# Glassblock /Bopoma Dam and Groundwater: Feasibility and Strategic Importance

Glassblock/Bopoma Dam Site September 2025

October 2025

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## Executive Summary

Bulawayo faces a persistent and worsening water crisis driven by declining dam yields, illegal mining in catchment areas, suppressed demand growth, infrastructure decay, and climate change. This feasibility and strategic assessment of the proposed Glassblock/Bopoma Dam (GBD) shows it is the most immediate and cost-effective solution to stabilise the city's water supply.

**Key Findings Of This Report:**

A. **Severe Shortages & Rationing:** Bulawayo currently endures up to 130 hours of weekly water outages, undermining public health, livelihoods, and social stability.
B. **Declining Dam Yields:** Actual yields are 34% below design capacity due to reduced rainfall, illegal gold mining, siltation, and poor catchment management. Inyankuni Dam receives only 6% of its intended inflows.
C. **Water Supply Costs:** Current Bulawayo dam water costs are USD 0.29/m³. Glassblock/Bopoma Dam will be 70 ML/day at USD 0.90/m³, raising the blended supply cost to USD 0.51/m³. By comparison, informal water vendors charge up to USD 12.50/m³.
D. **Glassblock/Bopoma Dam vs Gwayi-Shangani Dam:** Glassblock/Bopoma Dam can be completed in 3 years at USD 0.90/m³, while Gwayi-Shangani will take more than 10 years, at a cost of USD 2.47/m³, and requires a 252 km pipeline with a 500 m elevation lift.
E. **Groundwater Potential:** Nyamandhlovu and Epping Forest aquifers (design output 18 ML/day) currently deliver only 10 ML/day due to vandalism and poor maintenance. An additional 30 ML/day is possible from unproven aquifers, but costly and unsustainable without recharge.
F. **Population and Demand Outlook:** Bulawayo's population stagnated at +/-655,000 (2012–2022) due to water supply limits. Suppressed demand masks the true requirement, which could reach 465 ML/day if unconstrained. By 2050, demand could range from 114 ML/day (low growth) to 290 ML/day (high growth).
G. **Supply Gap:** Current conservative minimum supply is +/-155 ML/day. Without new infrastructure, Bulawayo faces a permanent deficit by 2040. Only large-scale projects (Glassblock/Bopoma Dam now, Gwayi-Shangani long-term) can close the gap.
H. **Strategic Importance:** Water insecurity constrains economic growth, deters investment, and risks urban decline. Immediate investment in Glassblock/Bopoma Dam, supplemented by aquifer protection, and medium-term reliance on Gwayi-Shangani pipeline, is critical to secure the city's future.

## Introduction By Senator David Coltart, Mayor Of Bulawayo

Bulawayo, Zimbabwe's second-largest city, stands at a critical juncture in its quest for water security. For decades, the city has endured chronic shortages, severe rationing, and the erosion of confidence in its ability to sustain both population growth and economic activity. Despite being the country's industrial hub and a regional centre of commerce, Bulawayo's progress has been systematically undermined by its fragile water supply system, much of which is dependent on aging dams whose yields have declined sharply due to siltation, illegal mining, inadequate catchment management, and the worsening impacts of climate change.

Water scarcity in Bulawayo is not simply an environmental challenge, it is a structural constraint on the city's growth, investment potential, and long-term viability. The absence of reliable water has suppressed urban expansion, deterred industrial development, and created a cycle of stagnation where demand has been artificially curtailed by crisis-driven rationing. With residents enduring outages of up to 130 hours per week, water insecurity has become not only a technical and financial issue but also a matter of public health, social stability, and political urgency.

This report presents a feasibility and strategic assessment of the proposed Glassblock/Bopoma Dam and associated pipeline, alongside a critical review of the role of groundwater in Bulawayo's water supply strategy. The analysis is anchored in historical and contemporary studies, including assessments by ZINWA, SWECO, BOSCH Stemele, ECA/Dorsch/BCHOD, and the World Bank, as well as recent Parliamentary inquiries. By consolidating these findings, the report highlights both the immediate imperatives and the long-term options available to secure Bulawayo's water future.

The central argument advanced here is twofold. First, the Glassblock/Bopoma Dam represents the most practical, least-cost, and fastest-to-implement solution to the city's current water crisis. With the potential to deliver 70 megalitres (ML) of water per day at a cost of USD 0.90 per cubic metre, and within a three-year construction timeframe, the dam offers a realistic opportunity to stabilise supply while other large-scale projects remain years away. Second, while groundwater resources, such as the Nyamandhlovu and Epping Forest aquifers, play an important supplementary role, they are neither sufficient nor sustainable on their own. Without urgent investment, rehabilitation, and protection of aquifer infrastructure, these resources will remain vulnerable to vandalism, over-extraction, and eventual depletion.

In doing so, the report situates Bulawayo's water challenge within broader demographic, economic, and climatic trends. With Africa projected to experience the fastest rate of urbanisation globally by 2050, and Zimbabwe's cities under increasing pressure to deliver reliable services, Bulawayo's trajectory will serve as a test case for how water security underpins urban resilience. The findings therefore extend beyond technical feasibility to address the strategic importance of securing water for livelihoods, industry, and sustainable growth.

Ultimately, this report underscores the urgent need for an integrated and sequenced water security strategy, the immediate construction of Glassblock/Bopoma Dam Dam, the upgrade of the Ncema works treatment facility and the Tuli reservoir, the rehabilitation and protection of groundwater resources, and the parallel development of long-term supply augmentation through projects such as the Gwayi-Shangani pipeline.

We need to identify and agree on the simultaneous construction phases.

**PHASE 1:** Construction of Glassblock dam and the water supply pipeline from Glassblock to the Ncema Pump Station.

**PHASE 2**: Upgrading Ncema Water Treatment Works and the treated water pumps which convey treated water to Tuli Reservoir to the south of the City. Double the capacity of Tuli Reservoir from 45ML to 90ML in order to store and distribute treated water to the east and northern suburbs of the City. As well as the increased volume of water which will be available through the construction of Glassblock Dam, the effective conveyance of this water to the City's reservoirs, some 60km away, is a vital component to ensure that the City benefits from the new dam. The completion of Phase 2 is therefore an integral component of the project. The Phase 1 and Phase 2 construction works, as described above, should take place simultaneously. This will ensure that after the construction of Glassblock Dam has been completed and after filling or partial filling of the dam in the first rainy season following construction, the necessary conveyance infrastructure has been constructed and commissioned to enable the City's residents and businesses to benefit from the increased volume of water from the new dam.

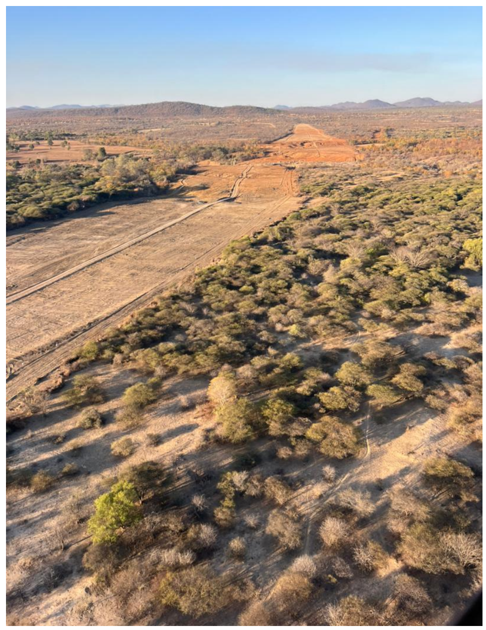
Without such a comprehensive approach, Bulawayo risks not only worsening shortages but also the erosion of its role as a dynamic urban and economic centre in Zimbabwe.

Senator David Coltart
Mayor Of Bulawayo

## 1. Compelling Reasons For Glassblock/Bopoma Dam And Pipeline

Water shortages, climate change, and siltation and river destruction from gold panning and dilapidated infrastructure, have reduced Bulawayo's dam yields. Residents currently experience extreme rationing (up to 120 hours weekly outages). Public health and social unrest risks are high. Glassblock/Bopoma Dam will offer 70 megalitres (ML) of water per day at USD 0.90 per $m^3$ and within 3 years as compared to Gwayi-Shangani (USD 2.47 per $m^3$, >10 years). Reliable water will anchor Bulawayo's economic revival. A growing population and increased water demand have increased the projected water requirements.

