
**Service activities relating to drinking
water supply, wastewater and
stormwater systems — Examples
of good practices for stormwater
management**

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 224, *Service activities relating to drinking water supply, wastewater and stormwater systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The objectives of stormwater management systems include effective control and management of flows; protection of water quality; preservation of water quantity; protection of the built, public and natural environments; water conservation and reuse; protection or enhancement of ecosystem health; protection or enhancement of public health, safety and welfare; protection or enhancement of social values; and facilitation of sustainable development and climate adaptation.

“Climate Change 2014: Synthesis Report: Summary for Policymakers, 2014, Intergovernmental Panel on Climate Change” gives us the warning that many global risks of climate change are concentrated in urban areas. It indicates that risks are amplified for those lacking essential infrastructure and services or living in poor-quality housing and exposed areas. The key risks, all of which are identified with high confidence, include those of severe ill-health and disrupted livelihoods for urban populations due to flooding from a range of sources including pluvial, fluvial, storm surges and coastal flooding.

Pursuant to the “World Urbanization Prospects: The 2011 Revision, 2011, United Nations”, the world urban population is expected to increase by 72 per cent by 2050, from 3,6 billion in 2011 to 6,3 billion in 2050. i.e. the same size as the world’s total population was in 2002. Virtually all of the expected growth in the world population will be concentrated in the urban areas of the less developed regions, which are deemed to be vulnerable to flooding. The report states that flooding is the most frequent and greatest hazard for the 633 largest cities or urban agglomerations analysed. Mud slides are often associated with severe weather conditions and flooding, particularly in rural areas and commonly will impact rural villages and small towns, or their associated transportation infrastructures.

Thus, climate change and urbanization with rapid growth in population in cities and surrounding areas are most likely to increase flooding and the risks associated with stormwater worldwide. Serious challenges for stormwater management are posed for an increasing number of stormwater utilities, which are responsible for the control of pluvial flooding that is caused by rainwater entering and surcharging stormwater systems or remaining on surfaces and flowing overland or into local depressions and topographic lows to create temporary ponds.

The immediate impacts of urban flooding can include loss of human life, damage to property, disruption of traffic and other services and deteriorations of limited freshwater resources, water ecosystems and hygienic living conditions. Effective stormwater management systems can enhance the resilience of communities by reducing the likelihood and severity of pluvial, fluvial and coastal flooding.

Planning methods for stormwater systems have been established in most developed countries but they do not always apply directly to other countries with different conditions. In order to help deliver the best solution to the targeted area, the framework and planning processes should be standardised, within a local institutional and regulatory context.

Urban stormwater management is usually the responsibility of municipal water and wastewater service providers. However, in some countries the urban stormwater system management is performed by separate entities especially established for this purpose. Sometimes these services are not financially supported from the municipal water and wastewater revenues but from stormwater levies applied to flood vulnerable properties concerned and created for that purpose or a local governing authority.

While it is largely and historically true that urban stormwater management has been the responsibility of municipal wastewater authorities, it is increasingly recognized that stormwater management may be best or additionally served through collaboration with other relevant stakeholders such as Forestry Commissions (for forested hill and mountain sides), Agricultural Commissions for upstream farming properties, river authorities or Port Commissions for the management of tidal surges on both marine and freshwater bodies or local governing authorities.

This document compiles examples of good practices in stormwater management.

These examples illustrate a wide range of measures including both asset and non-asset-related measures for various objectives relating to stormwater management.

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Service activities relating to drinking water supply, wastewater and stormwater systems — Examples of good practices for stormwater management

1 Scope

This document provides examples of good practices in stormwater management related to ISO 24536 and information on standards and guidelines used in various countries.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

4 Format and content of the examples provided in this document

Examples of stormwater management introduced here are classified by country and are described in [Annex A](#). They are also classified according to the objectives in ISO 24536:2019, Table 1, and are shown in [Table A.1](#). The examples were provided by country representatives and adapted to the format of this document. In addition, although various standards and guidelines are described in [Annex B](#), [Table B.1](#) and [Table B.2](#), they are shown only as a name and a reference URL.

[Table 1](#) illustrates the structure of the examples included in [Annex A](#).

Table 1 — The structure of the examples

Section	Content
Background	Provides background information on the project, such as characteristics of the watershed, social background, issues and tasks.
Purpose	Provides a description of the project objectives, such as improvements to be achieved.
Project outline	Provides a description of the project.
Organization	Provides simply the identity of the organization offering its experience.

Annex A (informative)

Examples of stormwater management

A.1 Introduction

There are many examples of good stormwater management practices that follow the procedures set by the ISO 24536. The examples have been classified according to the stormwater management objectives they were answering to.

Table A.1 — List of examples and their key objectives for stormwater management related to ISO 24536

Sub-clause	Title	Objectives according to ISO 24536								
		Effective control and management of flow volumes	Protection of water quality	Preservation of water quantity	Protection of the built, public and natural environments: infrastructure, property and resources	Water conservation and reuse	Protection or enhancement of ecosystem health	Protection or enhancement of public health, safety and welfare	Protection or enhancement of public social values	Facilitation of sustainable development and climate adaptation
A.2.1	Creation of a wetland in Mount Barker		X		X		X	X	X	
A.2.2	Stormwater harvesting and reuse in Murray Bridge			X		X				
A.3	Austria — Increasing storage capacity and implementing dynamic control in Vienna	X	X		X			X		
A.4.1	Improving sediment control through the implementation of a wetland in Hamilton		X				X		X	X
A.4.2	Planning effective stormwater management measures in Ottawa	X	X		X		X	X	X	
A.5	Denmark — Dynamic control in Kolding	X	X	X	X		X			
A.6.1	Disconnecting stormwater from the combined network in Killingworth and Longbenton, North Tyneside, England	X	X		X		X	X		X
A.6.2	River diversion and stormwater storage in Brunton Park, Gosforth, Newcastle, England	X			X		X	X		X
A.7	France — Real-time control of sewer systems for the reduction of combined sewer overflows in Biarritz	X	X		X					
A.8.1	Implementation of a real-time supervision for stormwater facilities operation and flood risk management in Nagoya	X			X					
A.8.2	Implementation of the stormwater management strategy of Niigata City	X								

Table A.1 (continued)

Sub-clause	Title	Objectives according to ISO 24536								
		Effective control and management of flow volumes	Protection of water quality	Preservation of water quantity	Protection of the built, public and natural environments: infrastructure, property and resources	Water conservation and reuse	Protection or enhancement of ecosystem health	Protection or enhancement of public health, safety and welfare	Protection or enhancement of public social values	Facilitation of sustainable development and climate adaptation
A.8.3	X-band radar observation and forecast for stormwater and flood risk management in Osaka City	X			X					
A.8.4	Implementation of a flood risk protection strategy in Tokyo	X			X			X		
A.8.5	Source infiltration promotion in Yokohama	X			X					X
A.8.6	Implementation of the stormwater management strategy in Kitakyushu City	X								X
A.8.7	Implementation of an early flood warning system in Toyama City				X			X		
A.8.8	Stormwater storage tank and reuse in Hiroshima City's new stadium	X				X				X
A.8.9	Flood risk protection scheme in Fukuoka	X								X
A.8.10	CSO reduction and flood prevention in Kyoto	X	X		X				X	X

A.2 Australia

A.2.1 Creation of a wetland in Mt Barker

A.2.1.1 Background

A new Environmental Services Centre is planned for Mt Barker adjacent to a wastewater treatment plant, Mt Barker Creek and a high school.

The area has a long history of disturbance being a former abattoir, tannery and now informal council works storage area. Despite this disturbance, Lathan's snipe (an endangered migratory bird from Siberia) and many other bird species have been sighted along the flood plain area.

A.2.1.2 Purpose

As part of planning for the Environmental Services Centre, a wetland and surrounding landscape was built to achieve multiple objectives, including:

- creating habitat for the Lathan's snipe and other birds species;
- becoming a recreational asset with high amenity, providing links to a linear trail along Mt Barker Creek and connecting to the school and depot;
- rehabilitating vegetation and creating a seed bank for local provenance plants in a range of ecosystems;
- providing stormwater treatment for runoff generated by the new depot and car park;

- providing opportunities for education and awareness programs, both for the school and for a planned community environmental centre servicing community groups, schools and the general public.

A design response was developed that addressed these criteria and was thoroughly tested during consultation with Birds SA, council, community groups and specialist ecologists.

The design also provides a range of ecological habitats for vegetation and bird species, encourages visitors yet provides secluded areas where birds will not be disturbed.

A.2.1.3 Outline

This project was developed to rehabilitate a degraded area on the banks of Mt Barker Creek as part of a planned council depot construction. The central component of the project is a constructed wetland which will protect the creek from increased pollutants, provide habitat for rare and endangered bird species and become a recreational node along the Mt Barker Creek linear path.

A broader objective of the project is to rehabilitate a range of ecological habitats surrounding the wetlands, including grasslands, wet and dry woodlands and riparian areas. Much of the impetus for the initiative is to improve habitat for a range of rare and endangered birds and therefore the design involved close consultation with Birds SA.

The design provides a range of ecological habitats for vegetation and bird species yet provides secluded areas where birds will not be disturbed.

Walking paths, viewing decks and a boardwalk encourage people to enjoy the wetland but manage their access and allow a variety of habitats to be created (riparian inundation, open grassland, tussock grassland and wet woodlands).

The 6 000 m² wetland was constructed in 2014 and an extensive search was performed to source local provenance plant species to use in the wetlands. A thorough mapping exercise was undertaken during planting to enable the wetland to serve as a seedbank for these rare local species into the future.

The wetland also provides best practice stormwater treatment for runoff from the (future) depot thus helping to protect Mt Barker Creek and ultimately the Bremer River from urban stormwater pollutants (see [Figure A.1](#)).

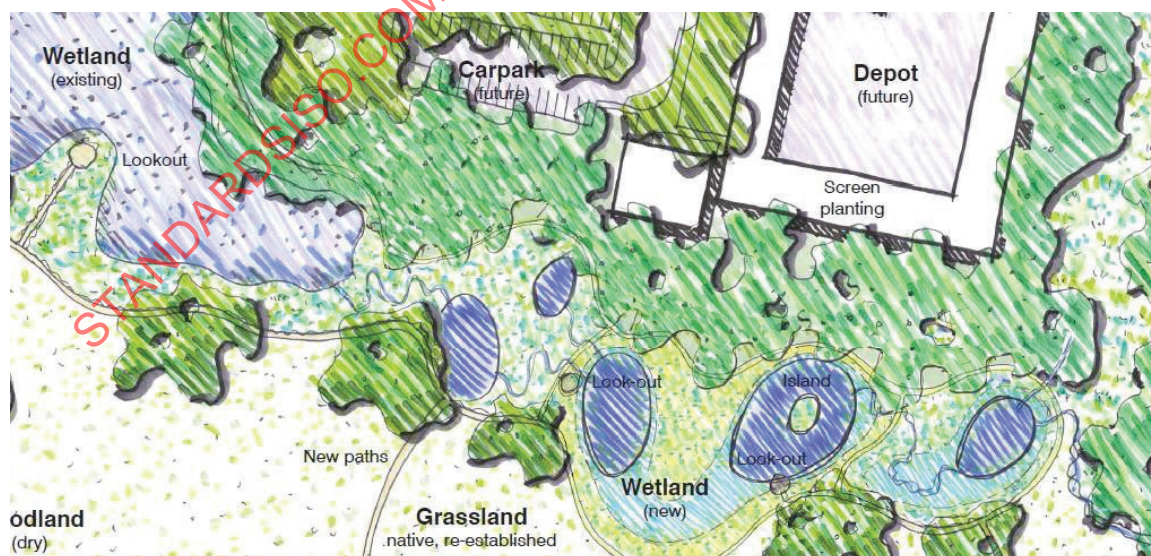


Figure A.1 — Future plan of Mt Barker Environment Services Centre wetlands

A.2.1.4 Organization

Mount Barker District Council

A.2.2 Stormwater harvesting and reuse in Murray Bridge

A.2.2.1 Background

Murray Bridge, South Australia, is situated on the banks of the River Murray and is one of the larger regional centres at the lower end of the Murray Darling Basin and an important hub for regional industries in the Lower Murrayland and Mallee Regions. Residential and industrial developments are a sign of the city's growing urban populations. Sustaining the city's many open spaces – parks, reserves and sporting facilities – is vital to the region and its local community.

In addition, major subdivisions are planned at the Newbridge (Old Racecourse) site and Gifford Hill, which are proposed to include in excess of 3 000 dwellings, and will constitute a major proportion of the proposed expansion of Murray Bridge over the next 20 years. A challenge for Council is the provision of infrastructure that can appropriately manage the increases in stormwater runoff associated with infill and greenfield developments.

A.2.2.2 Purpose

The Murray Bridge stormwater management and reuse scheme was built to provide an alternative, secure and sustainable source of non-drinking water supply to the Rural City of Murray Bridge. The Scheme harvests stormwater from eight basins and wetlands across Murray Bridge and transports it to a lined lagoon at Gifford Hill for long-term storage. When needed for irrigation, raw stormwater is pumped from the lagoon to the new treatment plant on Old Swanport Road, from which the treated stormwater is transported via distribution pumps and pipelines to the city's irrigation system.

The scheme was delivered by the Rural City of Murray Bridge, in partnership with the Australian Government and two private contributors. The total budget of \$14,23 million was supported through \$7,115 million of funding from the Australian Government's National Urban Water and Desalination Plan, to match the co-contribution from Council and in-kind works from the Gifford Hill Joint Venture. The scheme was completed on time and within budget, and with an impeccable safety record.

The Australian Government funding agreement required the scheme to decrease reliance on the River Murray and reduce potable water demand by up to 172 ML annually.

A.2.2.3 Outline

A.2.2.3.1 Scheme overview

The Rural City of Murray Bridge (Council) has a current water allocation of 250 million litres/year from the River Murray, and this allocation is subject to restrictions depending on flow conditions in the river. Council's allocation was significantly restricted during the drought years of 2006 through to 2010, dropping as low as 45 million litres/year (18 %) in 2008/09. These restrictions resulted in significant "browning off" and degradation of Council's reserves and sporting fields.

In response to the drought, Council identified stormwater as a valuable, untapped resource that can provide a secure, sustainable and diverse water supply to meet the future needs of the community. A strategy was soon developed for how stormwater can be harvested and reused across Murray Bridge to prevent a repeat of the devastating impacts of the drought, reduce reliance on mains and River Murray water, improve amenity of the many parks and reserves, improve drainage performance and flood protection, and improve water quality.

A.2.2.3.2 Design

In 2014 the Rural City of Murray Bridge entered into an Early Contractor Involvement (ECI) process with construction and design partners to optimize the previous concept design of the scheme. The

ECI process was facilitated by the scheme's project manager, with input from the scheme's Technical Advisor.

Due to a delay in the planned housing developments at the Old Racecourse (Newbridge) and Gifford Hill development sites, which were originally proposed to be the source of a significant portion of the harvestable volume of stormwater in the previous concept design, a comprehensive optioneering phase was undertaken to identify alternative harvesting sites that can meet or exceed the yield targets.

Through careful planning, design and management the yield (irrigation demand met) from the eight harvesting sites currently connected to the scheme is expected to be approximately 230 ML annually, based on average rainfall in Murray Bridge. The scheme has also made provision for the connection of future pump stations at the Newbridge (Old Racecourse) and Gifford Hill development sites. Once these pump stations are installed and the developments are completed, the total harvestable volume for the scheme may exceed 700 ML annually.

The ECI process also identified a parcel of vacant land on Old Swanport Rd that was ideally located to become the hub of the scheme (Figure A.2). Located between the existing and Rural Avenue Wetland and the Gifford Hill Lagoon, with existing power supply available from Old Swanport Rd and only a short drive to the Council Depot, the site was ideal for the construction of the new treatment plant.

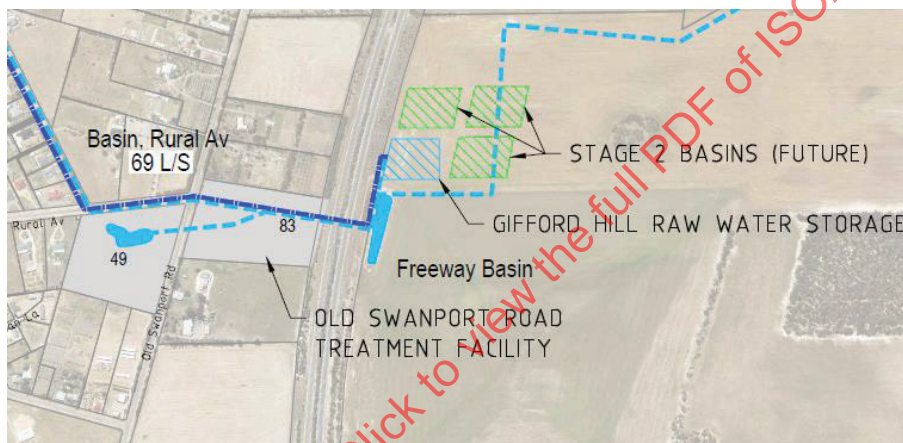


Figure A.2 — The ‘hub’ of the scheme; Rural Avenue Wetland, the treatment plant and Gifford Hill Lagoon

A route for the new pipelines along Rural Avenue, Prosperity Grove and Maurice Road was selected to provide a link between the treatment plant and the existing Council irrigation network on Adelaide Road. This route also enabled stormwater to be harvested from the existing Council wetlands and basins using parallel pipelines to reduce construction cost (i.e. one set of pipelines for harvesting, and another set of pipelines for distribution, within the same road reserve).

