High Tide 15:01 hrs Height 2.50 m SPRING TIDE IS NOT IN EFFECT*

Sunrise:	*05:44 hrs*	*Sunset:*	*18:11 hrs.*

SPRING TIDE ADVISORY: SPRING TIDE IS NOT IN EFFECT.

SEA CONDITIONS: SLIGHT TO MODERATE SEAS WITH EAST- SOUTHEASTERLY SWELLS REACHING HEIGHTS OF 1.5 TO 2.0 METERS (5 TO 7 FT)

-These waves will likely have periods of between 8 and 9 seconds.

Winds Light to Gentle East-Southeaserly breeze.

Extended Forecast:

Saturday: Cloudy to overcast skies with frequent showers, and continuous rain over inland regions. Elsewhere partly cloudy to cloudy skies with occasional showers and intermittent rain. Rainfall is between 20.0 and 40.0 mm, over inland regions Elsewhere, between 15.0 and 20.0 mm.

Sunday through Wednesday: Partly cloudy to cloudy skies in the early morning with occasional showers over regions 7 to 9, and coastal areas of regions 1 to 4. In the other areas, brief showers. For the remainder of the day, all regions can expect mostly cloudy skies with frequent showers and intermittent rain.

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Archived copies of cited *Daily Weather Briefs* are retained by the author (PDF downloads from the Hydromet's website: https://hydromet.gov.gy/weather/weather-brief/). These documents correspond to the dates referenced in the main text and contain the official daily rainfall, temperature, and forecast data issued by Hydromet.