**Photograph 1: Glassblock/Bopoma Dam Site September, 2025**



## 2. References For Statements[1]

This section summarises key studies and reports on water yields, demand, and pricing.

### 2.1 ZINWA 2015 Dam Yield Analyses

ZINWA found actual dam yields to be 34% lower than designed due to reduced rainfall, catchment disturbances, and siltation. This can be attributed to a variety of reasons, but ultimately the yield of a dam is a direct function of the Mean Annual Runoff (MAR) or in a layman's terms "the water that runs off the land into the lake".

Inyankuni Dam has been particularly heavily affected by rampant illegal gold mining, which has destroyed its catchment area. As a result, it has only received inflows that

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[1] https://www.zimbabwesituation.com/news/alarm-over-major-city-dams-low-waterinflows/ accessed 8 June 2025

https://www.heraldonline.co.zw/bulawayo-faces-another-hiccup-amid-water-crisisdams-remain-critically-low-since-independence/ accessed 8 June 2025 equate to approximately 6% of its designed capacity. If and when the Bulawayo City Council and the Government curb illegal mining activities, rehabilitation of the tributaries and streams leading to these dams will be necessary and will be a lengthy and costly exercise.

The table below is extracted from the analysis done by ZINWA in 2015 and compares the design yield with actual yield of Bulawayo's water sources:

**Table 1: 2015 ZINWA Bulawayo Water Sources Analysis**

| Dam | Design Yield ML/day | Reviewed yields[2] ML/day |
|---|---|---|
| Lower & Upper Ncema | 55.3 | 36.0 |
| Mzingwane | 35.3 | 24.1 |
| Inyankuni | 21.8 | 11.0 |
| **Sub Total** | **112.5** | **71.0** |
| Insiza | 64.0 | 39.4 |
| Mtshabezi | 19.7 | 16.0 |
| **Sub Total** | **83.7** | **55.4** |
| | | |
| Aquifers | 10.0 | 10.0 |
| **TOTAL** | **206.2** | **136.4** |

### 2.2 Water Demand and Suppression

Bulawayo Population (2012: 655,675 | 2022: 655,952) shows stagnation linked to water limits. Studies projected unsuppressed demand of up to 465 ML/day by 2020. Suppression since 1996 masks true demand. If built now, Glassblock/Bopoma Dam would in fact only secure supply until 2040.

#### 2.2.1 Supposition: Bulawayo has not grown because it cannot provide water.

**2.2.1.1** Estimates shown in the studies below predict increases in water demand (population) between 2.5% (SWECO) and 2.0% (BOSCH) per annum.

**2.2.1.2** As studies are sequentially completed, the supply of water is suppressed: Predicted figures for 2020 are as follows:

I. 1989 ZINWA: 300ML per day plus in 2020[3]

[2] These are based on information available with ZINWA and in reports listed. This is believed to be a realistic assessment of water available to Bulawayo at 4% risk from their dams. Mtshabezi Pipeline delivery as advised by Catchment Manager.

[3] Bulawayo Matabeleland Zambezi Water Feasibility Study | SWECO September 1996 | *Page 20 of Chapter 4.*

II. 1996 SWECO: 465ML per day in 2020 (1996 is the year in which Glassblock/Bopoma Dam was originally planned to be built).[4]
III. 2012 BOSCH: 175ML per day in 2020. Off a suppressed base.[5]
IV. 2013 ECA: 145ML per day in 2020. Off a suppressed base.[6]

### 2.3 Water Pricing

Bulawayo dams (city-owned) are low cost (USD 0.29 per m³). Adding Glassblock/Bopoma Dam (70 ML/day @ USD 0.90 per m³) keeps the average to USD 0.51 per m³. The equivalent cost of purchasing water at USD0.25 per 20litre bucket is USD 12.50 per m³. In a "willingness to pay" survey carried out in a similar environment in Zimbabwe showed that consumers were willing to pay USD 1.32per m³ for water.[7]

Table 2: Bulawayo Dams

| Dam | ML/day | m³/day | price per m³ | Total cost USD |
|---|---|---|---|---|
| Upper and Lower Ncema | 36.0 | 36000 | 0.29 | 10,440.00 |
| Umzingwane | 24.1 | 24100 | 0.29 | 6,989.00 |
| Inyankuni | 11.0 | 11000 | 0.29 | 3,190.00 |
| Insiza | 39.4 | 39400 | 0.29 | 11,426.00 |
| Mtshabezi | 16.0 | 16000 | 0.29 | 4,640.00 |
| Aquifers | 10.0 | 10000 | 0.51 | 5,100.00 |
| GLASSBLOCK/BOPOMA DAM | 70.0 | 70000 | 0.90 | 63,000.00 |
| **Totals** | **206.5** | **206500** | | **104,785.00** |
| | | | Average price per m³ | 0.51 |

### 2.4 Gwayi-Shangani Dam

Gwayi Shangani dam is a long-term solution to providing Bulawayo with water as there is considerable infrastructure to be built before it can deliver water to Bulawayo. In addition, the cost of pumping the water to Bulawayo will be high due to the long distance (252 kilometres) from the dam to Bulawayo and the difference in height (the dam site is some 500 meters lower in altitude than Criterion Reservoir in

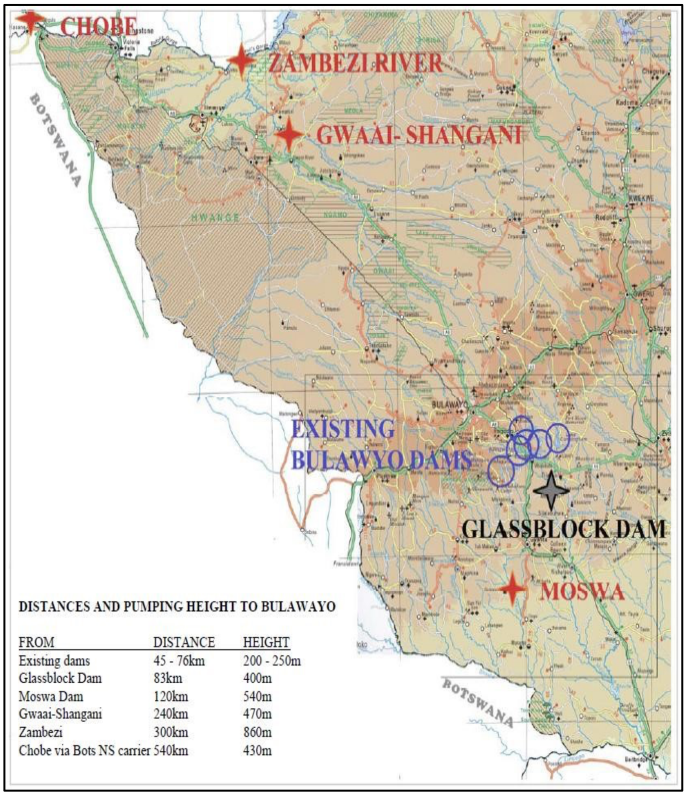
[4] Bulawayo Matabeleland Zambezi Water Feasibility Study | SWECO September 1996 | Figure 4.11.1 Water Demand Projections (Mm³/year)
[5] City Of Bulawayo Water and Wastewater Masterplan | Volume 2| Water Supply Master Plan Report | BOSCH STEMELE September 2012 | Figure 1 Present And Projected Future Water Demand & Available Water Resources
[6] Zimbabwe Water Sector Investment Analysis Summary Report | Economic Consulting Associates | World Bank | December 2013 | Figure 12 Supply Augmentation Options For Bulawayo
[7] Chitungwiza Water Willingness To Pay Survey | SESANI & Stewart Scott Zimbabwe | November 2017

Bulawayo). The cost of supplying this water is estimated by the ECA- World Bank report to be $2.47 per m$^3$ water.[8]

### 2.5 Dams Supplying Bulawayo With Water

The following is a map showing locations of the existing dams supplying Bulawayo with water, as well as Proposed Glassblock/Bopoma Dam, and Gwayi-Shangani, Zambezi, Chobe and Moswa Dam. The distances and heights are also listed.