The planning and design of the scheme included consideration of opportunities for future expansion to include additional harvesting sites, increased demand for treated stormwater, and a possible link to a regional water diversification scheme that links Murray Bridge to the District Council of Mount Barker.

Examples of the “future-proofing” measures that were incorporated into the design include:

- The siting of the 110 ML storage lagoon on land that acts as a buffer to the SE Freeway at Gifford Hill, with surrounding land available for additional storage lagoons in the future (an ultimate storage of 440 ML is envisaged).
- The inclusion of a UV disinfection unit in the Old Swanport Road treatment plant to provide treated stormwater that is fit for purpose under an “unrestricted” irrigation regime. This provides flexibility for Council and third party water users to irrigate public open spaces 24 h a day. Provision was also made in the treatment plant for a second UV disinfection unit to be retrofitted in the future, should higher treatment flow rates be desirable.

- The treatment plant and treated water storage tank have been sized to accommodate Council's peak irrigation demand (night time, typically from 10 pm to 8 am) while also filling the tank shared by two other local organizations. There is further opportunity to operate the treatment plant during non-peak times (day time, 8 am to 10 pm) to service additional Council sites and other water users.
- The harvesting and distribution pipelines were sized to accommodate stormwater flows from the planned housing developments at the Old Racecourse (Newbridge) and Gifford Hill development sites, to enable simultaneous pumping from these sites together with the current harvesting sites. In particular the pipe crossings of the SE Freeway, which were installed using horizontal directional drilling (HDD) techniques, have significant redundancy to accommodate increase flows.

With the Council's unique stormwater drainage system consisting of a series of stormwater basins in localized depressions, it was also important that the harvesting and reuse strategy was able to improve the performance of the drainage system and level of flood protection to public and private infrastructure.

The basins do not naturally drain to the River Murray, but rather they rely on infiltration or pumps to dispose of stormwater. In the past, these basins have not always been able to cope during large rainfall events, resulting in flooding of roadways and in some instances, private property, as represented in [Figure A.3](#). Floodplain modelling was therefore used to inform the selection of pump rates and to inform the scheme's control philosophy, to ensure that the improvements to drainage performance and flood protection were maximized.

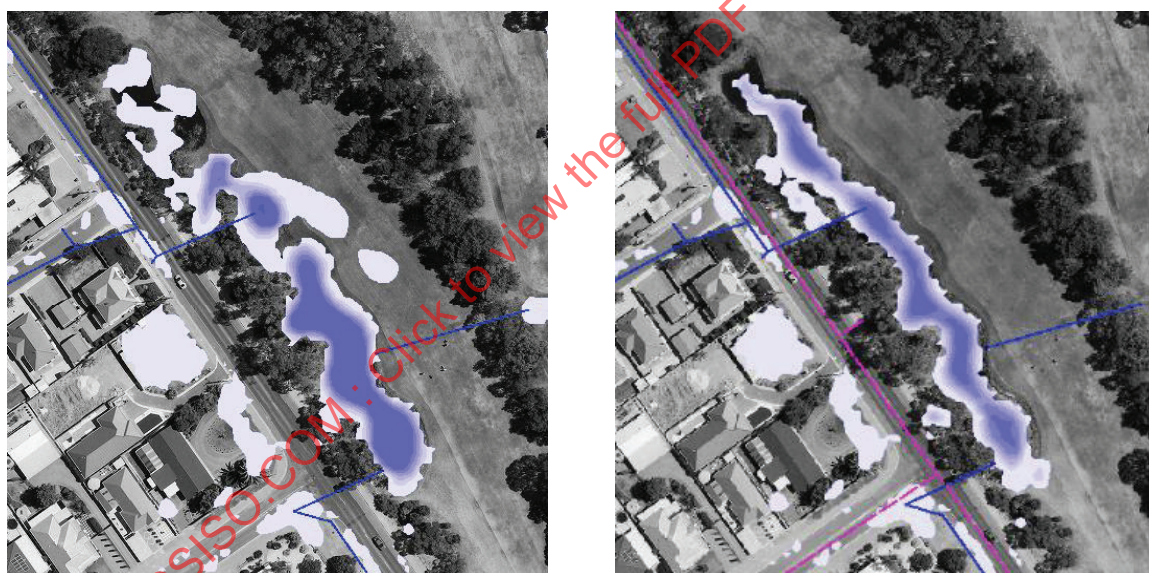


Figure A.3 — Before and after floodplain maps for golf course basin, 5-year average recurrence interval

The planning and design of the scheme also placed strong emphasis on the future operation and maintenance by Council staff. The scheme has a central Supervisory Control and Data Acquisition (SCADA) system located at the Old Swanport Road treatment plant that is connected to all sites via fibre optic cable or mobile phone-based telemetry systems. The SCADA system enables Council staff to remotely monitor the harvesting and distribution infrastructure for the purpose of automated control, using their personal computers and/or tablet devices. In addition, critical alarms are alerted to the operators via an SMS service.

Many of the new pumps utilize variable speed drive functionality to provide operational flexibility, reduce wear on the mechanical components of the system, and to maintain system pressure as required. Under standard operating conditions all harvesting sites will pump simultaneously to the Gifford Hill Lagoon at pre-determined flowrates, in order to maximize the harvestable volume that is generated by small and frequent rainfall events.

In anticipation of and during large rainfall events, Council staff can use the new control system to remotely monitor the water levels in the basins and adjust pump rates and sequencing to manage flood risk in real time. For example, Council will have the flexibility to reduce the pump rate at one site, to enable a higher pump rate to be achieved at another site that is considered to be at greater risk of flooding.

While the scheme has been designed to operate automatically with minimal operator intervention, manual and local modes have also been provided on all equipment to facilitate testing and operation in unusual circumstances

Other notable operation and maintenance provisions include:

- Lifting mechanisms in the treatment plant to enable the safe and practical maintenance of pump sets and filters.
- Two solar powered pump stations that can easily be converted to mains power supply if higher flowrates are required in the future (i.e. after the ultimate development scenario is reached).
- Control manholes with isolation valves at each of the harvesting sites, to provide safe inspection and access of submersible pumps.
- The selection of submersible pumps stations with pumps capable of being removed from the pump station without entry in to the pump sump, providing a safe means of pump inspection by the elimination of confined space entry.
- A concrete ramp at the Gifford Hill Lagoon to provide boat access in the event that chlorine dosing is required, or small machine access in the event that the lagoon needs to be cleaned out.
- Provision for portable diesel powered pumps to be fitted at the harvesting sites, to enable basins to be pumped out even if short-term power failure were to occur.
- Design of the treatment plant shed roof to accommodate a future solar array, when battery storage technology is sufficiently advanced.

A.2.2.3.3 Control devices information

The central Supervisory Control and Data Acquisition (SCADA) system enables all harvesting sites to pump simultaneously to the Gifford Hill Lagoon at pre-determined flowrates to maximize the harvestable volume generated by small and frequent rainfall events. In anticipation of, and during, large rainfall events, Council staff can remotely monitor the water levels in the basins and adjust pump rates and sequencing to manage flood risk in real time.

A.2.2.3.4 Environmental management

As part of the construction program a project specific Environmental Management Plan (EMP) was developed with site specific criteria. The EMP detailed methodology included procedures for the prevention of contaminated water entering watercourses and the stormwater system.

Site-specific sections of the EMP detailed how to deal with the discovery and presence of local fauna and flora during the construction phase. Specifically this involved relocation of frogs, yabbies and other fauna to adjacent areas of the site that were not subject to construction works.

Consideration was also given to the discharge of backwash water from the treatment plant. This water is used to flush the treatment plant vessels during operation and is then transferred to a harvesting site for reuse, thereby reducing any disposal or wastage of this water. The selection of an ultraviolet disinfection system for the treatment of the distribution water also has an environmental benefit by eliminating both the storage and use of significant quantities of hazardous chemicals.

In order to minimize the impact of the project to trees and shrubs, the pipeline alignment and construction techniques were developed to focus on trimming of trees in order to reduce the number of trees removed.

A.2.2.3.5 Community and stakeholder engagement

The construction of this project included a dedicated community and stakeholder engagement plan and team. The team liaised with residents and stakeholders through the design and construction process with the following outcomes being achieved.

- The pipe alignment was adjusted to minimize disruption and impacts on businesses and the community in general. An example of this is the realignment of the pipeline along Adelaide Rd. The pipe was realigned to pass through a carpark rather than crossing one of the busiest intersections in Murray Bridge. Local businesses were consulted and the realigned pipe was constructed in without disruption to customer access to the businesses.
- Project introduction letters were distributed by letter drop to the general community, with follow-up communication to affected community members by specific information drops.
- Where the construction works directly impacted on community members, specific one-on-one communication was undertaken.
- Due to the important and significant indigenous history at Murray Bridge, the Ngarrindjeri people as the traditional owners of the land were consulted and involved throughout the construction process to ensure that the works caused no damage to items of significance.
- The construction program was developed to take into account concerns of the local community. Examples of this include:
 - Pipe construction along Maurice Rd was completed as night works to minimize the impact to traffic on this busy road.
 - Access to materials and pipe construction in the vicinity of the Racecourse was programmed to avoid disrupting events and training schedules.
 - Construction within the Golf Course involved timing of the works prior to major events and the utilization of track mats to prevent damage to the course during works.
- Extensive consultation was undertaken with state government agencies during the design and approvals phase, including:
 - South Australian Murray-Darling Basin Natural Resources Management Board;
 - Department of Environment, Water and Natural Resources;
 - Environmental Protection Authority;
 - Department for Health and Ageing;
 - Department of Planning, Transport and Infrastructure;
 - Office of the Technical Regulator.

Indigenous participation was also a strong focus of the project, as Murray Bridge and its surrounding region has numerous sites of cultural and spiritual significance of the traditional owners of this land, the Ngarrindjeri people. An important part of the Early Contractor Involvement process was the Council project team's collaboration with the Ngarrindjeri Regional Authority to ensure that the selection of project sites and design of the proposed works was sensitive to the cultural and spiritual significance of these lands to the Ngarrindjeri people.

Council's partnership with the Ngarrindjeri Regional Authority continued through the design and construction stages of the project, involving cultural heritage assessments of the project sites and monitoring of earth disturbing activities to ensure that risks to cultural heritage were appropriately managed ([Figure A.4](#)).



Figure A.4 — Cultural heritage survey at Rural Avenue Wetland

The Ngarrindjeri Regional Authority also produced a video with their staff and Ngarrindjeri elders along with the scheme's project manager to showcase the benefits of forging strong partnerships and mutual respect between project teams and the Ngarrindjeri nation.

A.2.2.4 Organization

Rural City of Murray Bridge

A.3 Austria — Increasing storage capacity and implementing dynamic control in Vienna

A.3.1 Background

The wastewater management in various parts of the 11th district of Vienna (Simmering) is prone to overflow events. The area of Kaiserebersdorf ([Figure A.5](#), orange area) is especially affected. Due to the low altitude of the area, the sewers have a very low gradient and a very low depth of cover. In the case of backwater in the sewer network, the system overflows quickly. Especially where, in [Figure A.5](#), the areas highlighted in black and in orange overlap (circled in pink), there is a relatively abrupt change in terrain. Coming in from areas with higher altitude, the water has gained increased velocity and then reaches a sewer with a grade of less than 0,1 %. During heavy rainfall events, this leads to an outflow of water from the sewer. Due to the existing low depth of cover and the confined space conditions, an expansion of the sewer in this area is difficult or even impossible.

The sewer network in Simmering is influenced directly by the sewer in Liesingtal valley and with parts of the 10th district of Vienna ([Figure A.5](#), area highlighted in green). All wastewater from adjacent areas must be drained via the Simmering sewerage system and the Kaiserebersdorf lifting station, and directed towards the waste water treatment plant (WWTP). Up until the Kledering lifting station (screw pumping station), the water in the sewer network is drained with a separate sewerage system. Downstream from the lifting station, the water is drained with a combined system. In the separate system that feeds the Blumental storage basin, the stormwater sewers are directed into a body of water, the Liesing stream. Downstream from the Blumental basin, wastewater as well as stormwater sewers flow into the Liesing stream collection sewer-relief sewer (LCSR); however, the stormwater sewers have controlled overflow into the Liesing stream. The first place for a relief sewer in the combined system

is not until shortly before the main wastewater treatment plant, via the Kaiserebersdorf lifting station and into the Danube Canal (Figure A.5).

This lifting station actually consists of two lifting stations that interact with each other. The so-called “wastewater lifting station” Kaiserebersdorf and the so-called “stormwater lifting station” Kaiserebersdorf. The wastewater lifting station, as of now referred to as Lifting Station Kaiserebersdorf Waste Water, is responsible for lifting the combined wastewater that flows into Kaiserebersdorf towards the inflow of the main treatment plant so that it can be cleaned there.

If the maximum capacity of the wastewater lifting station is exceeded due to heavy rainfall, it is possible to implement gravity drainage into a body of water, namely the Danube Canal, to provide relief. If the Danube Canal floods, relief can be provided by use of the stormwater lifting station (Lifting Station Kaiserebersdorf Storm Water).

The total contiguous drainage area thus amounts to more than 69 km². To ensure sustainable water protection and flood protection in this area, which takes up almost 15 % of Vienna's total area, an extensive catalogue of measures based on comprehensive hydro-dynamic studies was composed.

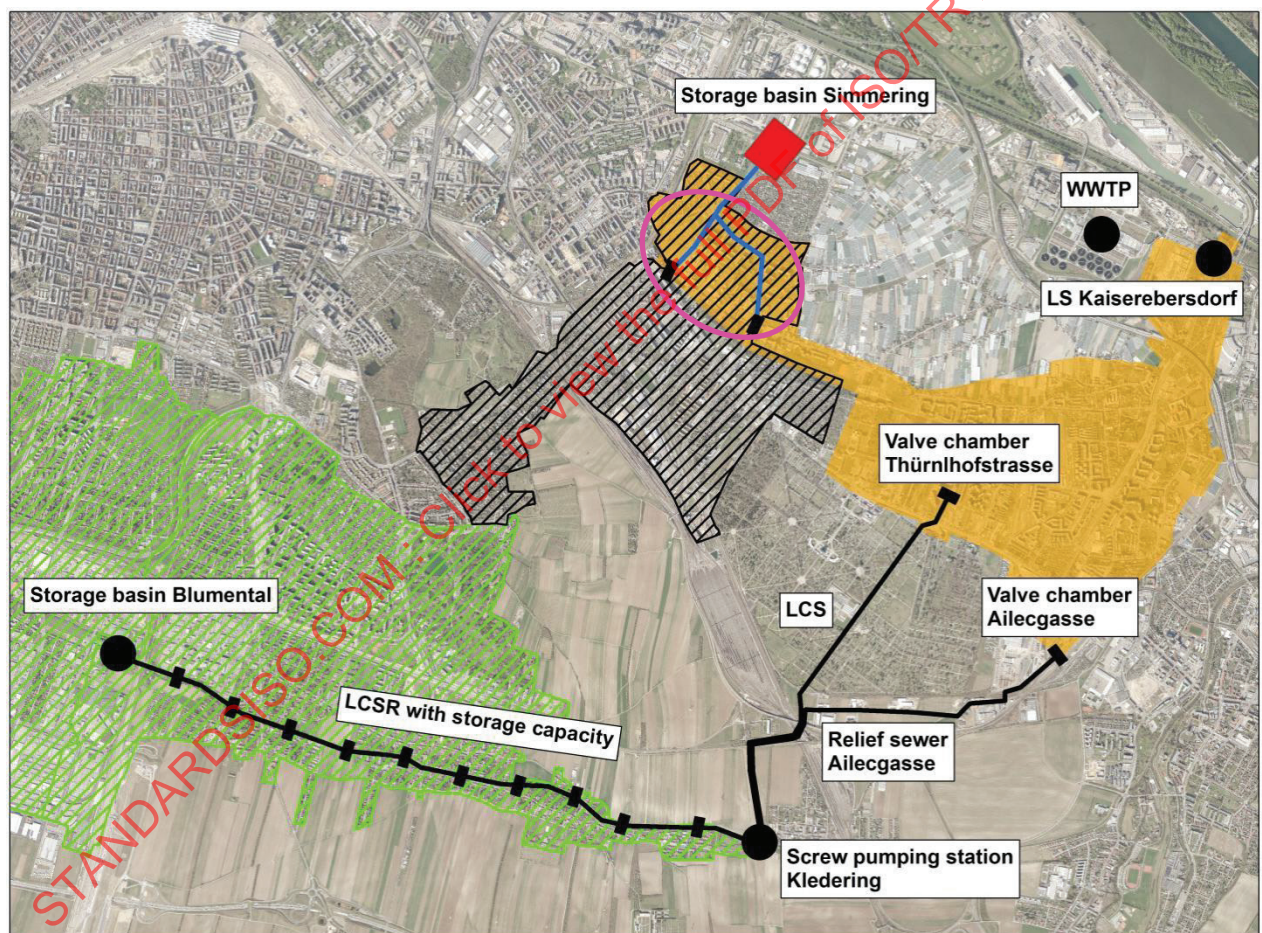


Figure A.5 — Overview drainage area for lifting station Kaiserebersdorf (23rd and parts of the 11th district)

A.3.2 Purpose

In the case of a heavy rainfall event, the wastewater coming in from the adjacent areas (Figure A.5, highlighted green) is to be retained for as long as possible, so that the problem areas further downstream are relieved and in order to reduce combined wastewater drainage into the Danube Canal.