Figure 1: Map Of Dams Supplying Bulawayo With Water




### 2.6 Devastating Effect Of Illegal Mining On All Of Bulawayo Catchment Areas

Bulawayo, depends on a network of dams located mainly in the Umzingwane catchment for its municipal water supply. Although rainfall in the 2023/2024 season was above average, the city has continued to experience critical water shortages. A key reason lies not in the volume of rainfall, but in the degradation of catchment areas caused by widespread illegal riverbed gold mining.

Over the past decade, artisanal and informal miners have turned the sandy riverbeds and tributaries feeding Bulawayo's dams into sites of uncontrolled excavation. This activity has destabilised river channels, stripped vegetation, and released vast amounts of loose sediment downstream. The result is severe siltation that has choked reservoirs and reduced their effective storage capacity. Inflows that should recharge dams are diverted

[8] Zimbabwe Water Sector Investment Analysis Summary Report | Economic Consulting Associates | World Bank | December 2013

into abandoned pits or lost through altered channels, while water quality has deteriorated due to increased turbidity and occasional contamination with mercury and other chemicals used in gold processing.

The impact is visible across the city's major supply dams: Umzingwane, Upper Ncema, Lower Ncema, Mtshabezi, Insiza, and Inyankuni. Several of these reservoirs have already been decommissioned because they can no longer hold or deliver usable water, leaving Bulawayo reliant on fewer, overstressed sources. Thus, despite favourable rains, the city finds itself in a prolonged water crisis.

Illegal riverbed mining has therefore transformed a climatic challenge into a structural crisis. Instead of being a temporary shortage linked to dry seasons, Bulawayo now faces a chronic supply deficit rooted in catchment degradation. Recognising this, government has moved to strengthen legal protections.

In November 2024, it enacted Statutory Instrument 188 of 2024 – Environmental Management (Control of Alluvial Mining) (Amendment) Regulations, 2024 (No. 3)[9].This instrument expressly prohibits alluvial mining in, on, or along rivers and floodplains and introduces the *Polluter Pays Principle*, obliging those responsible for catchment degradation to rehabilitate damaged ecosystems. Its provisions are directly relevant to Bulawayo's dams, as it targets the very practices undermining the city's water security. However, since the promulgation of the law there has been little enforcement of its provisions and widespread destruction continues.

**Photograph 2: A River On Bulawayo's Umzingwane Catchment Area Taken In September 2025**

[9] https://www.veritaszim.net/node/7288 accessed 22 September,2025.

### 2.6.1 Umzingwane Dam

Umzingwane has been repeatedly described by city engineers, parliamentary committees and research studies as the most heavily affected dam in Bulawayo's supply network. Illegal riverbed mining upstream has caused intense siltation, channel alteration and contamination risks (including reports of cyanide/mercury use), leaving the dam with negligible usable storage. Umzingwane was officially decommissioned in November 2023 after water levels fell to critically low (dead) levels and intake/pumping infrastructure was judged unreliable; the Senate and National Assembly Hansards record this decommissioning and the dam's near-zero storage[10].

Photograph 3: Umzingwane Catchment Area Taken In September 2025

### 2.6.2 Upper Ncema

Upper Ncema has experienced widespread alluvial panning along its upstream channels and immediate shoreline, producing siltation and damage to abstraction infrastructure (pumps and pipes). Multiple local reports and the Bulawayo City Council notice, record its critical condition[11].Upper Ncema was decommissioned in late Oct 2024, with very low remaining capacity (reported at less than 2%). This is listed in parliamentary/committee records as part of the city's loss of supply assets [12] . Police and council enforcement actions (arrests of panners at Upper Ncema) have been reported, but recurring re-entry of panners has been observed[13].

[10]https://www.parlzim.gov.zw/download/senate-hansard-10-june-2025-vol-34-no-52/ accessed 22 September, 2025

[11] https://miningzimbabwe.com/gold-panners-wreak-havoc-along-bulawayos-major-supply-dams/ accessed 22 September, 2025

[12] https://www.heraldonline.co.zw/upper-ncema-decommissioned-as-bulawayo-water-situation-worsens/ accessed 22 September 2025

[13] https://miningzimbabwe.com/gold-panners-wreak-havoc-along-bulawayos-major-supply-dams/ accessed 22 September, 2025

### 2.6.3 Lower Ncema Dam

Lower Ncema is suffering from siltation, poor inflows and risk of decommissioning. Parliamentary visits in 2024-2025 included Lower Ncema when assessing which assets were still usable for Bulawayo supply.[14]

### 2.6.4 Mtshabezi Dam

The Mtshabezi dam system is repeatedly named as a key remaining supply and as a catchment under pressure from riverbed panning. Reports highlight increased sediment loads from upstream panning and concerns about contamination and reduced inflows[15].

### 2.6.5 Insiza Dam

Insiza is one of the upland reservoirs subject to upstream panning or at least threatened by catchment degradation. Reports enumerate sediment increases, threat to intakes and heightened cost/security demands to keep panners away from critical infrastructure. Evidence in city reporting warns that upstream mining could undermine its reliability if not checked and rehabilitated[16]

### 2.6.6 Inyankuni

Inyankuni is another dam with documented panning activity on its inflows and immediate catchment. Press reporting and council statements list it among the dams affected by siltation and illegal panning. Continued panning in Inyankuni's catchment area threatens the system redundancy Bulawayo relies on[17].

## 3. Previous Water Demand Assessments

The last report using raw data (as opposed to using data from existing reports) is the ECA report done in 2013. However, Bulawayo's population (according to the census) has not grown (between 2012 and 2022) and no further water supply has been added to Bulawayo since Mtshabezi Dam in 1994. So, information in these reports is still valid.

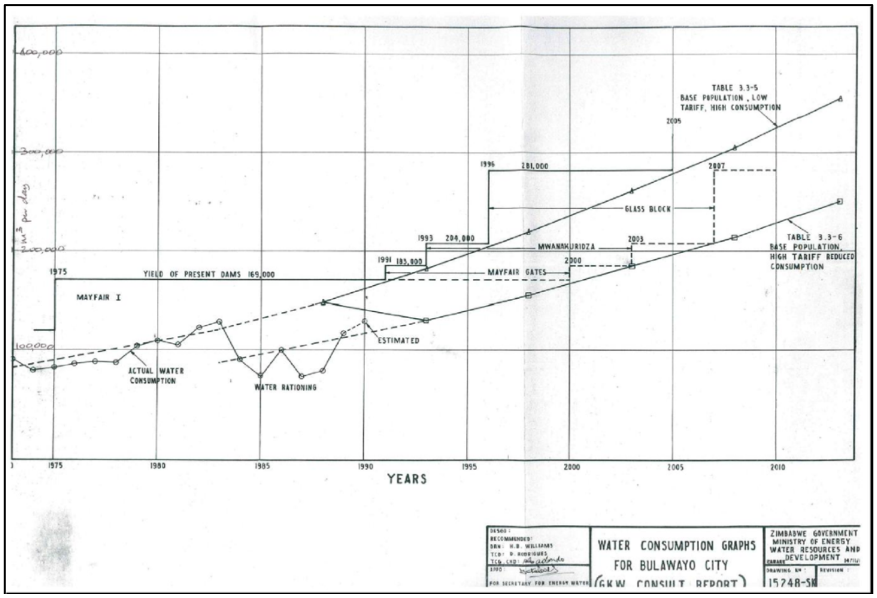
## 4. ZINWA 1989

This graph represents the Zimbabwe Government Ministry of Water (at the time) long term plan for water supply to Bulawayo. It clearly shows that Glassblock/Bopoma Dam is the next resource to be developed.

**This predicted that with Glassblock/Bopoma Dam, Bulawayo would have 281ML of water per day.**

[14] https://www.parlzim.gov.zw/download/senate-hansard-10-june-2025-vol-34-no-52/ accessed 22 September, 2025
[15] https://miningzimbabwe.com/gold-panners-wreak-havoc-along-bulawayos-major-supply-dams/ accessed 22 September, 2025
[16] https://opencouncil.co.zw/the-state-of-water-supply-in-bulawayo-parliament-report/ accessed 22 September, 2025.
[17] https://www.parlzim.gov.zw/download/senate-hansard-10-june-2025-vol-34-no-52/ accessed 22 September, 2025

Figure 2: Graph Representing 1989 ZINWA Water Plan[18]

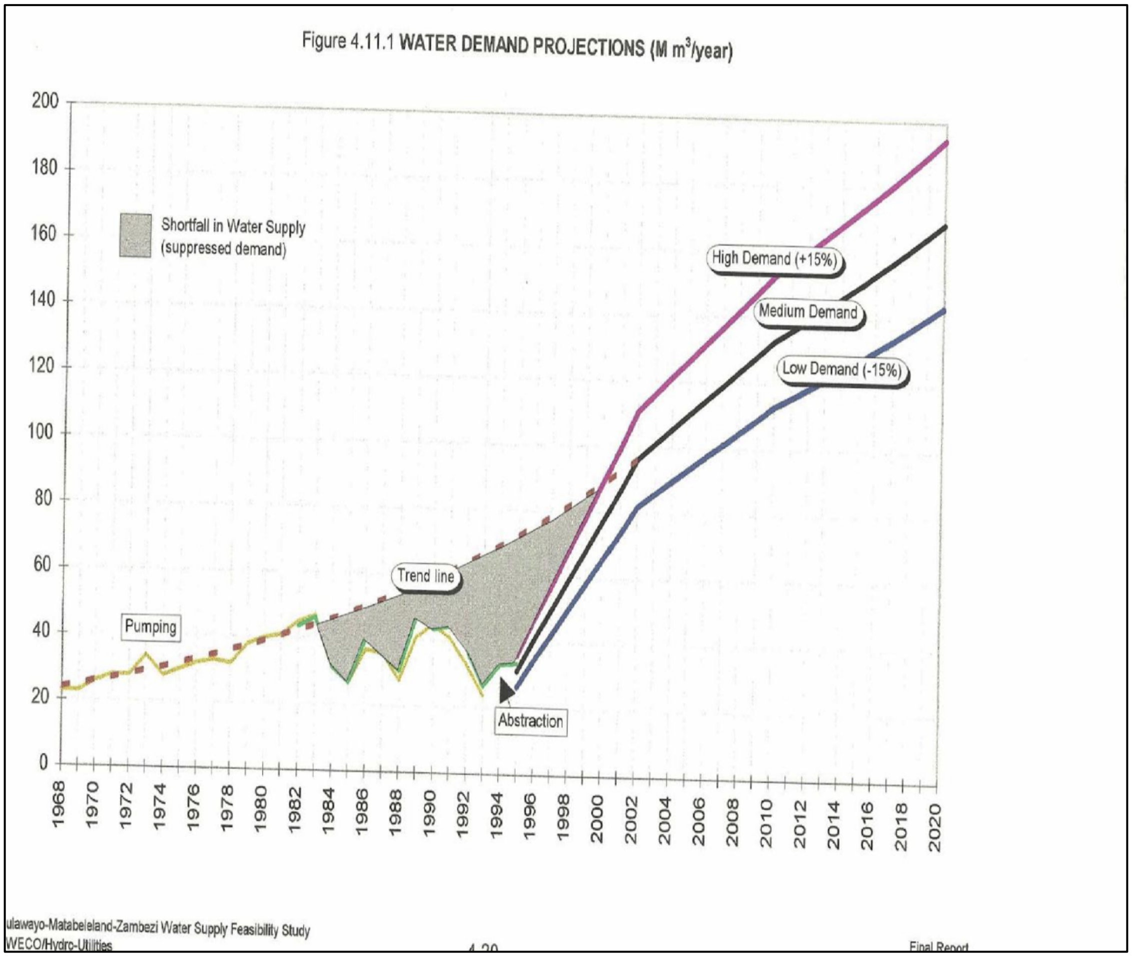



## 5. SWECO September 1996

This study was commissioned by Matabeleland Zambezi Water Trust to prepare a water resources development plan for Bulawayo and Mat North using water from the Zambezi. As part of the report, they analysed Bulawayo's water demand. It projected Bulawayo's unsuppressed daily demand in 2020 to be about 440ML of water per day.

[18] Bulawayo Matabeleland Zambezi Water Feasibility Study | SWECO September 1996 | *Page 20 of Chapter 4.*

Figure 3: Water Demand Predictions



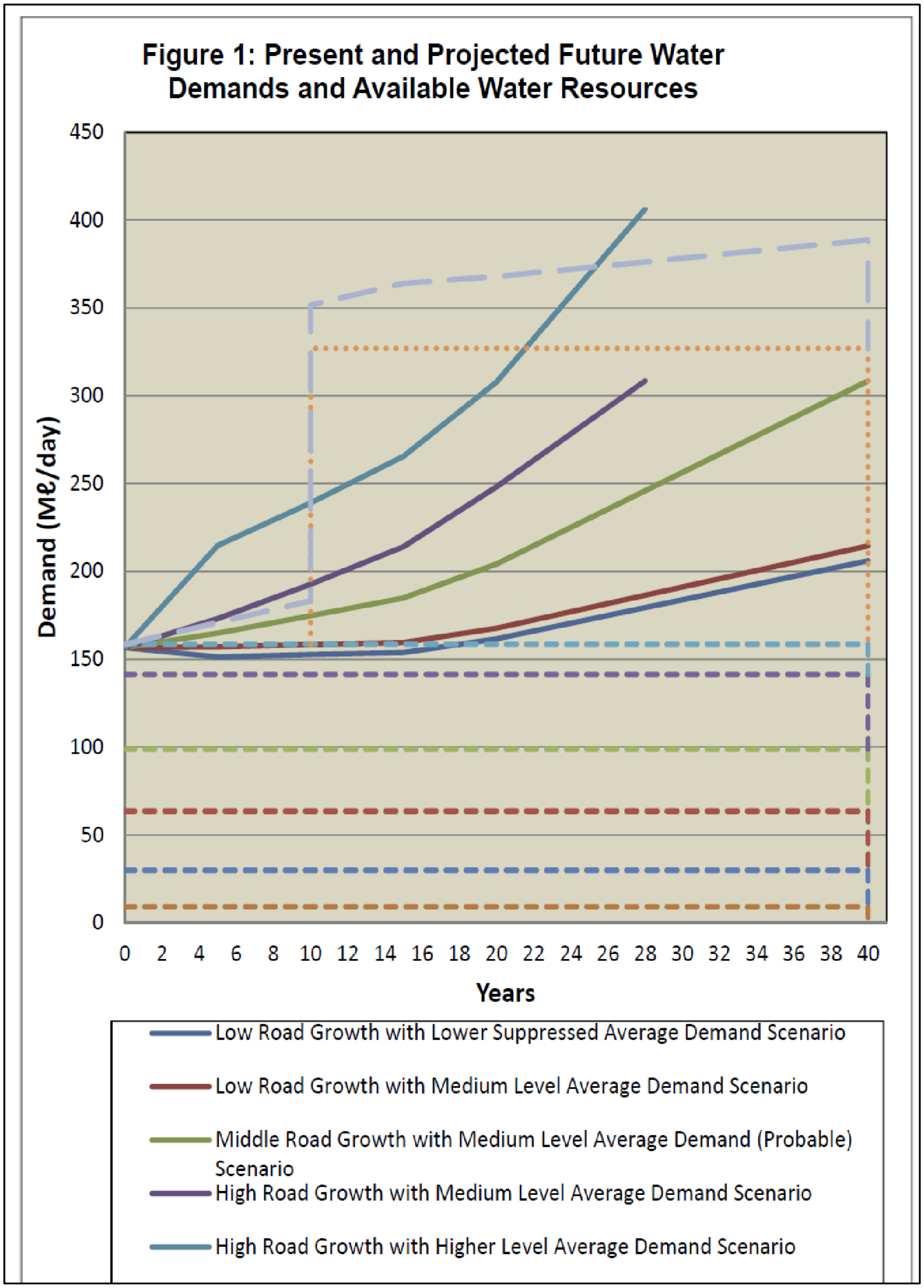

## 6. BOSCH Stemele September 2012

This project was commissioned by The City of Bulawayo to develop a Master Plan for water and wastewater services for the City of Bulawayo.

As part of the report, they analysed Bulawayo's water demand. This graph is from Volume 2 Page 17.

It projected Bulawayo's unsuppressed daily demand in 2030 to be about 260ML of water per day.