Outflow of water from the sewer network onto the surface must be avoided. Special attention must be paid to the area with abrupt change in terrain ([Figure A.5](#), circled in pink).

A.3.3 Outline

A total retention volume of more than 85 000 m³ was created. This was done through structural extensions on the one hand, and through the active management of the existing sewer storage.

The implemented sets of measures and the retention volume that was created is listed in [Table A.2](#).

Table A.2 — Measures and retention volume

Measures		Retention volume
1	Optimising the management of the LCSR and implementing the operating mode “flood protection”	~17 000 m ³
	Construction of valve chamber Thürlhofstraße	~8 000 m ³
	Construction of valve chamber Ailecgasse	~6 000 m ³
2	Reactivation of the abandoned wastewater treatment plant Blumental as a combined wastewater storage basin	~20 000 m ³
3	Construction of the Simmering storage basin (incl. transport sewers)	~34 500 m ³
4	Full expansion of the Kaiserebersdorf lifting station (SW/WW)	

Set of measures 1: The active management of the newly built Liesing stream collection sewer-relief sewer (LCSR) between Blumental and Kledering is in the focus of the measures already implemented, as well as the management of the old Liesing stream collection sewer (LCS) between Kledering and Thürlhofstraße. During a rainfall event, the new LCSR, with a diameter of 2,4 m and a length of about 5,3 km, and the old LCS can be divided into a cascading storage chain by means of 11 regulating structures. The cascading chain frees up storage capacity in the amount of 25 000 m³. Via the Kledering lifting station, the wastewater is divided, depending on the actual system's capacity, and directed towards the LCS and a newly built relief sewer in Ailecgasse. With the construction of a valve chamber in this new Ailecgasse collection sewer, an additional storage of approximately 6 400 m³ was created.

The higher-level control of the different regulating structures works automatically through the central control system of the Vienna sewer system, out of the control centre of the largest pumping station in Vienna.

Different operating modes allow for an optimized operation, tailored to the individual rainfall event. The modes were programmed in regard to water protection for the Liesing stream and to flood protection of the areas further downstream in Simmering. For instance, the flood protection mode ensures that any stormwater inflow into the LCSR is stopped and instead directed straight into the Liesing stream. This creates an additional storage volume in the LCSR (approximately 17 000 m³) for wastewater, allowing for it to be retained from the high-risk area for longer periods of time.

Set of measures 2: With the reactivation of the abandoned wastewater treatment plant Blumental (TPB) as a combined wastewater storage basin with a volume of 20 000 m³, the restraint effect of the LCSR was further enhanced.

In order to review the effects of sets of measures 1 and 2 on flood protection in the target area, hydro-dynamic calculations were carried out based on the “hydro-dynamic model Vienna”. For this, Euler Type II model rain with a duration of up to 6 h and annualities of 5 years and 10 years were used. Moreover, the heavy rainfall event of 13 August 2010 was calculated. Its recurrence interval is 50 years.

The result of the calculations showed a retention time of up to 2 h for the wastewater in the valley of Liesing stream during a rainfall event with an annuality of 5 years. This improved flood protection and the amount of stormwater draining into the Danube Canal through the relief sewer at the Kaiserebersdorf lifting station was reduced.

Set of measures 3: With the new construction of the Simmering storage basin as a relief for the Kaiserebersdorf collection sewer and the area further downstream, a storage volume of around

34 500 m³ was created, in combination with the two transport sewers (Figure A.6, catchment area hatched black, transport sewers in blue, inflow control structures marked with black rectangles).

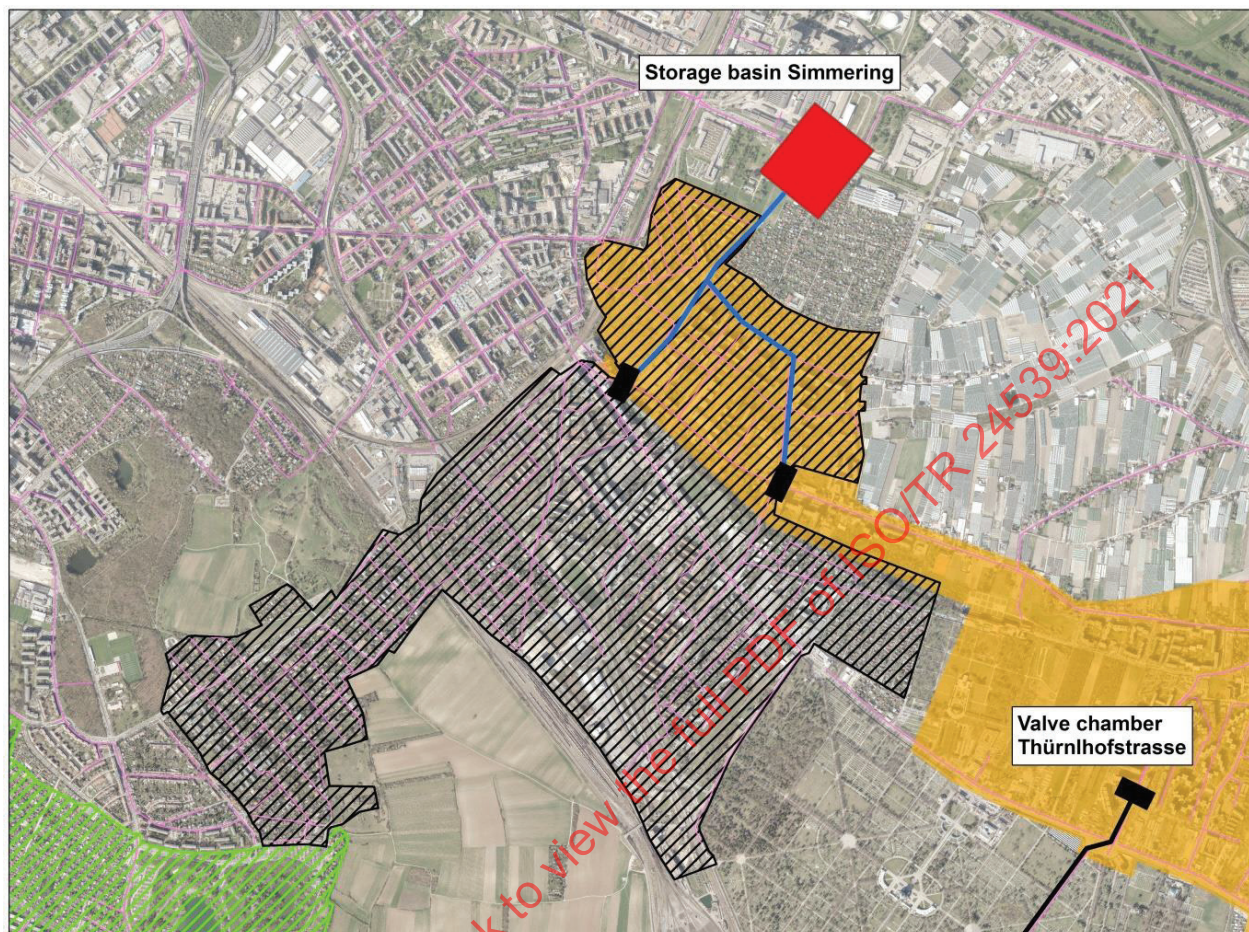


Figure A.6 — Drainage area Simmering storage basin

During heavy rainfall events, inflow into the storage basin and a redirection into the existing sewer network are controlled at two control stations. Each of the two stations has a transversal throttle valve to control the amount of water directed into the sewer network, and a flexible, longitudinal gate weir which controls the inflow into the storage basin.

The flow in the collection sewer in Kaiserebersdorfer Straße can be entirely redirected into the storage basin, so as to reduce the outflow and to relieve the area further downstream.

In order to measure and assess the effects of the storage basin, hydro-dynamic calculations based on the “hydro-dynamic model Vienna” were carried out.

The model rain Euler Type II was used with the following duration periods and annualities:

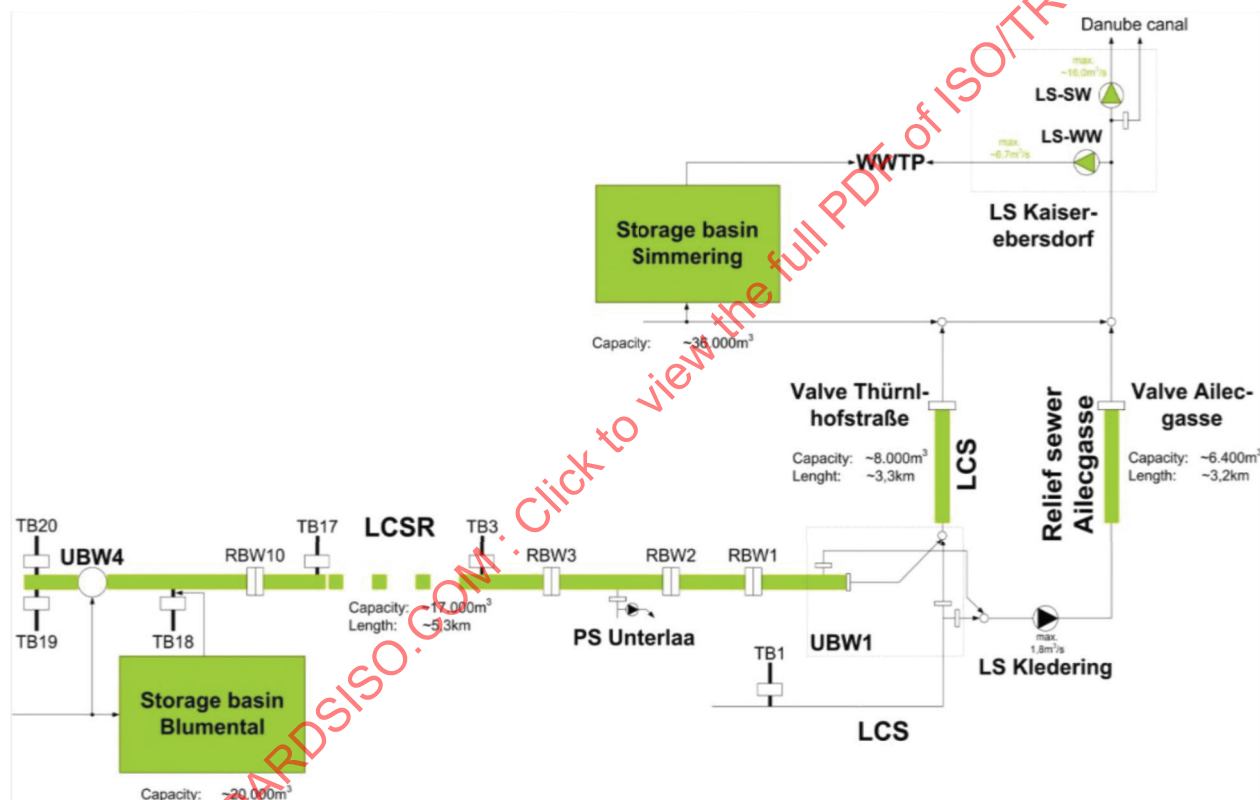
- duration of 60 minutes and an annuality of 5 years;
- duration of 120 minutes and an annuality of 5 years;
- duration of 60 minutes and an annuality of 10 years;
- duration of 120 minutes and an annuality of 10 years.

Moreover, a hydro-dynamic long-term simulation of 15 years and the heavy rainfall event from 13 August 2010 were calculated. This verified that in the target area, the model rain with an annuality of 10 years and a duration of 60 minutes can be stored temporarily and then drained.

Set of measures 4: Thanks to the full expansion of the Kaiserebersdorf lifting station, the wastewater lifting station now has five lifting screws with a performance rate of approximately 1,330 l/s each, which lift the wastewater out of the transport sewer. Moreover, the lifting station has a sixth, smaller lifting screw with a performance rate of approximately 200 l/s. This screw only removes the wastewater coming in from the Alberner-Hafen collection sewer.

Another screw was added to the stormwater lifting station, enhancing it to perform at a maximum flow rate of 16 m³/s. If the Danube Canal floods, this can be relieved only through the lifting station. The lifting station now has four lifting screws with a performance rate of 4 m³/s each.

All measures described are a significant improvement not only for flood protection, but also for water protection. From the point of view of water protection, the combined wastewater coming in from the Kledering area can be retained and temporarily stored before later being directed to the main wastewater treatment plant. Stormwater drainage into the Danube Canal from the area around Kaiserebersdorf lifting station can thus be reduced. In particular, the wastewater flowing in from the Liesing wastewater system can be retained. This leads to a reduction of the pollution load in the combined wastewater system underneath and thus also in the relieved combined wastewater.



Key

- RBW regulating structure to regulate the contents of the storage basins
- TB separating structure to control inflow into the storage sewer
- UBW control structure (for diversion purposes)
- LS lifting station with screw pumps
- PS pumping station with centrifugal pumps
- WW wastewater

Figure A.7 — Schematic representation of the implemented measures to improve flood protection

Due to their complex hydro-dynamic interplay, higher-level coordinated control between all plants is required ([Figure A.7](#)). The timely feeding and emptying of the individual storage basins is especially

important. For an adequate assessment of what “timely” must mean, a special online weather information system is used. It consists, on the one hand, of a network for precipitation measuring with 31 measuring stations across the city and its surroundings, and, on the other hand, a weather forecast portal tailored to the special requirements of sewer network management by the Austrian Central Institute for Meteorology and Geodynamics.

The effectiveness of the measures described in this subclause has already been confirmed during various heavy rainfall events in the past.

A.3.4 Organization

Vienna Wastewater Department

A.4 Canada

A.4.1 Improving sediment control through the implementation of a wetland in Hamilton

A.4.1.1 Background

Windermere Basin is located at the southeast corner of Hamilton harbour, at the mouth of Red Hill Creek, and began as a pre-industrial wetland. The basin has been historically subjected to contamination by industrial chemicals, sewage overflows, landfill leaks and eroded sediment from Red Hill Creek since the 1950s. The basin was significantly altered through dredging in 1990 to act as a sediment trap to protect shipping routes by preventing sediments conveyed by the Red Hill Creek from entering the harbour. Notable in the area is the Woodward Avenue Wastewater treatment plant, rated capacity of 409 million litres/day, and discharging directly into Red Hill Creek upstream of the basin. Located immediately downstream of the basin are Piers 24 and 25, where significant shipping activity occurs under the control of the Hamilton Port Authority.

In October 2000, the city of Hamilton and the Hamilton Port Authority (HPA) (formerly the Hamilton Harbour Commissioners) entered into an agreement which transferred ownership of the basin and surrounding lands to the city. As part of this agreement, the city assumed responsibility for maintenance dredging of the basin, to be undertaken in a timely matter to ensure that the build up of sediment would not impinge upon the shipping and navigation needs of the harbour.

Through undertaking bathymetric surveys, it was discovered that the basin had reached capacity and was no longer effective. The city undertook several studies to determine the best course of action to deal with its obligations to the HPA and how to best manage the basin property. It was determined that sediments within the basin should remain, dredging be completed at pier 25, and that the basin should be restored. With the help of a consulting engineering company, the city undertook a municipal class environmental assessment (Class EA), preliminary, detailed design and contract administration services for the enhancement of the basin. Upon completion of the Class EA, it was determined that the preferred solution was to construct a watercourse to direct sediment to Hamilton harbour and create an aquatic habitat (wetland) within the remainder of the basin.

The project was completed in 2013 and cost approximately CAN\$ 20 million, which came from the municipal provincial and federal governments as part of the Canada Strategic Infrastructure Fund (CSIF).

A.4.1.2 Purpose

The main objective of the project was to improve the stormwater runoff quality through sediment control of overland water draining to the basin.

A.4.1.3 Outline

A.4.1.3.1 General

After the basin was transferred to the city in 2001, a steering committee was formed to provide input to the city with regards to future activities and uses for the property. [Figure A.8](#) shows the transitions that were achieved in the project area at various stages in the implementation. The steering committee developed the following vision statement:

“Windermere Basin will be a restored estuarine ecosystem, providing a sanctuary for wildlife and passive recreational use. With improved water quality and habitat regeneration, Windermere Basin will be a “healed” area; a source of community pride; a place where citizens and visitors can witness the ongoing regeneration of the area to a healthy environment.”

“Windermere Basin will be a green area in an industrial waterfront. As a unique feature of the eastern gateway to the city of Hamilton, the basin will be an area where people can learn and understand about the area’s natural and cultural history. Trails will connect the basin with other natural and cultural attractions in the surrounding area, thus facilitating public access and linkages across the entire Hamilton Waterfront.”



a) 1950s-era photo of Windermere looking towards Hamilton harbour

b) June 2012, pre-construction

c) September 2012, substantial completion

d) October 2013, 1 year after completion

Figure A.8 — Transition of Windermere Basin

A.4.1.3.2 Triple bottom line — the environment, the economy and society

The city and the consulting team applied a triple bottom line approach, to ensure that works completed would provide benefits in the key areas of environment, economy and society.

A.4.1.3.3 Environment

The local environment has been significantly improved over the previous conditions by restoring approximately 15,4 hectares of the basin property, including approximately 11 hectares of Great Lakes coastal wetlands. The project provided the opportunity to create new Great Lakes coastal wetland area to counterbalance the loss of natural wetlands in southern Ontario (where, according to Environment Canada over two thirds of wetlands have been lost), also to restore the basin back to a pre-industrial wetland. Furthermore, the improvement in habitat conditions will contribute to the delisting of Hamilton harbour as an area of concern for the Great Lakes Water Quality Agreement. These improvements to the local environment were accomplished by improving the water and sediment quality by isolating the basin from the Parkdale Combined Sewer Outfall and Red Hill Creek, both sources of high levels of nutrients and contaminants. In addition, the project implemented capping of existing exposed contaminated sediment with 0,5 m thick clean fill to improve the water and soil quality. Planting of

native vegetation and habitat enhancement features offered improved aquatic and terrestrial habitat that will benefit a variety of birds, fish and other wildlife.