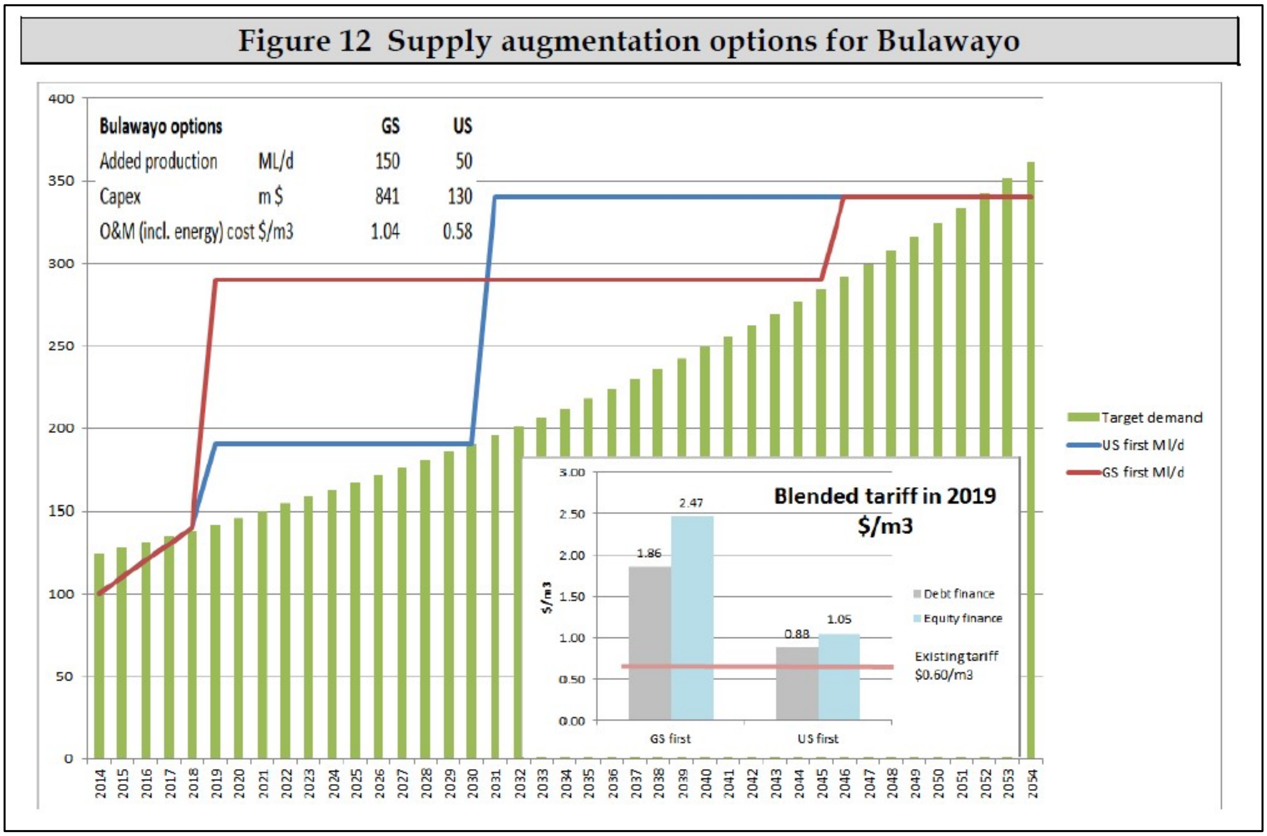
Figure 4: Present and Projected Future Water Demands and Available Water Resources




## 7. ECA/Dorsch/BCHOD December 2013

This study was commissioned by the World Bank to prepare a water sector analysis report to contribute to and support Zimbabwe Government Water Sector Investment Strategy. Bulawayo's water demand was predicted to be 190ML of water per day in 2030.

**Figure 5: Supply Augmentation Options For Bulawayo**




## 8. The State Of Bulawayo Groundwater

Ground water for Bulawayo exists but it should only be abstracted at the rate at which natural runoff replenishes it.

The design output from the Nyamandhlovu and Epping Forest Aquifers is 18ML/day but the present contribution from the aquifer to Bulawayo's Water Supply presently averages less than 10ML/day (This is small compared to GBD which will produce 70ML/day and is relatively low risk to operate).[19]

Undeveloped aquifers could potentially yield up to 30ML/per day, but these are unproven, and may have expensive pumping costs.

Well-field equipment is prone to theft and vandalism of pumps and lack of maintenance.

[19] Parliament Of Zimbabwe Report By The Joint Portfolio Committee On Local Government, Public Works, National Housing And The Thematic Committee On Sustainable Development Goals On The State Of Supply Water In Bulawayo | 11 June 2025

## 8.1 Historical & Technical Studies

### 8.1.1 Kabell, E. T. (1989). Bulawayo Water Supply: Future Sources for Development. Harare: DWD annual Conference. (ZINWA)

Page 6, article 8 is as follows:
*8. Miscellaneous Options*
*a) Groundwater.*
*The Nyamandlovu acquifer is about 60km from Bulawayo, and at present is used for agricultural purposes. A field study completed in 1977 calculated the neutral recharge of 400km*$^2$ *of the aquifer as 8000ML*[20] *per year. If this could be fully exploited by a large number of deep, large diameter boreholes, it could make some contribution to the Bulawayo water supply, but at the expense of losing present agricultural production. Further field studies of the acquifer are planned.*

**Photograph 4: Glassblock/Bopoma Dam Site September 2025**

### 8.1.2 SWECO. (September 1996). The Bulawayo-Matabeleland-Zambezi Report. Harare: SWECO/Hydro Utilities

This Feasibility Study analyses the existing water supply conditions and presents a water resources development plan to meet the water supply requirements of the City of Bulawayo and Matabeleland North along the pipeline corridor for the next 25 years.
Page ES8, item No 0.2.2 notes that:

[20] 8000ML per year equates to 21ML/day. And this is the total potential yield, including for agriculture.

*The pre-feasibility study established a close relationship between the distance of the source to Bulawayo and the cost of the water. The closer to Bulawayo, the lower the cost…. Recommends that the necessary groundwater studies should be carried out simultaneously with this Feasibility Study to determine the potential of this source of water.*

This study was carried out by Martinelli and reults are in the next seciton. In this SWECO study they only mention groundwater as a source to be investigated, but do not quantify it or take it into account when calculating water supply parameters to Bulawayo.

**8.1.3 Martinelli. (1996). Consultancy services for geophysical and hydrogeological investigations, aquifer modelling and monitoring of the Nyamandhlovu Aquifer. Bulawayo: Lamont**

This study was commissioned by the Danish Embassy though DANIDA on behalf of DWR (ZINWA) to quantify the resources of the Nyamandhlovu aquifer, and to evaluate the potential of the aquifer for further exploitation and to minimise conflict between existing agricultural abstraction and the DWR abstraction

*Page iv Item 7 Aquifer Model states that*

*The agricultural Community abstracts 6,600 $m^3$/day and that: Abstractions by DWR should be pegged at 12,000 $m^3$/day (this is 12ML per day)*
*Page vi item 9 Future Development states that*
*Further investigations must be made to extend expoitation of the Nyamandhlovu aquifer further to the northwest towards Sawmills, preferably between the railway line and the Bulawayo/Victoria Falls road.*

*No further development can be considered in the area of intensive agricultural abstraction and DWR wellfield.*

*The southern part of the study area, which comprises the periphery of the Karoo Basin is unsuitable for wellfield development.*

**8.1.4 Danielson. (2007:15 ). Geophysical and hydrogeologic investigation of groundwater in the Karoo stratigraphic sequence at Sawmills in northern Matabeleland, Zimbabwe: a case history. *Hydrogeology Journal*, 945–960**

Geophysical and hydrogeological investigations have been carried out around Sawmills in Zimbabwe. The investigations are components of a larger investigation to assess the groundwater potential of the Karoo sedimentary basin with regards to supplying water to Bulawayo City. The sustainable yield of the Sawmills acquifer is estimated to be 0.5 ML/day.

**8.1.5 Stemele, B. (2012). City of Bulawayo Water and Wastewater Masterplan. Bulawayo: City of Bulawayo**

As part of the twinning arrangement between Ethekwini Municipality (i.e. City of Durban) and the City of Bulawayo (CoB), Ethekwini Water and Sanitation (EWS) officials visited Bulawayo at the end of 2009 to assess the status of water and waste water systems.
*On page 23, Item 11.2, they state that*

*Borehole Supply from Nyamandlovu Aquifer: Due to maintenance problems and power supply interruptions associated with the 77 no. boreholes in the Nyamandlovu Aquifer, the full potential supply of 16 ML/day from this source is not being fully realised. It is recommended that CoB engage with ZINWA and ZESA to ensure that the boreholes which are currently not operational due to maintenance problems and power supply limitations, are brought back into service. The sustainable yield from the Nyamandlovu borehole Aquifer has been taken as 9 ML/day*

**8.1.6 Morris, E. P. (July 2014). Options to improve the security of Bulawayo's water supply. Harare: World Bank**

This Presentation is an updated version of a presentation made to Bulawayo in February 2014 and examines water supply options available to the City. It includes material on ground water provided by Dr Richard Owen.

In the report they estimate that there could be an additional 30ML/day water from new underground sources of water, noting that these are ancient sources of water. i.e. not rechaged by annual runoff.

*These sources remain to be investigated.*

**8.1.7 World Bank Water Sector Mission to City of Bulawayo February 2013**

Clause 55 states that the reliable yield of Nyamandlovu Acquifer is 12ML/day.
Clause 56 states that Epping Forest wellfield has potential to deliver 10ML/day.
Clause 64 says that there are good ground water prospects north of Bulawayo, but they are far – 50km, 150km and 175km from the City(GBD pipeline is 34km). There is likely to be a significant head difference as well, so pumping and operating costs will be high.

**8.1.8 The state of water supply in Bulawayo: Parliament Report dated 11th June 2025:**

*4.2.3 Nyamandlovu Aquifer*
*The Committee gathered that the aquifer was established during the 1991-92 drought season as an emergency measure to supply water to the City of Bulawayo. It was developed alongside the Rochester Water System, with a design capacity to deliver 18 mega liters of water per day. The aquifer consists of 40 installed boreholes, of which only 23 are currently operational, representing 58% of its total capacity. However, out of the 23 functional boreholes, six have been rendered inactive due to vandalism, primarily from*

*stolen electrical transformer cables. Due to vandalism, only 17 boreholes were fully operational within the Rochester system. The boreholes were sunk 200 meters apart. The Rochester Pumping Station is equipped with two storage tanks, each with a capacity of 2,880 cubic metres, from which water is pumped to supply the City of Bulawayo. The Committee found out that the City was only receiving on average 10 megalitres of water per day, way below the aquifer's current potential supply capacity of 18 megalitres per day. Vandalism of infrastructure was identified as the chief culprit on the reduced water supply capacity in Nyamandlovu and Epping Forest.*

## 9. Bulawayo's Population Growth Projections And Water Needs[i]

Africa is set to experience the world's strongest urban expansion over the next three decades. According to the UN's World Urbanization Prospects (WUP) 2018, nearly 90% of the increase in the world's urban population to 2050 will occur in Asia and Africa, with Africa's contribution rising sharply. The continent's share of the global urban population is projected to grow by more than 70%, from about 13% in 2018 to 22% by 2050. In absolute terms, the UN projects roughly 1.5 billion urban dwellers in Africa by mid-century—nearly triple its 2018 urban total.

This surge reflects two reinforcing dynamics highlighted by the UN:

I. overall population growth
II. a steady rise in the proportion of people living in urban areas. While Africa was "mostly rural" in 2018 (about 43% urban), the trajectory to 2050 is decisively urban, driven by natural increase within cities, rural-to-urban migration, international migration, and the reclassification of formerly rural settlements as they densify. Globally, the UN expects the urban share to climb from 55% in 2018 to 68% in 2050, a shift that increasingly centres future population growth in cities—especially in lower-income regions such as Africa.

Country contributions within Africa will be highly concentrated. Nigeria, for example, is projected to add about 189 million people to its urban areas between 2018 and 2050, making it one of the three largest national drivers of global urban growth (alongside India and China). The Democratic Republic of the Congo is also among a small group of countries each expected to contribute more than 50 million additional urban residents over the period.

City size classes will continue to diversify. The UN notes that Africa's roster of very large cities is expanding: by 2030, Dar es Salaam and Luanda are projected to join Cairo, Kinshasa, and Lagos as African megacities (with over 10 million people). The number of "large cities" (5–10 million) in Africa is expected to rise from five in 2018 to thirteen by 2030. These trends indicate a widening pyramid of urban agglomerations, from many fast-growing secondary cities to an expanding set of megacities that will anchor national urban systems through 2050.

The planning implications are clear. Because urban growth will be fastest where fiscal and administrative capacities are often thinnest, sustainable development outcomes will hinge on how effectively African countries manage land, housing, basic services, jobs, and climate risk. The UN stresses that integrated policies are essential to harness the demographic and economic dividends of urbanization. Finally, the scale of change is framed by broader population prospects: sub-Saharan Africa's total population is expected to almost double by the late-2040s, intensifying the urban pull and the urgency of sound city governance and investment.

### 9.1 Implications for Urban Water Demand and Management

The rapid urban population growth projected for Africa has profound implications for urban water demand, access, and management. The main impacts can be summarized as follows:

#### 9.1.1 Sharp Increase in Total Water Demand

I. Africa's urban population is expected to nearly triple between 2018 and 2050 (from about 548 million to over 1.5 billion). This means hundreds of millions more urban residents will require water for drinking, sanitation, food preparation, and industry.
II. The UN World Water Development Report 2023 projects global freshwater demand to rise by 20–30% by 2050, with the steepest growth in Africa due to demographic and urbanization pressures.
III. Municipal water demand in African cities will therefore expand far faster than in most regions, especially in large economies such as Nigeria, Ethiopia, Tanzania, Egypt, and the DRC.

#### 9.1.2 Growing Demand–Supply Gap

I. Currently, about 400 million Africans already lack access to basic drinking water services. Rapid urbanization will enlarge this gap unless infrastructure investment accelerates.
II. Many African cities already face "chronic water stress," where infrastructure is underdeveloped, water sources are degraded, and climate change reduces reliability. The increase in demand will intensify pressure on already stressed aquifers and rivers.

#### 9.1.3 Infrastructure Strain in Megacities

I. By 2030-2050, megacities like Lagos, Kinshasa, Dar es Salaam, Luanda, and Cairo will require massive expansion of piped water networks, wastewater treatment, and stormwater management.

II. Without such investment, informal settlements—which absorb much of the new urban population—will continue to rely on unsafe or costly informal water markets, deepening inequality.

### 9.1.4 Climate Change Multiplier

I. The UN projects that water-related climate risks (droughts, floods, erratic rainfall) will disproportionately affect Africa's fast-growing cities.
II. Drought-prone regions (Horn of Africa, Southern Africa, Sahel) may see acute water scarcity, while coastal megacities (Lagos, Dar es Salaam) face saltwater intrusion and flood risks that threaten freshwater sources.

### 9.1.5 Economic and Governance Challenges

I. Rapid urbanization without proportional investment in water infrastructure risks undermining health, productivity, and economic growth.
II. Urban water security is central to achieving SDG 6 (clean water and sanitation) and SDG 11 (sustainable cities) in Africa. This requires governance reforms, better financing, and regional water-sharing agreements.

### 9.1.6 Projected Outlook by 2050

I. Africa's urban water needs will at least triple. In some megacities, demand may rise fivefold if per capita consumption increases alongside incomes.
II. Unless investment and planning catch up, the UN warns of a future where urban water scarcity and inequality worsen, fueling health crises, food insecurity, and social instability.

Table 3 summarises the current water situation in Bulawayo. While precise future projections (e.g., to 2050) would require more modeling, this table captures the latest actual data to give insight into existing demand and infrastructural dynamics:

Table 3: Current Water Situation In Bulawayo

| Metric | Status / Figure | Notes & References |
|---|---|---|
| Population (2025) | 690,000 | Census 2022: 655,952; projected 2025 mid-growth [ZINWA 2015; Parliament Report 2025] |
| Daily Required Water (Unrestricted Demand) | 145–190 ML/day (suppressed); true demand > 260 ML/day | Historic studies: SWECO (1996), BOSCH (2012), ECA/World Bank (2013) |
| Currently Pumped Supply (2025) | 136 ML/day | ZINWA 2015 dam yield reassessment |
| Per Capita Use (Estimated) | 160–190 L/person/day | Based on 136 ML/day ÷ 690k people |

| Metric | Status / Figure | Notes & References |
|---|---|---|
| Council Rationing (High-Density Areas) | Water once every 5–7 days (120 hrs weekly outages) | Bulawayo City Council reports, 2025 |
| Council Rationing (Low-Density Areas) | Water every 2–3 days | BCC reports, 2025 |
| WHO Benchmark | 100 L/person/day minimum | WHO Water, Sanitation and Hygiene Standards |
| Dam Levels (2025) | Operating at 66% of designed yield (206 ML/day vs 136 ML/day) | ZINWA 2015 reassessment |
| Infrastructure Constraints | Illegal mining, siltation, vandalism of pumps, no new dam since 1994 | Parliament Report 2025, World Bank studies |

## 10.Bulawayo Projected Outlook

This table below presents a critical long-term forecast of Bulawayo's water situation, modelling the relationship between population growth, water demand, and potential supply scenarios through 2050. The data tells a clear story: without significant and sustained investment in its water infrastructure, Bulawayo is on a path toward a severe and escalating water deficit as its population grows.