A.4.1.3.4 Economy

Construction of a channel through the basin and dredging at pier 25 will provide economic benefit to the city by allowing an ongoing dredging program that has a manageable cost, in comparison to sediment management of the entire basin at a 200 % to 300 % higher cost. Dredging at pier 25 permits more efficient dredging operations. A sediment management plan was developed that addresses the long-term requirements for meeting the city's commitments to the Hamilton Port Authority.

Additional economic benefits will also be realized through providing additional tourism opportunities. Hamilton Harbour is a well known birding area, with the existing basin being a prime location to observe a number of species. The enhanced basin, with the new diversity of habitat conditions, will offer further opportunities to see an increased variety of birds and wildlife. To facilitate this activity, a viewing area has been constructed on the east side of Red Hill Creek, which offers excellent sight lines across the site.

A.4.1.3.5 Society

The enhanced basin provides substantial societal benefits to the city and its residents. The wetland, in comparison to its existing conditions, will offer a greater variety of bird watching opportunities and will tie in to the previous work conducted by the Hamilton Waterfront Trust. The project will assist in creating a natural eastern gateway to the city and a significant positive public profile will be generated through the project.

A.4.1.3.6 Maintenance

Although the basin wetland design has been developed to minimize the amount of maintenance, regular inspections of the site will be necessary to ensure that engineering structures are in good working order. The proper operation of the wetland will also require some maintenance to manage the ecology along with potential invasive species such as phragmites and common carp. In addition, a monitoring program has been developed to ensure ecological sustainability and allow for an adaptive management strategy.



a)



b)



c)



d)

Figure A.9 — Overview of Windermere Basin

Representative images in [Figure A.9](#) provide a bird's eye view of the basin itself and the principal features, a pictorial image of the foreshore and images of two of the key transitional activities.

A.4.1.4 Organization

City of Hamilton.

A.4.2 Planning effective stormwater management measures in Ottawa

A.4.2.1 Background

Many cities face significant land use changes over the years from forest, to agriculture, to a predominantly urban/suburban character, often exacerbated by changes from low density residential/commercial to high density with infilling. As a result, there is the potential for flooding within the area and the possibility of unmanaged stormwater runoff into adjacent water systems. The question is "how to introduce effective stormwater management where the evolving land use pattern does not have appropriate designs and infrastructure?" The city of Ottawa decided to examine alternative SWM solutions through the development of a SWM retrofit plan in its Pinecrest Creek and Westboro Beach area.

The Ottawa River Action Plan (ORAP) of 2010 governs the issue. It has two key objectives: a) optimize recreational use and economic development of the river, with a focus on reducing beach closures; and b) maintain a healthy aquatic environment within the river.

It was noted among other things that urban development has greatly increased imperviousness and drainage efficiency (resulting in increased flooding and erosion within the Pinecrest Creek corridor); transportation, infrastructure and recreational uses have encroached into the creek corridor (constraining its ability to adjust to changes in flow regimes and increasing risk of infrastructure erosion and flooding); Pinecrest Creek has been disconnected from the Ottawa River due to piped sections (resulting in an extremely limited fish population); and the separate storm sewer outfalls upstream of Westboro Beach were identified as key contributors to “wet weather” bacterial contamination during and after rainfall events (resulting in closures of about 30 % of the swimming season (mid-June to late August)).

An extensive initial public consultation was carried out which identified three key themes:

- 1) The city must address impacts of uncontrolled stormwater runoff as well as combined sewer overflows (CSOs). Several ORAP projects address urban stormwater; however, it is recognized that stormwater pollution is as important an issue as combined sewer overflows.
- 2) Residents and businesses must take responsibility for their discharges to the environment (i.e. source control). At present, the city needs a communication plan for improving awareness of, and action on, water environment issues at the community level.
- 3) A watershed approach is needed to ensure that the full range of pollutant sources and impacts are addressed.

Further public consultation took place during the Pinecrest Creek/Westboro retrofit study.

A.4.2.2 Purpose

The purpose was to recommend what stormwater management techniques to apply in the study area that would provide the best solution considering a number of economic, environmental and social factors.

A.4.2.3 Outline

A retrofit study was the first step and identified a potential long-term plan comprising a range of programs, capital projects and outreach efforts aimed at reversing or partially reversing the historical impacts of development on Pinecrest Creek and local reach of the Ottawa River (Westboro Beach). The study area is almost completely developed, with only minor undeveloped areas remaining. It comprises:

- 18 849 households;
- 227 hectares of existing pavement/concrete;
- 272 km of streets.

Of the original 4 km of creek bed, only 2,5 km remain open, the rest being enclosed in pipes.

SWM drainage system retrofit measures are categorized by the location where they operate and include:

- Lot level: These are located at the source of runoff and function to reduce the amount or volume of rainfall that runs off and to prevent pollutants from being picked up and conveyed off the lot.
- Conveyance: The means by which stormwater runoff is transported from one location to another.
- End-of pipe measures: Larger-scale facilities that receive the accumulated runoff collected by the conveyance system.
- Stream rehabilitation: These measures are undertaken when the implementation of retrofit measures within the watershed is not sufficient to address erosion and stability impacts.

To develop the retrofit plan, key steps (consistent with Municipal Class Environmental Assessment requirements) had to be undertaken:

- i) Setting the stage: identifying existing conditions and SWM retrofit potential.
- ii) Establishing scenarios for retrofit options and selection of the preferred scenario.
- iii) Public consultation and communications.
- iv) Preparation of an implementation and monitoring plan.

Five implementation scenarios were examined, evaluated and ranked according to predicted abilities to meet the objectives and targets: existing conditions – or “do nothing”; highest practical implementation (without end-of-pipe facilities); highest practical implementation (with end-of-pipe facilities); moderate implementation (of highest practical implementation); and a public-property-only implementation.

The retrofit plan objectives, consistent with the overall goal of a healthier creek and river and reduced closures at Westboro Beach, are as follows:

- 1) Reduce flood risks to public health and safety and to property along the Pinecrest Creek corridor.
- 2) Reduce erosion impacts in the Pinecrest Creek corridor that are detrimental to property, infrastructure and stream habitat.
- 3) Re-establish a more natural hydrologic cycle for the Pinecrest Creek sub-watershed.
- 4) Improve water quality in Pinecrest Creek and the Ottawa River by reducing the impact of stormwater runoff.
- 5) Reduce the impacts of stormwater runoff on Westboro Beach.
- 6) Protect, enhance or rehabilitate natural features and functions along the Pinecrest Creek corridor.
- 7) Increase public awareness about stormwater management and public involvement.

Associated targets (i.e. numerical benchmarks) were assigned to each objective to represent the desired condition to be achieved.

The five retrofit scenarios considered comprised different combinations and amounts of lot level, conveyance and end-of-pipe measures that would be retrofitted into the existing rights-of-way, open spaces, and a proportion of public and private properties within the study area. The list of measures included in the different retrofit scenarios were:

- lot level: downspout disconnection/redirection; rain barrels/cisterns and rain gardens; and for sidewalks and parking lots, porous/permeable pavement/concrete;
- conveyance: street narrowing; and infiltration measures;
- end-of-pipe: wet ponds; and oil/grit separators.

The study identified a number of long-term plans comprising a range of programs, capital projects and outreach efforts aimed at reversing or partially reversing the historical impacts of development. Each of the retrofit scenarios derived encompassed a range of potential implementation levels (i.e. a greater or lesser amount of retrofit effort) for the various measures within the study area.

A primary consideration of the study was the degree of “uptake” or the extent of implementation that can reasonably be anticipated at the lot level measures on private property. Actual uptake will ultimately depend on a number of factors, for example:

- Acceptance: will the homeowner be willing to implement one or more lot level measures and will they actually do it? Will commercial establishments be willing to participate with retrofit measures when rehabilitating properties and buildings?

- Feasibility: are the lot level conditions physically suitable for the various measures considered?

The scoring method developed captured the benefits and limitations of each of the five scenarios evaluated, including the timing to implement, the degree of control likely to be achieved and the cost.

Based upon the evaluation, the “moderate” retrofit scenario was selected as the preferred retrofit plan. Although the moderate scenario did not have the highest score, it was nevertheless selected as it provided the most cost-effective overall approach – it achieved significant benefits, even if less than the two highest practical scenarios. While additional improvements were provided by the highest practical scenarios, these incremental improvements were not significantly greater and were considered less cost-effective given the required significant increase in cost to achieve them.

The moderate plan comprised:

- two rain barrels at 25 % of households (total number of households in study area = 18 849);
- downspouts redirected from impervious to pervious surfaces at an additional 7 % of households (over existing conditions);
- 48 hectares of pervious pavement/concrete on driveways, parking lots and sidewalks (total area of existing pavement/concrete in study area = 227 hectares);
- 9 km of streets narrowed by 1 m;
- 20 km of infiltration trenches;
- rain gardens at 10 % of households;
- two oil and grit separators;
- two stormwater management ponds.

A 50-year timeframe was suggested to complete implementation of the retrofit plan to allow for retrofits within the rights-of-way and on city-owned properties to be completed “opportunistically,” i.e. when roadways, city buildings and parking lots come to the end of their life cycle. This timeframe also recognized the considerable challenge of engaging sufficient participation from residential and other private property owners. The estimated 50-year life cycle cost of the preferred retrofit plan is \$43M.

The retrofit plan includes a monitoring plan intended to track the effects and to assess the overall progress in achieving the objectives and targets. The monitoring program has eight components (flood risk, erosion of channels, aquatic habitat, hydrologic cycle, water quality, natural features, SWM retrofits and development intensification). Within each component, there are designated indicators and a recommended frequency for recording the indicator data.

The retrofit plan is in the process of being implemented (2019). It is expected to take several years before a significant number of retrofit measures are implemented.

Because the selected retrofit scenario assumes considerable uptake by private property owners, continuing public awareness campaign will be essential to achieving the desired uptake. Implementation of the public awareness program has begun.

A.4.2.4 Organization

The city of Ottawa.

A.5 Denmark — Dynamic control in Kolding

A.5.1 Background

Kolding is a medium-sized Danish city with approximately 60 000 inhabitants and with a seaport facing Kolding Fjord reaching out to the Little Belt between Jutland and Funen ([Figure A.10](#)).

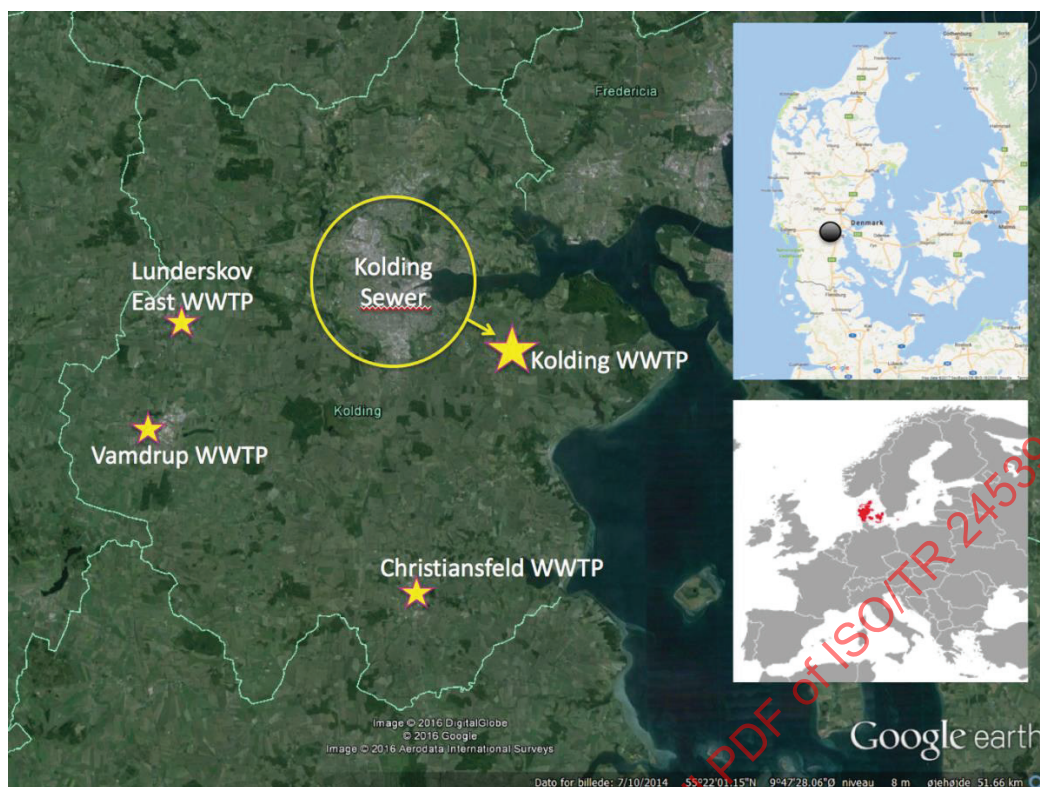


Figure A.10 — Geological location of Kolding municipality

Kolding Municipality is conscious of the environmental and recreative values of streams and bay waters ([Figure A.11](#)).



Figure A.11 — Views of Kolding municipality

The wastewater system is managed by the wastewater utility company. It is a 230 km combined network with 18 combined sewer overflow (CSO) structures.

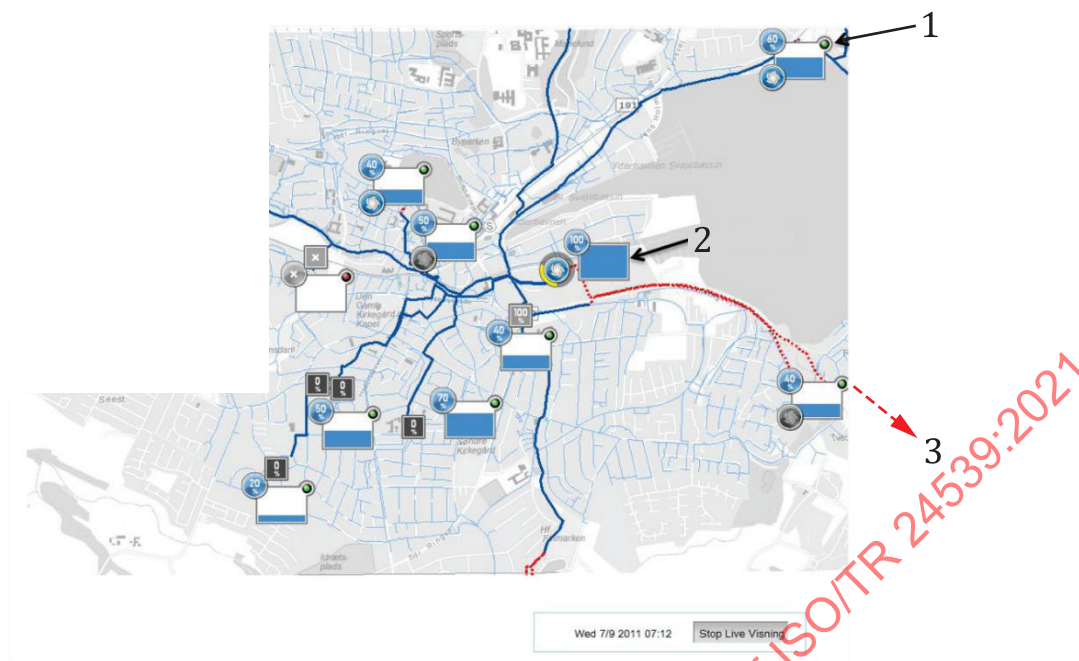
A.5.2 Purpose

In the context of the rehabilitation of the harbour area, Kolding municipality had to reduce, by 2012, CSO volumes discharged to the bay to half the amount (from 150 000 m³ to 75 000 m³) and to reduce the frequency of CSO occurrence by two thirds (from 35 to less than 10).

The original project proposed to meet these goals was through the construction of a combined sewer storage tank of 6 000 m³ at the harbour near the city centre. An alternative solution using a dynamic control system was finally chosen because it significantly lowered the capital investments, reducing the required storage tank volume to 3 000 m³, while still meeting the required level of service.

A.5.3 Outline

The dynamic control system controls the operation of the gates, weirs and pumps in the combined sewer network, to maximize the utilization of the available storage volumes, the sewer network transport capacity and the wastewater treatment plant capacity in order to reduce the combined sewer overflow ([Figure A.12](#)).



Key

- 1 STAR active at location? green = yes, red = no
- 2 basin “forrens”
- 3 kolding WWTP

Bassins

-  the filling of each retention basin is shown from 0 % to 100 %
-  when overflow, the background changes to yellow

Pumps

-  pumping station is active
-  pumping station is not active

Gates

-  the opening of of each gate is shown from 0 % to 100 %
-  gate closed (0 % open)

Communication is missing

-  a white “x” on grey background indicates missing data

Figure A.12 — Sewer network system in Kolding municipality

It does so by combining real-time data from the sewer network with rain and flow forecasts, thus identifying optimal settings for weirs, gates and pumps within the network. At the core of this innovative technology is a continuous dynamic overflow risk assessment that uses a genetic algorithm to minimize the total expected environmental impact.

By choosing the dynamic control system, Kolding municipality was able to successfully meet its environmental performance goals at a capital investment cost 22 % lower than originally anticipated.