### 10.1 The Driving Force: Population Growth

The forecast begins with three population growth scenario low, medium, and high to account for different demographic possibilities. In all scenarios, the population is projected to increase steadily. By 2050, the city's population is estimated to be between 766,000 (low growth) and nearly 1.2 million residents (high growth). This inexorable rise in population is the primary driver of the escalating water demand projected over the next 25 years.

### 10.2 Escalating Water Demand

The table calculates future water demand based on three different per capita consumption rates: a conservative 150 litres/day, a moderate 200 litres/day, and a higher 250 litres/day. The combination of population growth and varied consumption rates reveals a wide range of possible demand futures:

I. Even under the most conservative assumptions (low population growth and 150 L/day consumption), daily water demand is projected to climb from 101.4 ML/day in 2025 to 114.9 ML/day by 2050.
II. In a high-growth, high-consumption future, the demand escalates dramatically, rising from 176.7 ML/day in 2025 to a staggering 289.8 ML/day by 2050. This represents a more than 60% increase in water demand over the period.

### 10.3 The Core Conflict: A Growing Gap Between Demand and Supply

The most critical insight comes from comparing the escalating demand against three static supply scenarios:

I. **Conservative Supply (155 ML/day):** This figure likely represents the city's current or near-future operational capacity, factoring in existing infrastructure limitations. The table shows that demand is projected to exceed this supply level relatively quickly. By 2040, even a medium population growth with moderate consumption (165.1 ML/day) would create a deficit. By 2050, under a high-growth scenario, the city could face a daily water shortfall of nearly **135 ML**, creating a permanent state of crisis.

II. **Medium Supply (225 ML/day):** This scenario may represent a future where planned upgrades and some new projects are successfully implemented. While this level of supply provides a buffer for the medium term, it is not a permanent solution. By 2040, a high-growth, high-consumption scenario (237.8 ML/day) would already surpass this capacity. By 2050, the city would once again face a significant deficit under multiple medium and high-growth scenarios.

III. **Optimistic Supply (445 ML/day):** This highly ambitious scenario likely represents the successful completion of major, long-term water augmentation projects, such as the Gwayi-Shangani pipeline. According to the table's projections, achieving this supply level would secure Bulawayo's water future through 2050, as it comfortably exceeds even the highest projected demand of **289.8 ML/day**.

Table 4 serves as a stark warning and a strategic planning tool. It demonstrates that maintaining the status quo (Conservative Supply) is unsustainable and will lead to a chronic water crisis. Moderate improvements (Medium Supply) will only delay the inevitable deficit. The data powerfully argues that long-term water security for Bulawayo is entirely dependent on the successful, timely, and large-scale implementation of major infrastructure projects capable of delivering a supply aligned with the “Optimistic” scenario. Failure to bridge this projected gap between demand and supply will severely constrain the city's growth, impact public health, and undermine its economic stability.

Table 4: Projected Water Needs For Bulawayo

| Year | Pop (low / med / high) | Demand @150 L | Demand @200 L | Demand @250 L | Supply — conservative | Supply — medium | Supply — optimistic |
|---|---|---|---|---|---|---|---|
| 2025 | 676k / 690k / 707k | 101.4 / 103.5 / 106.0 | 135.2 / 138.0 / 141.3 | 169.0 / 172.6 / 176.7 | 155 | 225 | 445 |
| 2030 | 693k / 733k / 780k | 104.0 / 109.9 / 117.0 | 138.6 / 146.5 / 156.1 | 173.3 / 183.2 / 195.1 | 155 | 225 | 445 |
| 2040 | 728k / 825k / 951k | 109.2 / 123.8 / 142.7 | 145.6 / 165.1 / 190.2 | 182.0 / 206.4 / 237.8 | 155 | 225 | 445 |
| 2050 | 766k / 930k / 1,159k | 114.9 / 139.5 / 173.9 | 153.2 / 186.0 / 231.9 | 191.4 / 232.5 / 289.8 | 155 | 225 | 445 |

## 11. Conclusion

The feasibility and strategic review of Bulawayo's water supply confirms that the city faces a mounting crisis driven by inadequate dam yields, suppressed demand growth, vandalism of infrastructure, and climate pressures. Current supply levels (136 ML/day) are insufficient to meet unconstrained demand, which could exceed 260 ML/day and rise further by 2050. Severe rationing has masked the scale of demand but has also stifled population and economic growth.

Glassblock/Bopoma Dam emerges as the least-cost, fastest-to-deliver intervention, capable of supplying 70 ML/day within three years at USD 0.90 per cubic metre. This project offers immediate relief and can anchor Bulawayo's short- to medium-term water security. Groundwater, while an important supplement, remains insufficient on its own and is plagued by sustainability and infrastructure challenges. The long-term strategy must include the Gwayi-Shangani Dam and pipeline, despite its higher cost and extended timeframe.

An integrated water security plan for Bulawayo is therefore essential: deliver Glassblock/Bopoma Dam urgently, secure and rehabilitate aquifers, and advance the Gwayi-Shangani project for the future. Without these measures, Bulawayo risks deepening shortages, public health crises, and constrained economic development.

## Appendix 1: Summary Of Notes On Bulawayo Groundwater – Tim Broderick (2025)

Tim Broderick's (2025) "Notes on Bulawayo Groundwater" provides a contemporary overview of the geology, hydrogeology, and management challenges of Bulawayo's groundwater systems. The report emerges from discussions between municipal officials, including the Mayor of Bulawayo, and technical experts, and critically assesses recent claims regarding the potential of deep drilling as a sustainable solution to the city's water crisis. It situates Bulawayo's groundwater within the context of regional geology and draws on over a century of technical work and observations.

The city of Bulawayo is underlain largely by the Bulawayo Greenstone Belt, a complex of metamorphic and igneous rocks surrounded by granite intrusions of various ages (Garson, 1991). These "hard rock" environments contain limited groundwater storage capacity, with aquifers generally confined to the upper weathered and fractured zones. Recharge occurs primarily through direct rainfall infiltration, and the fresh bedrock below is largely impermeable, containing only occasional water-bearing fissures. Given the area's semi-arid climate and low average annual rainfall of approximately 650 mm, the aquifers experience limited recharge, and the sustainability of groundwater extraction is a persistent concern.

Broderick (2025) notes that groundwater abstraction has intensified since the 1992 drought, with deeper boreholes-often exceeding 100 metres-being drilled to chase water at depth. This has led to "groundwater mining," where abstraction rates exceed natural recharge, causing local water table declines. While some areas within the greenstone belt yield relatively successful boreholes, others in the granitic terrain show variable and often poor performance. Monitoring of water levels and water quality remains essential to maintaining borehole viability, particularly in high-density western suburbs where groundwater serves as a community resource.

The report highlights the Nyamandhlovu Aquifer, situated about 40 kilometres north of Bulawayo, as the most significant external groundwater source. First developed during the 1992 drought, this semi-confined sandstone aquifer (Beasley, 1984) has provided critical supplementary water to the city. Managed by ZINWA and the Bulawayo City Council, the aquifer has experienced operational difficulties due to over-pumping, vandalism, and unreliable electricity supply. Rehabilitation initiatives supported by GIZ (2015) and other partners have sought to restore yields through borehole recommissioning, submersible pump installations, and enhanced monitoring. Further exploration at Epping Forest has aimed to expand the wellfield, using deeper boreholes with wire-wound screens to tap higher-elevation zones of the Forest Sandstone aquifer system.