The additional storage volume was reduced to 3 000 m³ instead of 6 000 m³ through the implementation of a dynamic control system along with online sensors, the installation of moveable gates and online communication.

A.5.4 Organization

Kolding municipality.

A.6 Great Britain

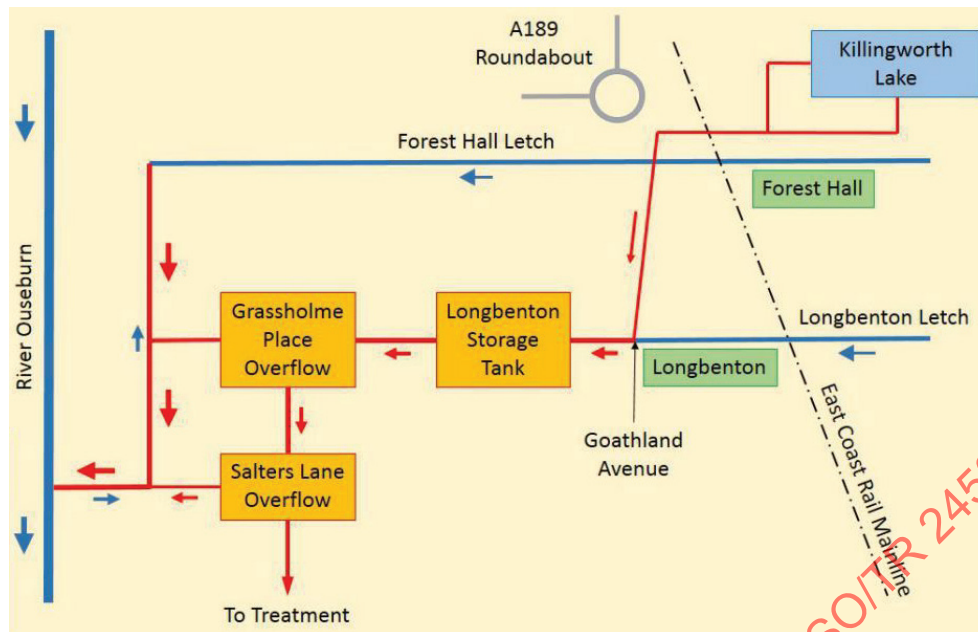
A.6.1 Disconnecting stormwater from the combined network in Killingworth and Longbenton, North Tyneside, England

A.6.1.1 Background

There is a long history of stormwater flooding in North Tyneside, though it was the severe rainfall event of June 2012 that captured the attention of national media, politicians, local communities, businesses, government bodies and local authorities. Hundreds of residents and businesses across the area reported internal flooding and transport systems became gridlocked as everyday life ground to a halt. The social, environmental and economic costs are still being counted today.

This led to increased pressure on the flood risk management authorities (RMA) to identify, justify and implement a coherent plan for flood risk management into the future. It is accepted that it is impossible to guarantee that flooding will never happen again but there is a clear expectation that the responsible authorities will work together to minimize the impacts on society and the environment.

The flood risk originates as a consequence of an overall incapacity within the drainage system during storm events resulting in fluvial, highway and sewer flooding. The incapacity is exacerbated when flows are high in the Ouseburn River which then impacts on the effectiveness of those drainage systems interacting with it. [Figure A.13](#) demonstrates the complex interactions between the drainage systems in the area.

**Key**

— open watercourse

— in pipe

Direction of flow

— small

— medium

— large

Figure A.13 — Schematic of the interactions between the drainage systems

The consequences of the incapacity during stormwater events are:

- Flood risk to 3 594 properties (over 500 reported incidents).
- Disruption to strategic transport links in the area, affecting access to residential areas, local business parks and access in and out of Newcastle City centre. This has an adverse cost to commuters and employers, thus impacting on the local economy.
- Increased levels of stormwater entering the combined sewerage system which are then passed forward to the sewage treatment works.
- Combined sewer overflows discharging to the Ouseburn River which are contributing to its current status as moderate in the European Union Water Framework Directive classification. The aim is to achieve good status by 2027.
- Inability of the existing drainage system to accommodate future growth and climate change.

The integrated nature of the drainage system meant that it was not practical to assign responsibility for managing the flood risk to a single RMA and a collaborative approach was required. The RMAs therefore agreed to the joint delivery of an integrated drainage project to fully understand and quantify the problem, identify the opportunities and benefits associated with a collaborative approach to risk management and deliver a coherent risk management plan for the area.

A.6.1.2 Purpose

The overall objective of the collaborative approach was to use innovative and sustainable approaches to stormwater management to produce a design that reduces flood risk while fitting in well with the local communities, adding to the amenity and biodiversity of the area and accommodating future growth and climate change.

A.6.1.3 Outline

A.6.1.3.1 The scheme

The philosophy adopted for this project was one of stormwater management good practice in accordance with the SuDS Management Train, essentially looking to deal with surface water as close to the source as possible. Construction of the scheme began in August 2016 and is due to be completed within 3 years. [Figure A.14](#) highlights the three principle components of the scheme and how they fit strategically to deliver the project objective.

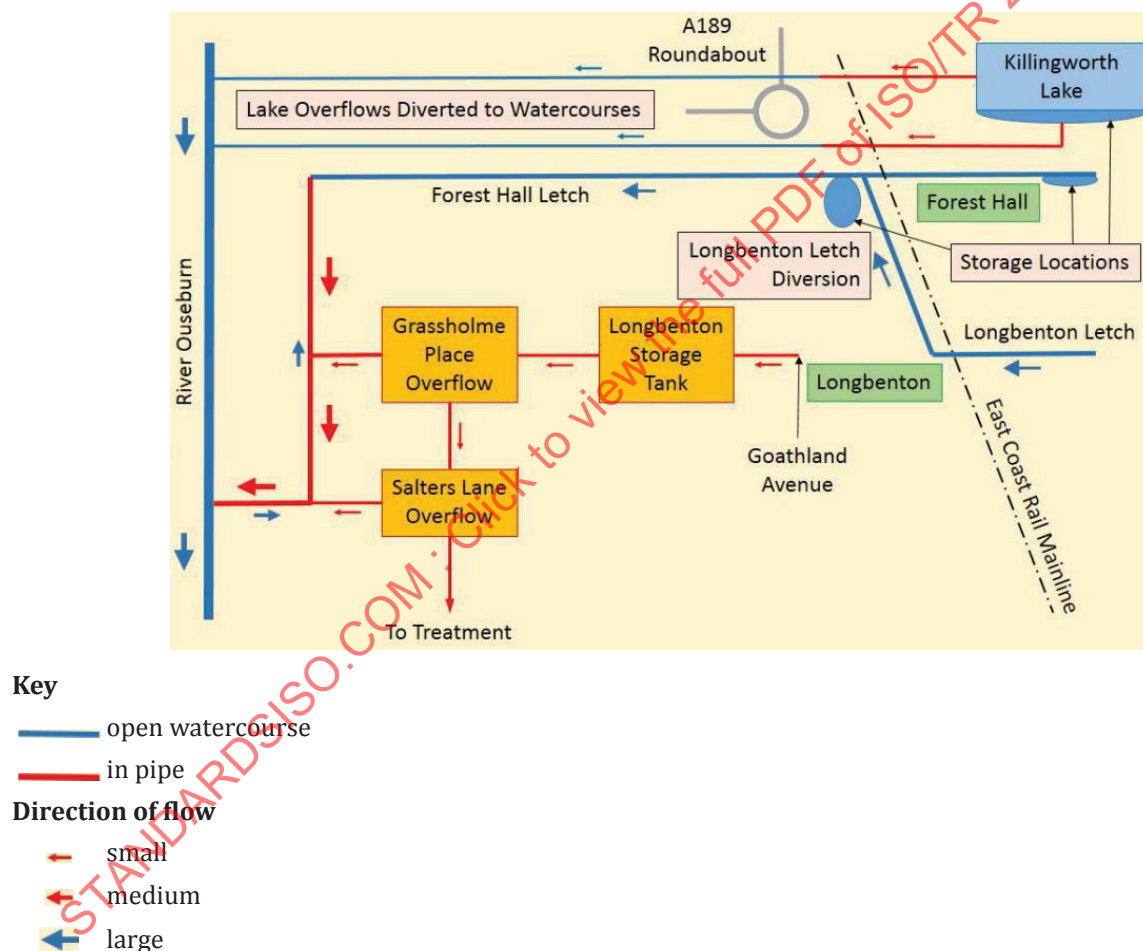


Figure A.14 — Schematic of the components of the scheme

The three principal components of the scheme are:

- 1) The removal of Longbenton Letch (main river) from the combined sewer by diverting the flows northwards into the adjacent Forest Hall Letch (main river). Due to topography and land use, part of the route passes beneath a cemetery. The chosen option is to use 700 m of 1 200 mm diameter concrete pipes.

- 2) To enable Forest Hall Letch to accommodate the additional flows from Longbenton Letch, without increasing flood risk, stormwater attenuation features are required at two locations. Firstly, a managed flood plain, or two-stage channel, is required at the upper reaches of Forest Hall Letch. [Figure A.15](#) shows a cross-section of the managed flood plain and [Figure A.17](#) shows the completed managed flood plain.

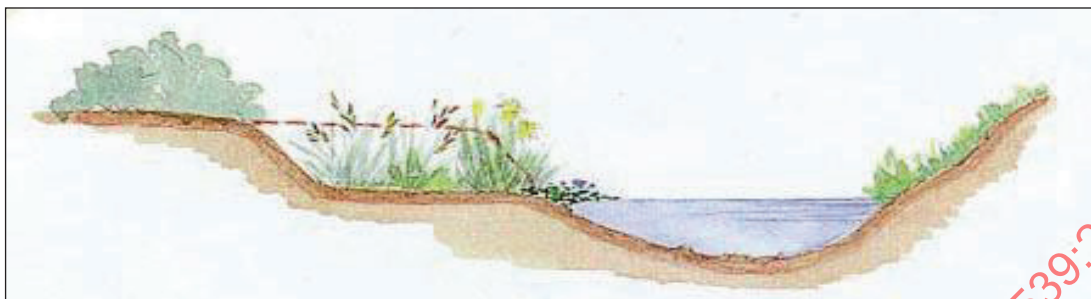


Figure A.15 — Managed flood plain in the upper reaches of Longbenton Letch

These areas provide over 5 000 m³ of storage and form part of the Killingworth Moor Drainage Master Plan, designed to facilitate future housing growth on adjacent land. Secondly, an 'amphitheatre' style detention basin (see [Figure A.16](#)) and a managed wetland, situated within the grounds of Longbenton Community College, provides an additional 5 000 m³ of storage.



Figure A.16 — Amphitheatre detention basin

The design was created through a detailed engagement process with the college and best meets their requirements for future land use and supports the education curriculum.

- 3) Killingworth Lake is a large artificial stormwater storage area that is central to community activities within the area, with various clubs and community groups using the lake on a daily basis. Detailed engagement with these bodies identified an exceedance area to the south of the existing lake as a preferred option for removing the overflows from the lake out of the combined sewer. This attenuation area has a capacity of 12 000 m³ with the overflow connecting back to the natural environment via a section of concrete pipework to an existing watercourse.

A.6.1.3.2 Benefits

A.6.1.3.2.1 General

The benefits accrued as a result of this scheme can be grouped into three categories: social, environmental and economic.

A.6.1.3.2.2 Social

- Reduced probability of flooding to all 3 594 residential properties ([Table A.3](#)).

Table A.3 — Flood risk

Deprivation index	Flood risk		
	Very significant	Significant	Moderate
20 % most deprived areas	145	70	187
60 % least deprived areas	1 972	544	676

Particular attention is drawn to the improvement in number of properties within the '20 % most deprived areas' where the residents are likely to be less able to take individual action to mitigate flood risk.

- The scheme reduces flood risk to the Killingworth, Longbenton and Forest Hall areas, helping to alleviate stress and health-related impacts to the residents. The scheme supports an improvement in the health and wellbeing of the community by:
 - engaging the community in the design process to deliver features that enhance the local amenity and are accepted by the community;
 - reducing the levels of stress and health-related impacts associated with flood risk;
 - providing multi-use spaces that can be used for recreational purposes when not attenuating/storing stormwater;
 - creating closer and more trusting relationships between RMA and communities;
 - improving public awareness of stormwater issues and the role we all have in providing a sustainable approach to its management – this is epitomised within the educational opportunities from the creation of the attenuation and wetland areas within Longbenton Community College;
- Reduction in disruption to traffic movement.

A.6.1.3.2.3 Environmental

- Creation of 3 hectares of water-dependent habitat.
- Water quality improvement assisting movement from moderate to good European Water Framework Directive status of the Ouseburn by providing a:
 - reduction in peak flows and sediment transportation;
 - reduction in combined sewer overflow spill volumes by approximately 82 000 m³ per annum.
- Reduction in energy usage and associated carbon footprint with a reduction in flow of 477 330 m³ of stormwater per annum to the sewage treatment works.
- Alignment with and supporting delivery of the biodiversity action plan for the area.

A.6.1.3.2.4 Economic

- A collaborative approach with shared resources has allowed this scheme to happen. Without this partnership approach the scheme would have been unaffordable.
- The CIRIA Benefits Estimation Tool – valuing the benefits of the blue-green infrastructure, BeST which builds upon the ecosystem services approach to the evaluation of benefits identified total benefits in excess of £51m. This indicates a benefit/cost ratio of 10:1.

- The reduction in storm flow to treatment equates to the foul flow only equivalent from 3 363 properties. This 'headroom', combined with the new stormwater management features can now be used to facilitate new development and housing growth, which brings wider economic benefits to the region.

A.6.1.3.3 Performance targets

The scheme is designed to accommodate rainfall events with a return period of once in 40 years for the sewerage system and once in 100 years for surface water ([Table A.4](#)).

Table A.4 — Technical information

Design criteria – return period	40-year sewer flooding protection 100-year surface water flooding protection
Design criteria – duration (worst case)	M100–30 (100 years return period, 30 minutes duration) 900 w (900 minutes winter storm), 1 440 w (minutes winter storm)
Design criteria – runoff	New UK runoff was used with antecedent API30 (Antecedent Precipitation Index) values of 14,2 mm and 9,8 mm for winter and summer (soil class 4) Fixed runoff coefficients 70 % for roads, 85 % for roofs
Asset-related solutions	12 000 m ³ exceedance basins 10 000 m ³ attenuation controlled by throttle pipes 340 m overflow in pipework from lake to alternative water-course 33 847 m ² wetland 701 m transfer of watercourse flows from Longbenton Letch to Forest Hall Letch in 1 200 mm diameter culvert
Non-asset-related solutions	Economic growth opportunities Community engagement and involvement Corporate responsibility opportunities
Investigations	Integrated drainage model built in commercial software Manhole surveys Topographic surveys Ground model build from LiDAR and topographical surveys Geotechnical bore hole data Services information Asbestos surveys Ecology reports including tree and bat surveys
Landscape publicity figures and drawings	Landscaping photos used for publicity attached and link to drawings.



Figure A.17 — Completed managed flood plain at Kilingworth and Longbenton

A.6.1.3.4 Population

The catchment area is measured as 1 111 hectares with a population of 39 150 people based on a property occupancy rate of 2,4 persons per property.

A.6.1.4 Organization

The flood risk management authorities for this area collectively established the Northumbria Integrated Drainage Partnership (NIDP) to facilitate the project. The NIDP is an innovative partnership working initiative, with the local environmental agency, the local water and sewerage company for the area and North Tyneside Council as the lead local flood authority working closely together to develop an integrated approach to reduce flood risk and implement sustainable drainage in the northeast of England. The need for this collaborative effort was first identified and recommended as part of the Tyneside Sustainable Study, which was led by the local water and sewerage company to identify opportunities for better stormwater management.

A.6.2 River diversion and stormwater storage in Brunton Park, Gosforth, Newcastle, England

A.6.2.1 Background

There is a long history of stormwater flooding within Brunton Park residential estate as a consequence of an overall incapacity in the stormwater drainage system impacting on the performance of the fluvial, highway, overland and public sewerage systems.

During heavy rainfall events approximately 100 properties in this estate were at risk of flooding from multiple sources – 74 fluvial, and 61 from a combination of either the surface water or foul drainage systems. Significant flooding in 2008 ([Figure A.18](#)) served to highlight the critical interaction between river levels in the Ouseburn River and the operation of the drainage systems within the estate.



Figure A.18 — Flooding in Brunton Park

In investigating these incidents, separate studies were carried out by the members of the Northumbria Integrated Drainage Partnership to identify the best interventions to reduce flood risk in this area. A stand-alone fluvial linear flood defence was determined to be non-cost beneficial while a traditional “grey” sewer flooding solution was expensive, impractical in the urban area and less resilient to the needs of the community. The common conclusion was that investment in isolation was not the way forward to enable effective flood risk reduction for these residents.

All parties decided to enter into a partnership agreement to work together to reduce the risk of flooding in the area from all sources. The agreement allowed the organisations to share funding, jointly procure design and construction services and work together to deliver a mutually beneficial scheme.

A.6.2.2 Purpose

The overall objective of the collaborative approach was to use innovative and sustainable approaches to stormwater management in order to produce a design that reduces flood risk while fitting in well with the local communities, adding to the amenity and biodiversity of the area and accommodating future growth and climate change.

A.6.2.3 Outline

A.6.2.3.1 Scheme

The partnerships were keen to identify and implement the most appropriate sustainable approach to flood risk management while still meeting their individual business needs. This meant that the scheme would comprise “blue”, “green” and “grey” infrastructure.

The joint project team identified that diverting 360 m of the river channel to create 7 500 m³ space for surface water storage would also enable a cost effective flood embankment to be constructed (see [Figure A.19](#)).

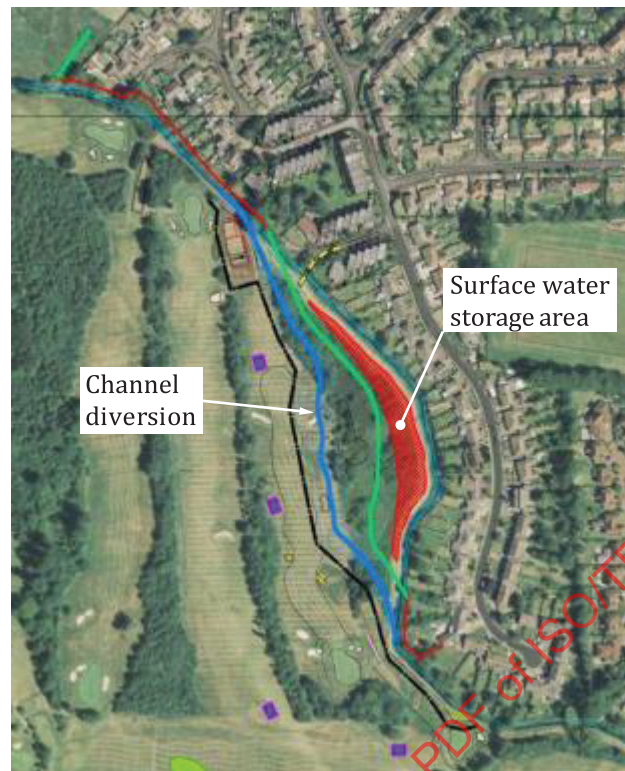


Figure A.19 — Diverted route of the Ouseburn River and storage area created from the diversion

The Ouseburn River is situated between the Brunton Park estate and the city of Newcastle golf course. Proposals for the diversion of the channel meant there would be an inevitable impact on the golf course. Initial discussions with the golf club were negative with the club objecting to the scheme on the grounds of disruption and associated financial risk.

Understanding their reservations was critical to the progression of the scheme. A mitigation plan was developed to address the club's major concerns. The plan included the appointment of an international golf course designer who integrated the proposals into the existing golf course, thereby providing long-term enhancements (see [Figure A.20](#)). By listening to their concerns the partnership managed to successfully engage and embed the golf club within the project team.



Figure A.20 — View of the diverted section of the Ouseburn River next to the golf course

Elsewhere on the estate and complementary to the river diversion, the scheme included upsizing of 2,0 km of new surface water and foul sewers, a new underground foul water storage tank and further flood defence walls delivering much needed additional flood protection to the community.

A.6.2.3.2 Benefits

By far the area of greatest benefit is that of flood risk reduction to properties on the Brunton Park estate where the partnership approach has greatly enhanced the performance of the overall drainage system.

The scheme which was completed in July 2016 reduced the risk of property flooding to over 100 properties from multiple sources providing up to 200-year protection from fluvial flooding and minimum of 40-year protection from the surface water and foul systems. By utilizing the additional capacity in the new channel, river levels were managed so that properties that have previously experienced flooding were protected during significant storms in January 2016.

The sustainable approach also provided the opportunity to enhance biodiversity by creating 3 000 m³ of water dependent habitat and associated planting

The partnership scheme delivered a more effective and sustainable solution, providing a greater level of flood protection to properties, wider benefits to the community and significant environmental enhancements. The integrated scheme has been delivered at a lower overall cost than can be achieved by the individual organisations.

A.6.2.3.3 Performance targets

The scheme is designed to accommodate rainfall events with a return period of once in 40 years for the sewerage system and once in 200 years for the Ouseburn River (fluvial) ([Table A.5](#)).

Table A.5 — Technical information

Design criteria – return period	40-year sewer flooding protection 200-year fluvial protection
Design criteria – critical storms intensity	Durations of design storms considered range from 15 min to 8 h for the sewer network and from 15 min to 2 d for the SuDS storage area
Design criteria – runoff	Wallingford runoff has been used with fixed coefficients An antecedent depth of 10 mm has been used
Asset-related solutions	The scheme includes 2 000 m of new or upsized pipes of 150 mm to 825 mm diameter A foul pumping station with local storage and a weir overflow has been constructed Surface water is discharged to a 3 000 m ³ SuDS storage area with a throttle pipe outlet control
Non-asset-related solutions and opportunities	— economic growth opportunities — community engagement and involvement — corporate responsibility opportunities

Table A.5 (continued)

Investigations	The scheme has been modelled using an integrated 1D/2D hydrodynamic modelling software (verified for Brunton Park), incorporating sewer models from Northumbrian Water and an Environment Agency river model of the Ouseburn imported from HEC-RAS The ground model is based on topographical survey and LiDAR data There have been extensive ground investigation and manhole surveys Landscaping of elements of an adjacent golf course has been critical to its success and a specialist designer was engaged for this purpose
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A.6.2.3.4 Population

The population of the Brunton Park estate is 1 266 people with an area of 58 hectares. The wider Ouseburn catchment has a population of 156 588 people over an area of 2 511 hectares.

A.6.2.4 Organization

This collaborative opportunity was first identified and recommended by the Tyneside Sustainable Study which then led to flood risk management authorities for this area collectively establishing the Northumbria Integrated Drainage Partnership (NIDP) to facilitate the project. The NIDP is an innovative partnership working initiative, with the local environmental agency, the local water and sewerage company for the area and Newcastle City Council as the lead local flood authority working closely together to develop an integrated approach to reduce flood risk and implement sustainable drainage in the northeast of England.

A.7 France — Real-time control of sewer systems for the reduction of combined sewer overflows in Biarritz

A.7.1 Background

Biarritz (25 000 inhabitants) is a city located in the southwest part of France, along the ocean. The sewer network in the northern part of the city is of the combined type and its downstream capacity is limited by the capacity of the pumping station (Port des Pêcheurs) at the inlet of the wastewater treatment plant. Two retention tanks are located in the upstream part of the catchment (Kleber and Maysonnable, with a total capacity of 34 000 m³). In the downstream part of the network, several structures offer the possibility to implement a local and reactive control of the filling of two retention tanks (Palais and Casino) for a total storage capacity of 20 000 m³.

The coastal area around Biarritz encompasses six beaches along 4 km.

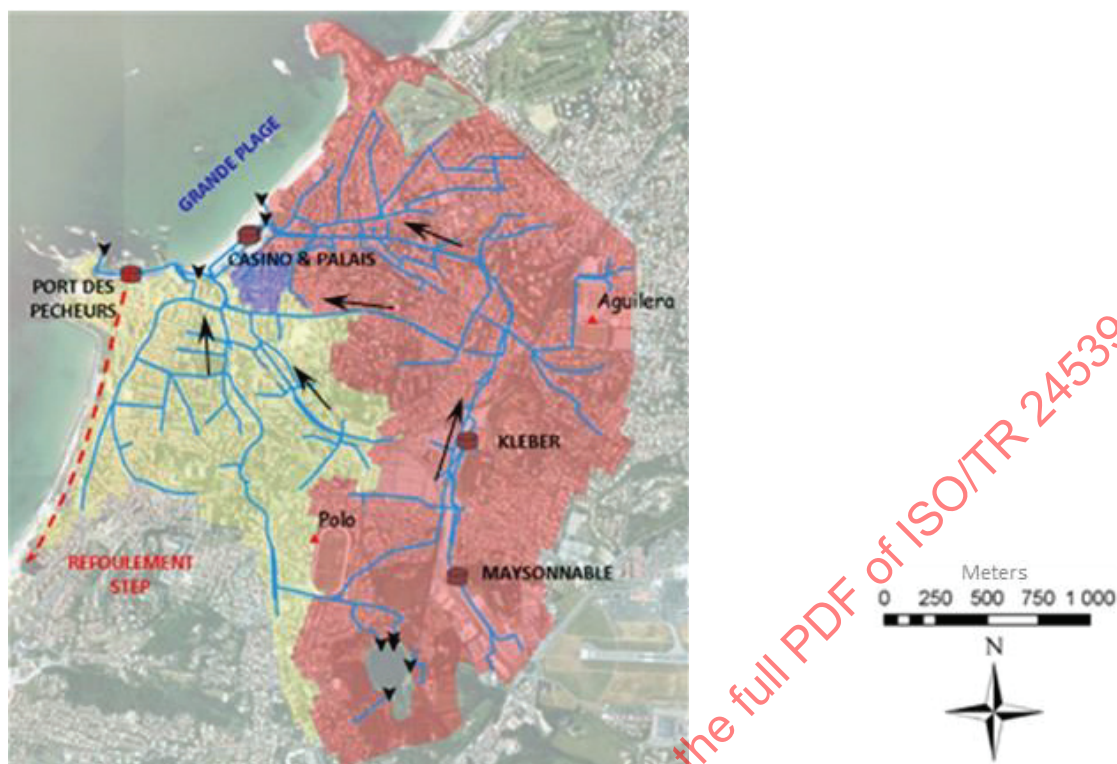
A.7.2 Purpose

Stormwater management is a major issue for the city of Biarritz considering environmental, economic and touristic stakes. The region of Biarritz ([Figure A.21](#)) is the one with the highest yearly rainfall depth in France. Its sewer network is very reactive to rainfall events that can generate combined sewer overflows near very sensitive bathing areas, as soon as the rainfall return period exceeds 1 month (design return period of the sewer network).

Within that context, the objective of the project was to implement an operational predictive real-time control (RTC) system of the Biarritz sewer network to:

- optimize the functioning of the existing structures and to maximize the filling of the retention tanks for small to medium rainfall events;

— reduce the need for building new retention tanks;
while still maintaining the same level of protection against flooding.



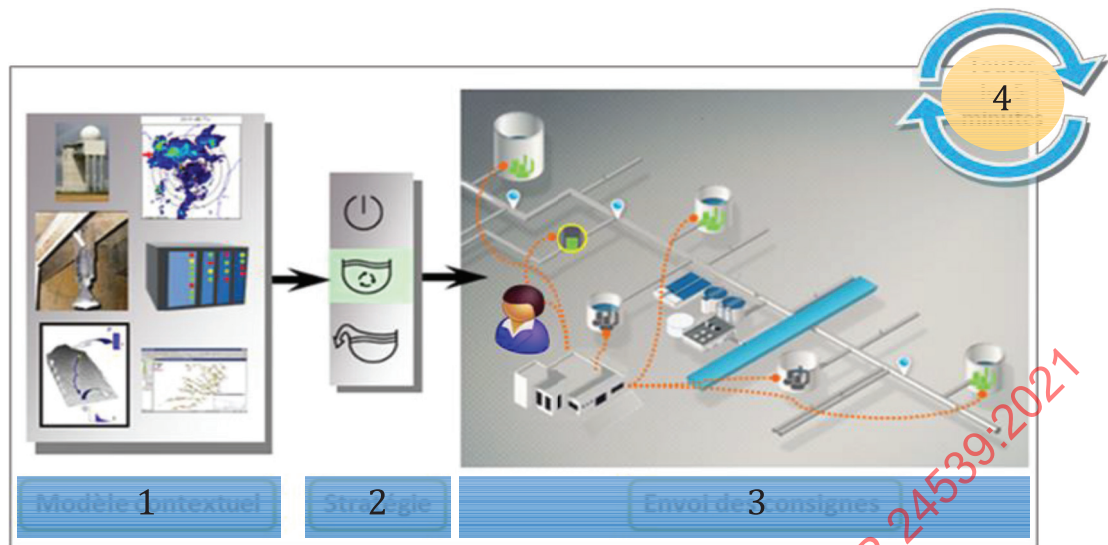
Key

-  Rain gauge
-  storage capacity
-  outfall
-  main pipe
-  north catchment
-  centre catchment
-  south catchment

Figure A.21 — Simplified scheme of Biarritz sewer system

A.7.3 Outline

The RTC system of Biarritz ([Figure A.22](#)) was developed and deployed in 2015. It has been in operation since 2016.

**Key**

- 1 contextual mode
- 2 strategy
- 3 control strategies
- 4 every 5 min

Figure A.22 — General functioning of real-time platform

It is based on a generic real-time platform. Based on local measurements (inside the network) and the rainfall forecasts provided by the French National Meteorological Office a hydraulic model and an optimization engine are run every five minutes over the coming hours to predict the functioning of the sewer network and provide optimized control strategies of storage infrastructures (retention tanks and oversized pipes).

In the case of Biarritz, all the control gates and weirs present in the network are controlled ([Figure A.23](#), Maysonnabe, Kleber, Sahel, Piron, Gardères, Palais and Casino retention tanks).

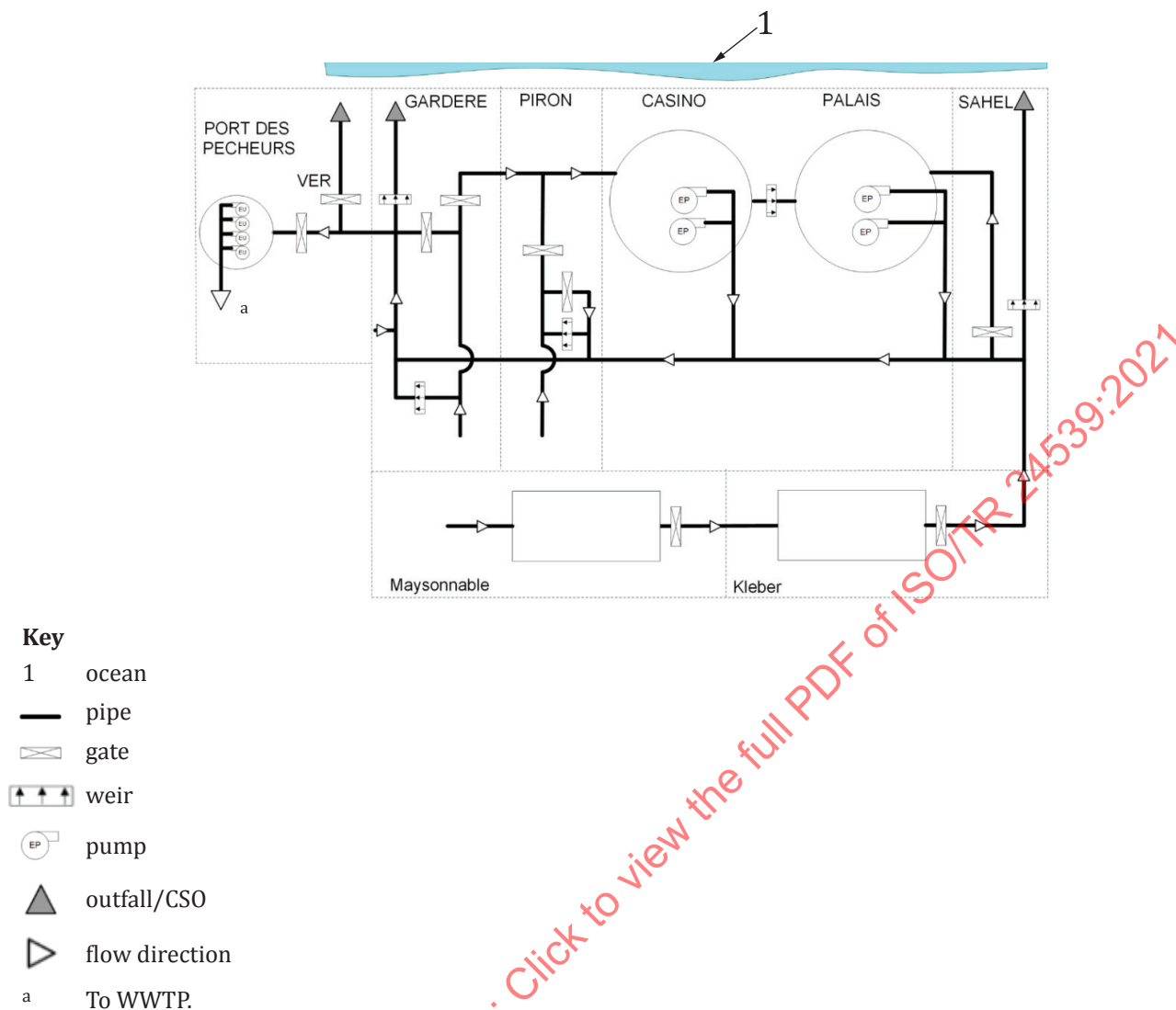


Figure A.23 — Main network and facilities of collection system

This global predictive RTC relies on three control strategies:

- dry weather: the system operates dry weather inflows;
- depollution: the system increases the filling of the storage capacities and the transport capacities to minimize combined sewer overflows while maximizing the volumes sent to the WWTP;
- flooding: this strategy is proposed to the operator when an intense storm event is forecasted or the retention tanks capacities reach their maximum capacities.

This is based on these three control strategies, updated every five minutes, that the RTC system defines the optimized control rules. These control rules are directly sent to the control structures (gates, weirs, pumping stations) through the SCADA system.

Since its deployment, the RTC system of Biarritz sewer system has allowed to reduce by 40 % the volume of effluents overflowed to the ocean. This system is part of a global and long-term approach. The building of new structures will allow to further decrease combined sewer overflows in the coming years.

The monitoring of bathing water quality also showed a significant improvement following the deployment of the RTC system in terms of bacterial contamination of water and beaches closure durations ([Figure A.24](#)).



Figure A.24 — User interface of the Biarritz RTC platform

A.7.4 Organization

City of Biarritz.