Broderick situates Bulawayo's groundwater history within a wider national context, referencing the work of the Zimbabwe Railways hydrogeologists who, during the midtwentieth century, secured key water supplies along the Bulawayo–Dett railway line (Bond & MacDonald, 1962; MacDonald, 1970). These efforts established a legacy of deep borehole development in Karoo and post-Karoo sedimentary formations, notably at Sawmills, Gwaai, and Intundhla. Subsequent studies by SWECO (1995; 1996) and Danielsen et al. (2007) expanded on these findings, identifying the post-Karoo sediments and Forest Sandstone as promising targets for sustainable groundwater development.

In his conclusion, Broderick (2025) cautions against unverified claims by private firms promising 100% success in deep drilling. He emphasises that Bulawayo's geology is complex and differs markedly from sedimentary basins like the Kalahari or Namib, where such success rates might have been observed. Instead, he advocates for a scientifically rigorous, phased approach to groundwater exploration—particularly along the Gwayi–Shangani corridor, where the Forest Sandstone and overlying formations show potential for sustainable yields. Properly designed geophysical surveys, test drilling, and aquifer analysis are necessary to refine understanding of these systems. Ultimately, Broderick's analysis underscores the need for continued hydrogeological research, sustainable abstraction practices, and integration of groundwater resources within Bulawayo's broader water supply planning framework.

## Appendix 2: Summary Of Groundwater Resource Evaluation Of Urban Bulawayo Aquifer – Rusinga & Taigbenu (2005)

Rusinga and Taigbenu's (2005) landmark paper, published in Water SA, presents a detailed hydrogeological and numerical analysis of the Matsheumhlope well-field-the main urban aquifer underlying Bulawayo. Conducted under the auspices of the CSIR and the National University of Science and Technology (NUST), the study was motivated by the city's chronic water shortages, especially following the 1991–1992 drought. The authors aimed to quantify groundwater potential, recharge mechanisms, abstraction rates, and sustainable yields through field data, pumping tests, and computational modelling.

The study begins by outlining the hydrological challenges facing Bulawayo, a city located in a semi-arid region frequently affected by droughts. Historically, the Bulawayo City Council (BCC) relied heavily on surface reservoirs located 45 kilometres southeast of the city. However, during extreme dry periods, the council resorted to emergency groundwater abstraction from the Matsheumhlope well-field and the Nyamandhlovu aquifer (Rusinga & Taigbenu, 2005). The authors identify the lack of a systematic groundwater management policy as a key limitation that has led to unregulated borehole drilling and uncertain abstraction data.

Hydrogeological investigations revealed that the aquifer is predominantly unconfined and hosted within weathered and fractured metavolcanic rocks of the Upper Greenstones, consisting mainly of metabasalts and mafic sills. Pumping tests conducted on 18 boreholes confirmed moderate aquifer properties, with hydraulic conductivity values ranging from 0.1 to 2.09 metres per day and specific yield between 0.02 and 0.11. These characteristics suggest a relatively low-yield but sustainable groundwater system if managed properly.

Recharge to the aquifer was estimated using a water balance approach. The study calculated a total annual recharge of approximately 105.5 mm, derived from three main sources: direct rainfall (38.4%), water mains leakage (52.1%), and sewer leakage (9.5%). The predominance of recharge from leaking infrastructure underscores the urban nature of the aquifer system. The authors caution that improvements in the city's water distribution system-if not accompanied by groundwater management reforms-could inadvertently reduce aquifer recharge and lead to declining water levels.

A significant component of the research involved the use of the Green Element Method (GEMFLOW) to numerically model groundwater flow. This advanced computational tool simulated subsurface hydrodynamics and was calibrated using field data collected in 2001 and 2002. The results showed groundwater flow moving predominantly northward with an average gradient of 1:250. The model indicated that a long-term sustainable abstraction of $6.1 \times 10^6$ $m^3$ per year-equivalent to about 15% of Bulawayo's total water demand-could be achieved without causing harmful drawdowns. However, excessive pumping during droughts could lead to localised declines in water levels, particularly in vulnerable suburbs such as Ilanda, Hillside East, Barham Green, and Morningside.

Rusinga and Taigbenu (2005) highlight the absence of a reliable borehole database as a serious gap in the city's groundwater governance. They recommend that BCC establish a comprehensive monitoring network and maintain detailed records of abstraction volumes, borehole locations, and pumping rates. The study further emphasises the importance of groundwater protection from contamination, especially given the high incidence of coliform bacteria detected in urban wells by previous research (Mangore, 2002).

The authors conclude that the Matsheumhlope well-field is a valuable but limited water source that can make a measurable contribution to Bulawayo's supply if managed scientifically. Its sustainability depends on balancing abstraction with recharge and ensuring that borehole drilling is regulated. The research set a benchmark for urban hydrogeological studies in Zimbabwe, combining fieldwork, modelling, and policy implications into one of the most comprehensive analyses of its kind. The findings continue to inform groundwater management practices and development planning for Bulawayo two decades later.

## Appendix 3: Summary Of Geophysical And Hydrogeological Investigations Of The Nyamandhlovu Aquifer – Martinelli & Hubert (1996)

The report by Martinelli and Hubert (1996), prepared under the Royal Danish Embassy's consultancy programme, represents one of the foundational technical studies on the Nyamandhlovu Aquifer, which serves as a key groundwater source for Bulawayo. Entitled "Consultancy Services for Geophysical and Hydrogeological Investigations, Aquifer Modelling and Monitoring of the Nyamandhlovu Aquifer, Bulawayo, Zimbabwe," the report provides a detailed account of field investigations, geophysical surveys, and aquifer characterisation carried out during the main investigation phase of the Bulawayo water supply feasibility programme.

Martinelli and Hubert (1996) describe the Nyamandhlovu Aquifer as part of the regional Forest Sandstone Formation, which underlies basaltic lava flows of Karoo age. The aquifer system is semi-confined, with groundwater occurring within the upper sandstone unit beneath a variable cover of Kalahari sands and basalts. Yields are generally high, with productive boreholes averaging 90 metres in depth. The aquifer's structure and permeability are influenced by both depositional features and post-depositional fracturing, creating significant heterogeneity across the wellfield. The report's geophysical surveys—principally resistivity profiling and borehole logging—were used to delineate sandstone thicknesses, confining layers, and water-bearing zones.

Recharge to the Nyamandhlovu Aquifer occurs through infiltration from rainfall, percolation through overlying Kalahari sands, and limited lateral inflow from adjacent formations. The aquifer was found to exhibit semi-confined conditions, with artesian to sub-artesian behaviour in certain areas. Martinelli and Hubert (1996) estimated recharge and transmissivity parameters that were later validated by subsequent studies (Danielsen et al., 2007). Water quality was generally good, suitable for both domestic and irrigation use, though careful monitoring was advised to prevent contamination from agricultural activities.

The consultancy's modelling component provided early estimates of sustainable yield and groundwater balance, forming the basis for later operational management of the Nyamandhlovu wellfield. The report identified a number of critical management challenges, including declining yields due to over-pumping, mechanical failures of pumps, and the need for systematic maintenance and data collection. It recommended the establishment of a continuous monitoring network to track water levels, pumping rates, and quality parameters, along with the implementation of submersible pump systems to improve reliability.

A significant contribution of the Martinelli and Hubert (1996) study was its delineation of the potential for aquifer expansion to the north and northwest, beyond Nyamandhlovu and Highfields along the railway corridor. The report's findings suggested that the Forest Sandstone extends across a broader area than previously mapped, offering opportunities for new borehole siting and phased development. This insight later informed subsequent feasibility work under the SWECO (1996) and World Bank (2013) programmes, as well as GIZ-supported rehabilitation projects in the 2010s (Broderick, 2025).

In conclusion, Martinelli and Hubert (1996) provide a technical and methodological foundation for understanding the Nyamandhlovu Aquifer system. Their integrated use of geophysical techniques, borehole data, and modelling established the conceptual framework for later groundwater development in western Zimbabwe. The study underscored the importance of systematic monitoring, regulated abstraction, and institutional collaboration between the City of Bulawayo, ZINWA, and donor agencies. The report remains a key reference in assessing the long-term sustainability and expansion potential of the Nyamandhlovu wellfield as part of Bulawayo's strategic water supply portfolio.

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