A.8 Japan

A.8.1 Implementation of a real-time supervision for stormwater facilities operation and flood risk management in Nagoya

A.8.1.1 Background

In September 2000, the Tokai District experienced the heavy rain of unprecedented severity, so-called Tokai heavy rain. In Nagoya City, the 24-h maximum rainfall reached 534,5 mm, causing sewer flooding and inundation of about 40 % of the city area. At that time, reporting of the pump operation state was not automated and the on-site operation was concentrated to prevent stop of the pumps. As a result, the status report to the main office tended to be delayed. In certain cases, quick response to the customers' inquiry was impossible.

A.8.1.2 Purpose

The main purpose is to collect information on the pump operation state, the water level in the conduit or storage facilities as rapidly as possible for utilization in the rapid and adequate response during disaster. This is in line with one of the objectives of the information communications infrastructure concept for the entire city, that is, "rapid transmission of disaster-preventive and disaster-related information." The stormwater drainage information system of the city Waterworks and Sewerage Bureau was established.

This system utilizes the sewer fibre-optic network to collect, in real time, the information critical for disaster control, such as the operation state of each pump, the water level in the inflow pipe, pump well, discharge pipe, communicating well, the still images of the receiving rivers, and rainfall data figures.

A.8.1.3 Outline

In Nagoya City, the fibre-optic network is used for the internal office system for the entire city office, such as document management. In the ward offices, the information system for residents' registration, taxation, welfare and so on is operating.

In the city Waterworks and Sewerage Bureau, the information system for remote monitoring and control as well as for design and estimation, accounting and so on is operating.

The stormwater drainage information system of the city Waterworks and Sewerage Bureau enables the staff to view, for example, the pump operating state on PC connected to the office intranet. Conventionally, the pump operation state has been confirmed by calling the pump management division via telephone. This in turn enables rapid and adequate response to the inquiry from customers and during flood fighting activities. The Fire Bureau (the disaster management headquarters of the city) and other divisions of the city office can view the pump operating state via the "Nagoya City Stormwater Drainage Information System" for utilization in the flood control activities.

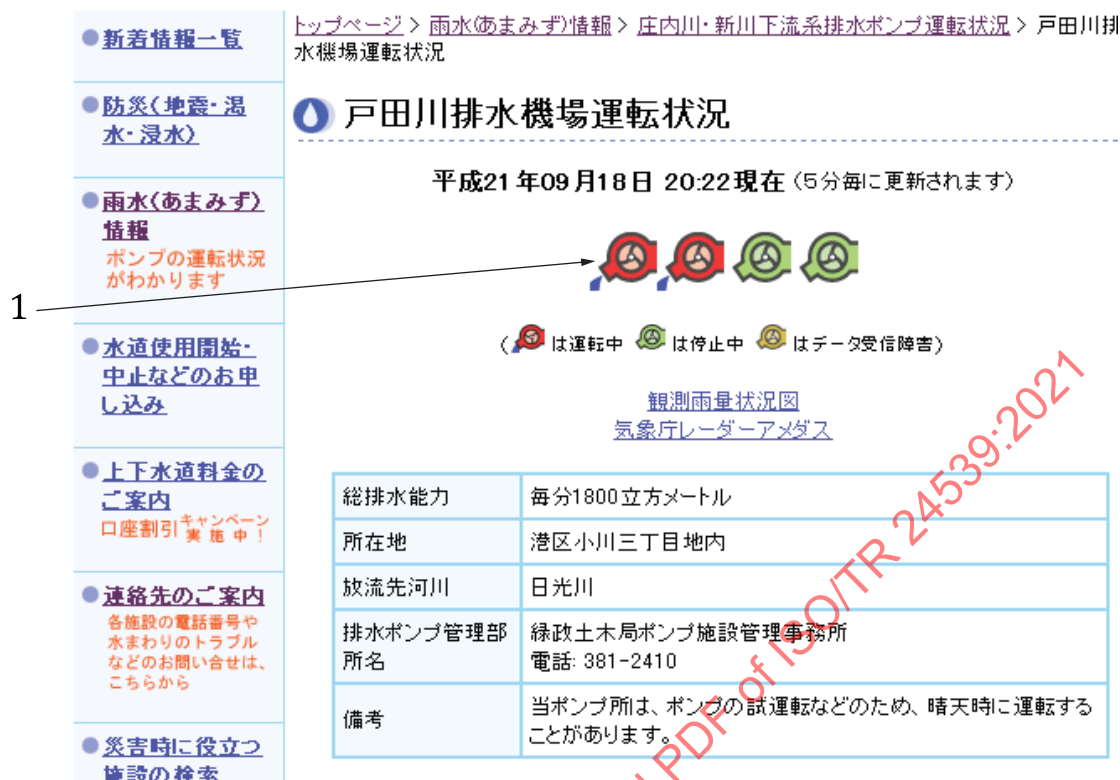
The data accumulated at present is utilized for re-evaluation and improvement of the pump operation method, conduit route, and weir height.

The Nagoya Municipality proceeds with the "Emergency Stormwater Improvement Project" for the areas where remarkable flood damages occurred during Tokai heavy rains at the end of August 2008, and the areas where urban functions are concentrated. Nagoya City is mainly enhancing the pump ability and building stormwater reservoirs based on the project. Some areas have already shown good results from these measures (Table A.6). These institutional developments are the core of flood control measures, but their achievement level is limited. Besides, large scale measures will require a long period for implementation. Accordingly, for further mitigation of the disaster in the situation where heavy rains exceeding the developed level occur frequently, the self-help and the mutual assistance of customers are vital in addition to institutional measures.

Table A.6 — Example of project effect (example of the result)

District		Yamato district, Chikusa Ward	
Measures		Installing a stormwater reservoir (Volume: 4 000 m ³)	
Date of the heavy rain		Tokai heavy rains at the end of August 2008 (before measures completed)	4 September 2013 (after measures completed)
Maximum hourly rainfall (mm/h)		95,5	94,0
Damage of the flood (number of living units)	Inundation above floor level	24	0
	Inundation under floor level	40	4

Since 1 June 2006, the Nagoya Municipality is providing a part of the stormwater drainage information system as "Stormwater (AMAMIZU) information", via the Bureau's web page, to the customers (Figure A.25). This system is designed to collect data by utilizing the sewer fibre-optic network. This page gets 10 000 website traffics per month in high season.



Key

1 showing how many pumps are working at the moment



in operation



operations suspended

Figure A.25 — Example of the webpage about stormwater (AMAMIZU) information

A.8.1.4 Organization

Nagoya city waterworks and sewerage bureau.

A.8.2 Implementation of the stormwater management strategy in Niigata City

A.8.2.1 Background

Niigata City has urban areas extending in the plain at the mouth of the Shinano River and the Agano River. The areas cover many lowlands at sea level elevation and have suffered frequent flood damages (Figure A.26). After the heavy rainfall (with the maximum rainfall intensity of 97 mm/h) on 4 August 1998, which caused above and below floor inundation of as many as 10 000 houses, the underlying level for development of the sewer system stormwater plan was reviewed. Namely, the rainfall intensity has been increased to 50 mm/h for promotion of improvement of the facilities, such as storm sewers and pumping stations. However, recent increases in localized heavy rainfall and accelerated urbanization have resulted in large volumes of stormwater runoff within a short period. There is a limit on handling of all stormwater by means of stormwater drainage only.

The Niigata municipal authorities considered the stormwater runoff control effective as a complementary approach for development of the stormwater facilities. The authorities are engaged in flood control measures while working hand-in-hand with the private sector by installing stormwater storage and

infiltration facilities inside the public facilities and by providing the subsidization scheme for the infiltration inlet and the stormwater storage tank to be installed in the residential premises.



Figure A.26 — Flood damage (4 August 1998)

A.8.2.2 Purpose

The purpose of this project is to implement the Niigata Minazuki Plan, which is the basic plan to identify the strategy for stormwater runoff control and the use of stormwater in the future, as comprehensive independent and mutual-assistance flood control measures.

A.8.2.3 Outline

A.8.2.3.1 General

The Stormwater Drainage Suppression Study Committee for the implementation of the Niigata Minazuki Plan was organized by the concerned municipal agencies. This committee undertook the preparation of the draft guideline for storm runoff control facilities for public-facilities improvement, development activities and review of the development effects.

A.8.2.3.2 Preparation of the infiltration area map

The infiltration area map was prepared as a specific means of review on installation of the storm runoff control facilities. This was considered necessary for understanding the ground conditions and drainage state of the area where installation of the infiltration facilities is necessary, including steep slopes and selection of the facilities appropriate to these factors.

A.8.2.3.3 Operation of the draft technical guideline for storm runoff control facilities

To promote wide application of the storm runoff control facilities positively, the technical guideline was drafted, which summarizes the technical requirements for planning and design up to construction of the facilities.

A.8.2.3.4 Installation of the storm runoff control facilities

To control storm runoff from the premises, installation of the infiltration inlets and the stormwater storage tanks in the public facilities as well as provision of the storage infiltration facilities utilizing the school playground are promoted. The subsidization scheme has also been implemented in which the municipality will absorb a part of installation costs of citizens for installation of storm runoff control facilities in the residential area.

By the end of 2011, the stormwater storage and infiltration facilities were installed in 65 school grounds, attempting to mitigate loads on the surrounding stormwater facilities by reducing the peak flow during rainfall. Thus, direct runoff of stormwater falling on schools can be prevented, resulting in reduction of complaints from the local citizens.

The total volume of stormwater controlled by the storm runoff control facilities in the residential areas and public facilities was about 109 000 m³, equivalent to about 380 25-m pools.

A.8.2.3.5 Establishment of the maintenance method for infiltration facilities in the residential area

More than a decade has passed since the beginning of the subsidization scheme. The next subject is maintenance of the infiltration facilities installed in the residential areas. The infiltration inlets with long elapsed years may possibly suffer deterioration of the infiltration function due to blocking of the infiltration layer. For maintenance of the infiltration facilities in the residential area, the adequate maintenance method must be established because it tends to be outside the reach of, for example, administration and cleaning, and tends to be totally dependent on the installer.

In Niigata City, the field test was conducted using the existing infiltration facilities in the residential area for the purpose of verifying these facilities, such as reviewing recovery of infiltration effects by means of cleaning, identification of the causes responsible for deterioration of the infiltration capacity and so on. The questionnaire survey was also conducted for installers, surveying the maintenance state of infiltration inlets in the residential area.

A.8.2.3.6 New challenges toward mitigation of flood damage

In Niigata, the focus is placed on the support for the self-help measures taken by the citizens to reduce the flood damage, in addition to promotion of the storm runoff control measures. The waterproof plate installation subsidization system was started in 2008 and the house raising subsidization system was started in 2009. In 2011, the subsidization system was expanded by raising the subsidization ratio in response to flood damage due to the Niigata Fukushima heavy rains.

A.8.2.4 Organization

Niigata city sewerage bureau.

A.8.3 X-band radar observation and forecast for stormwater and flood risk management in Osaka City

A.8.3.1 Background

In recent years, concentrated heavy rainfalls of more than 50 mm/hour called “guerrilla squalls” (local, sudden, intense and short-term rainfalls) have occurred more frequently. This has led to more widely reported overflowing riverbanks and flood damages. For example, the drowning incident in the Toga River in Kobe’s Nada ward and the record-breaking 77,5 mm/hour rainfall recorded in Osaka on 27 August 2011 (announced by the Osaka Regional Headquarters of the Japan Meteorological Agency) are novel events in the public memory.

In Osaka, 90 % of the city’s geographical area requires pump drainage to drain rainwater, meaning that flood prevention measures are an extremely important policy issue. One element of these measures involved the installation of independent radar and application of pump operation support, but due to facility deterioration, upgrades were required.

High-resolution radar with a high update frequency is needed to predict the guerrilla squalls that occur locally and suddenly. A radar using C-band (frequency 4 to 8 GHz, wavelength 37 to 75 mm) capable of detecting the range of about 200 km radius at intervals of 5 minutes has already been installed by MLIT (Ministry of Land, Infrastructure, Transport and Tourism), but in order to capture the guerrilla squall, its update frequency and resolution were insufficient.

A.8.3.2 Purpose

The original X-band (frequency 8 to 12 GHz, wavelength 25 to 37 mm) radar system was installed on the roof of the Oak Building in Bentencho. It began operation in 1993, and was useful for pump operation support. The original system used short-wavelength electromagnetic waves known as X-band waves, but it was easily affected by rain attenuation. Due to this, at times, the system recorded less rain behind areas of heavy rainfall than was actually present.

Therefore, in accordance with updating of this radar, it was necessary to develop and install a new radar which is not easily influenced by rain attenuation, has sufficient update frequency and resolution, and more efficient pump operation control.

A.8.3.3 Outline

A.8.3.3.1 Development of new radar

Earlier types of radar emit only horizontal single-polarized waves of X-band. However, the new radar was designed to emit two types of radio waves in the horizontal and vertical directions in order to limit the impact of rain attenuation. With this dual polarized wave, strong rainfall observation became possible, and observation accuracy also increased. In addition, observing changes in the raindrops, and as a result, quantitative observation of rainfall became possible. This dual polarization radar is also called MP radar.

Correction by the ground rain gauge was indispensable for the X-band radar before updating and many ground rain gauges were necessary, but the new X-band MP radar will possibly come to demonstrate sufficient precision with a smaller number of ground rain gauges.

The observation range of the installed X-band MP radar is 80 km radius, the update interval is 1 min, and the resolution is 250 m mesh.

A.8.3.3.2 Utilization of radar observation data

Measurement data from precipitation radar is sent to central monitoring rooms for sewage treatment plants and pump stations. The radar is used as operation support to optimize operation of water drainage pumps, and is also used as a mobilization system during disasters or at times when warnings and alerts are issued. When stormwater influent to sewage treatment plants and pump stations can be predicted in advance, pumps are put into preemptive standby operation (full capacity) and preparatory work such as turning operation of engine pumps is conducted. Furthermore, in cases where heavy rains are predicted, the water level in pump wells is reduced to a low level to prepare for a sudden influx of stormwater. At the Department of Construction, precipitation data are transmitted along with information on circulation pumps, stormwater drainage pump operation, river water levels, and the closing or opening of sluice gates. Previously, the Department of Construction had an independent network to transmit precipitation data internally, and this information was transmitted to dedicated terminals installed in monitoring rooms at sewage treatment plans and pump stations. However, following the upgrade, data are sent to the notebook computers used for everyday duties using the existing departmental network. This obviated the need for the independent network and dedicated terminals, resulting in reduced maintenance costs.

Precipitation data are not only transmitted within the Department of Construction, but are also transmitted to citizens via the internet and fax. Because time was required for information processing, within the Department of Construction, data were updated once every two minutes, while data transmitted to citizens were updated every 10 min.

Following the upgrade to the precipitation radar, data transmitted to citizens are updated by the minute, and rainfall intensity is expressed verbally in four levels, "violent rain," "heavy rain," "moderate rain," and "light rain," and numerically in eight levels. Information is sent to citizens over the internet and mobile phone networks, and when alerts or warnings are issued regarding heavy rain, faxes of precipitation data are also sent to registered members. Precipitation data are sent out as self-help

support, and underground and low-lying areas are evacuated first, or protected with sandbags. Sandbags are loaned out by the Department of Construction's Engineer Management Office.

In addition to the Kinki region (within 80 km), Osaka Prefecture (within 40 km), and Osaka City (within 20 km), precipitation information is also distributed for each administrative district. Based on river, railroad, and highway information, each person can easily check the precipitation status at his or her current location. Though rain movement is not predicted, a history function has been added, allowing users to predict rain movements for them to a certain extent by viewing the rain movement history.

For internal sewer pipe work, the status of the mains can be checked, so construction can be halted if rain is detected upstream. Long pipe extensions may not show immediate changes when rain begins to fall, so care must be taken. Lighted billboards are installed near easily flooded areas such as riverbanks and underpasses, to make warnings and alerts more visible. Currently, warnings are issued based on measurements from water level gauges installed nearby, but in the future, rainfall prediction and detection will enable warnings to be issued earlier. It is hoped that application of precipitation radar will allow early detection of upstream rainfall, making damage control possible.

A.8.3.3.3 Future issues

To improve measurement accuracy, actual measurement data was verified in 2012. Another future application of X-band MP radar data under consideration is sewer pipe influent forecasting. It is expected that by combining this with precipitation forecasts, pump operation can be optimized. The new radar is useful not only for flood protection, but also for measuring total rainfall and total inflow, enabling improved confluence operation through retention operation when mains have room to spare. However, the possibility of a guerilla squall occurring during retention operation poses a risk, so retention operation should be conducted with a certain margin of error. It is also hoped that influent forecasts will enable automated operation of rainfall drainage pumps.

To implement these applications, quantitative measurement of precipitation must be reliable, and the precision of precipitation forecasting and influent forecasting must be improved. Improvement in precision will reduce the instance of false warnings and mobilization alarms. In addition, three dimensional measurement and coordinated operation with MLIT's X-band MP radar may allow detection of the formation of sudden guerilla squalls even when no rain has been predicted enabling faster disaster control.

Future issues for X-band MP radar are precision improvement and operation method optimization.

A.8.3.4 Organization

Osaka City Department of Construction Administration Division, Facilities Section.

A.8.4 Implementation of a flood risk protection strategy in Tokyo

A.8.4.1 Background

In recent years, heavy rainfalls exceeding predictions have become more common throughout Japan, and in light of this, the Flood Control Act and the Sewerage Law were revised in 2015. These revisions establish a system for predicting, to the greatest extent possible, the regions where the highest volume of runoff and worst flooding will occur. In addition, the revisions determine flood damage control regions while soliciting private cooperation where possible in promoting flood control measures. Beyond this, runoff and flood control guidelines (known as the "Seven Stars") were set out along with the legal revisions. By identifying areas most in need of flood control measures, these guidelines endeavour to minimize flood damage by improving the efficiency of hard measures in combination with soft measures and self-help.

The first basic sewer plan for the Tokyo Metropolis was set out in 1908, and sewers have functioned in part to drain rainwater in order to prevent flooding since that time. Since 1970, sewer infrastructure has been upgraded to manage rainfalls of up to 50 mm/h. However, rainfalls exceeding predictions have been occurring frequently, and within the past 30 years, rainfalls of more than 100 mm/h have been

recorded, causing substantial flood damage. Due to this, Tokyo's Bureau of Sewerage partnered with the Bureau of Construction overseeing river work and the Bureau of Urban Development overseeing urban planning to create the "Tokyo Metropolitan Torrential Rain Measures Basic Policy," published in 2007. The policy was then revised in 2014 based on subsequent heavy rains, and measures against heavy rain are now being implemented with full force.

The policy sets a future goal of 100 mm/h rainfall, while also setting practical goals for upgrades to river and sewer infrastructure, falling mainly under the following holistic initiatives:

- Identify specific regions for river and sewer infrastructure capacity upgrades.
- Promote installation of storage and infiltration facilities, including on private land, in watershed areas.
- Implement flood control measures for underground spaces.

Implementing this policy will include fleshing out plans for flood control measures in large-scale underground urban spaces, and raising awareness of the dangers posed by flooding. Regarding initiatives to notify the public of areas where flooding is predicted in the event of rainfall in excess of 100 mm/h, and initiatives to provide information on precipitation sewer pipe water levels, the revised Flood Control Act and Sewerage Law will serve as valuable resources in adapting to the new system, as explained in detail in the next subclause.

A.8.4.2 Purpose

In order to protect human life and assets from inundation damage, hard and soft measures are gradually developed. The project is divided into three stages as it is expected that a long term and a large cost will be required until the final achievement of the project ([Table A.7](#)).

Table A.7 — Purpose by stage, target rainfall, control methods

	Purpose	Standard	Target rainfall	Control method
Stage 3	Life saving	Life saving	Extreme	Strengthen evacuation policies
Stage 2	Reduce asset damage to protect municipal functions	Prevent inundation above floor level	75 mm/h	River and sewerage infrastructure (public), housing design and urban planning measures (public and private)
Stage 1	Prevention of asset damage	Prevention of flood damage	60 mm/h	River and sewerage infrastructure (public), flow control measures (public and private)

A.8.4.3 Outline

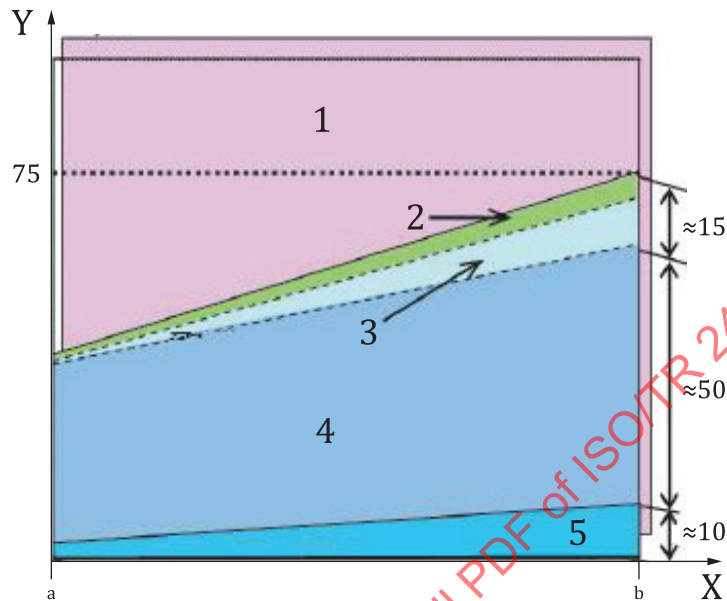
A.8.4.3.1 General

In addition to combining measures to be implemented by each major party at each phase, the policy identifies specific regions as focus points for measures. Practically speaking, this means selection of areas where precipitation and flood damage are likely to be severe, and specification of those regions as watersheds requiring stronger measures (rivers) and districts requiring stronger measures (sewer systems). River and sewerage infrastructures in these regions will be upgraded.

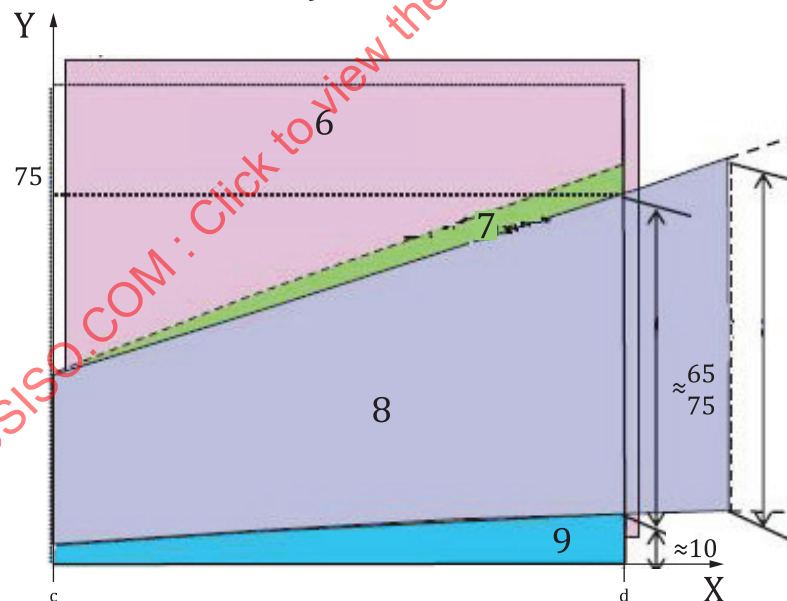
Regions where sewerage infrastructure will be upgraded include four districts requiring stronger measures to handle up to 75 mm/h, six districts requiring upgraded measures to handle up to 50 mm/h, and nine districts requiring measures for underground spaces, for a total of 19 selected regions. For areas outside of these selected regions, sewerage facilities with a capacity of 50 mm/h will be installed, and the capacity will be raised to 75 mm/h through a combination of hard and soft measures undertaken through public-private partnerships. To achieve this, in districts and underground spaces requiring upgraded measures with a capacity of 75 mm/h, sewerage facilities (public, hard) will be

upgraded to handle a capacity of 75 mm/h. Flow control measures and measures involving housing design and urban planning may be implemented in both districts earmarked for special upgrades, and in other areas. Implementation of such measures will raise the total capacity of the measures to above 75 mm/h. (Figure A.27)

Dimensions in mm/h



a) General areas



b) Regions earmarked for special measures

Key

1	evacuation measure strengthening	6	evacuation measure strengthening
2	housing design and urban planning measures	7	housing design and urban planning measures
3	river infrastructure (storage facilities)/ sewerage infrastructure	8	sewerage infrastructure (downstream facilities/ storage facilities)
4	river infrastructure (downstream facilities)/ sewerage infrastructure	9	watershed measures
5	watershed measures	X	time period
a	Time of establishment.	Y	mm/h
b	About 30 years.		
c	Current.		
d	About 30 years.		

Figure A.27 — Breakdown schematic of the role of each measure

A.8.4.3.2 Sewers with a capacity of 75 mm/h: real examples

A.8.4.3.2.1 Facility planning/design methods

Regions where infrastructure with a capacity of 75 mm/h will be installed include four urban districts and nine underground areas, for a total of 13 regions. (The name of the districts where measures will be strengthened to 75 mm/h was changed to “Urban Measure Districts” under the 2016 management plan.) When planning and designing sewer pipes with a capacity of 50 mm/h, runoff volume was original calculated using the rational runoff formula, and the cross-section of supplementary expansion pipes was calculated so that both existing pipes and planned expansion pipes would have a free water surface. In order to plan and design a capacity of 75 mm/h for this system, the capacity of existing pipes must be utilized to maximum extent. To achieve this, a runoff analysis simulation was used to calculate the dynamic water level in the pipes, and this value was used to calculate the scale of the expansion pipes and storage pipes. (Figure A.28)

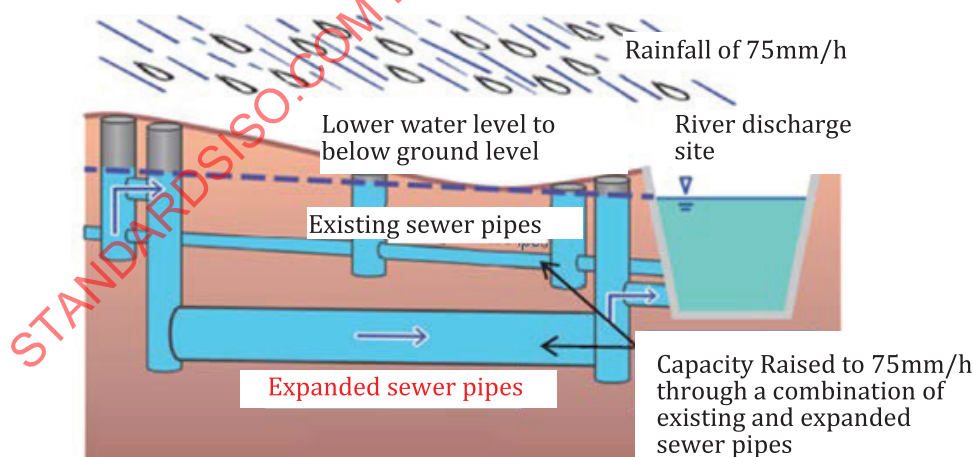


Figure A.28 — Example installation of infrastructure with a capacity of 75 mm/h

A.8.4.3.2.2 Urban Measure Districts: real example

Sengoku in Bunkyo Ward and Minami-Otsuka in Toshima Ward will be used as real life examples of Urban Measure Districts. In these regions, a second Senkawa sewer main (including two channels, one with an internal diameter of 1,7 m and one with internal dimensions of 5,0 × 3,6 m, with a total length of approximately 7,0 km) will be installed to supplement the existing Senkawa sewer main (including

two channels, one with an internal diameter of 1,0 m and one with internal dimensions of 5,3 × 3,1 m, with a total length of approximately 7,0 km) to raise capacity to 50 mm/h. The watershed area for both these mains will be approximately 450 hectares.

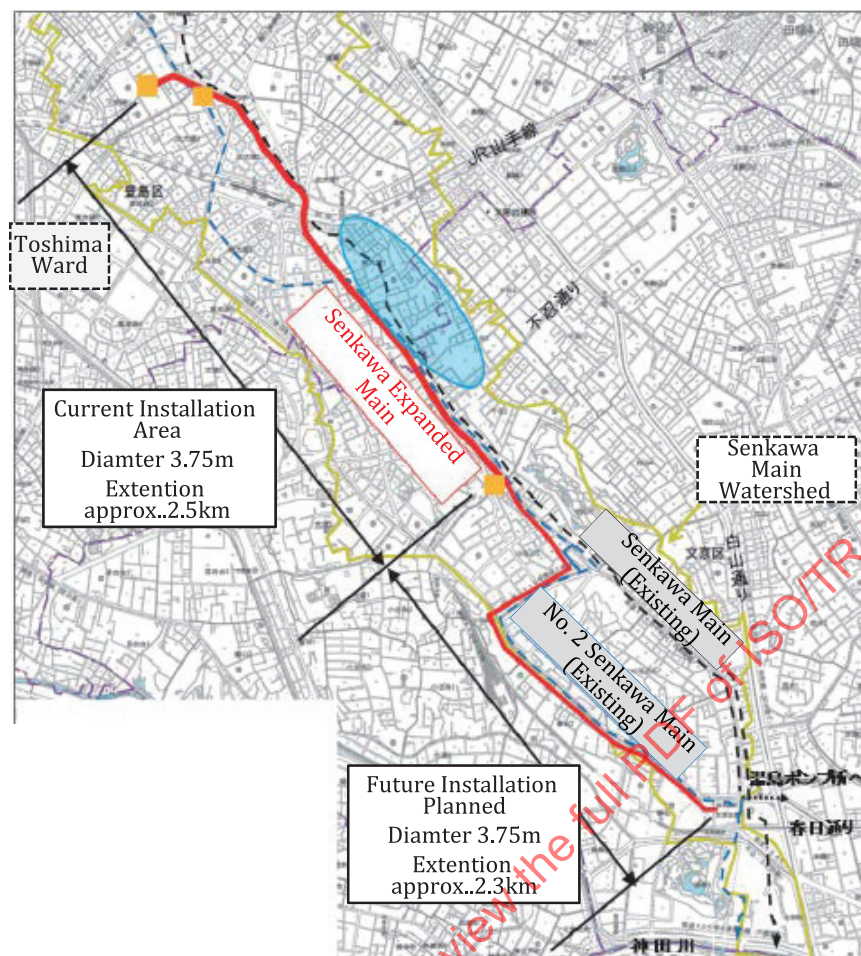
A model was created showing the existing pipes for the entire area, including branch pipes, and a simulation of 75 mm/h rainfall was conducted, to calculate the scale of expansion pipes. Expansion pipes will split the flow of rainwater with existing pipes, and the overall scale will have an internal radius of 3,75 m and an extension of 4,8 km.

In addition, restructuring work is currently underway on a portion of the existing Senkawa main, and the cross-section of this main was modelled based on the future scheduled cross-section following completion of the restructuring work.

In addition to the simulation, candidate shaft sites were selected, and after a route was considered, the overall plan was created, as shown by the red line in [Figure A.29](#).

Furthermore, since the entire plan calls for the scale necessary to handle a capacity of 75 mm/h across the entire watershed area, including the restructured existing Senkawa main and the branch pipes, it is planned that installation will be conducted in phases, with areas where measures are deemed to be most effective given first priority.

Practically speaking, areas which may experience rainfall causing severe flood damage include 2,5 km of the total 4,8 km pipe extension, and shaft excavation is scheduled to begin in 2017.



Key

- expanded main
- existing Senkawa main
- existing no.2 Senkawa main
- Senkawa/no.2 Senkawa main watershed
- shaft

Figure A.29 — Senkawa expanded main outline

A.8.4.3.3 Evacuation measure strengthening: real examples

Among the strengthened evacuation policies (soft measures) set forth in the policy for life-saving purposes, Bureau of Sewerage initiatives include the revision of predicted flood areas, Tokyo Amesh, and the provision of information on water levels in sewer mains.

A.8.4.3.4 Revision of predicted flood areas

Since 2001, the Tokyo Metropolitan Government has used the Tokai floods of 2000 as a guideline for creating a flood prediction diagram showing river overflow, sewer flooding, flood scale, and flood depth, to be used as an aid to flood damage prevention and swift evacuation.

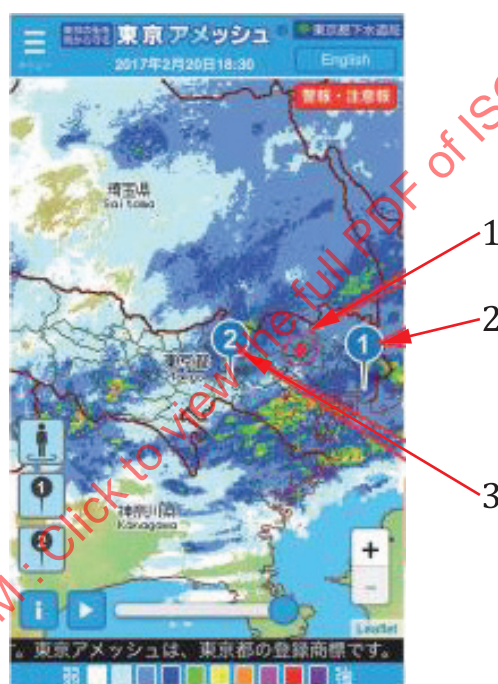
In line with the revision of the Flood Control Act and the Sewerage Law, updates to this flood prediction diagram are currently being considered, including a switch from matching the Tokai flood records to

matching the maximum predicted scale of rainfall, and an update to reflect newly installed river and sewer infrastructure.

A.8.4.3.5 Tokyo Amesh

Tokyo Amesh is a facilities operation management system which was introduced in 1988. Data from this system was released to the public starting in 2002, and it has been useful in organizing the activities of Tokyo residents during rainstorms. From April 2016, the resolution of the display grid was increased from 500 m to 150 m, and the rainfall intensity display resolution was increased from eight levels to 10 levels. Slight drizzles which were not previously displayed are also made visible under the updated system.

In addition, starting in April 2016, a smartphone version of Tokyo Amesh was released to the public via the system website. This includes improved operability and visibility suitable for smartphones, and addition of a GPS function allows display of current location and registration of other specific locations. (Figure A.30)



Key

- 1 current location
- 2 registered location
- 3 registered location

Figure A.30 — Smartphone display

A.8.4.3.6 Sewer main water level information

To handle flooding from heavy rains, it is extremely important that data on the water level inside sewer mains can be measured and provided to the district in charge of flood control management to be used for flood control measures. To achieve this, since 2002, upon request of each district, the Bureau of Sewerage has been using its fibre-optic network to provide information about the water levels in shallow mains and other mains with a high risk of flood damage.

Currently, water level information from eight sewer mains is being provided to the concerned parties in six districts (Figure A.31), and some of these districts have been publishing this information on their public web pages. Going forward, the service will be provided for an increasing number of sewer mains.

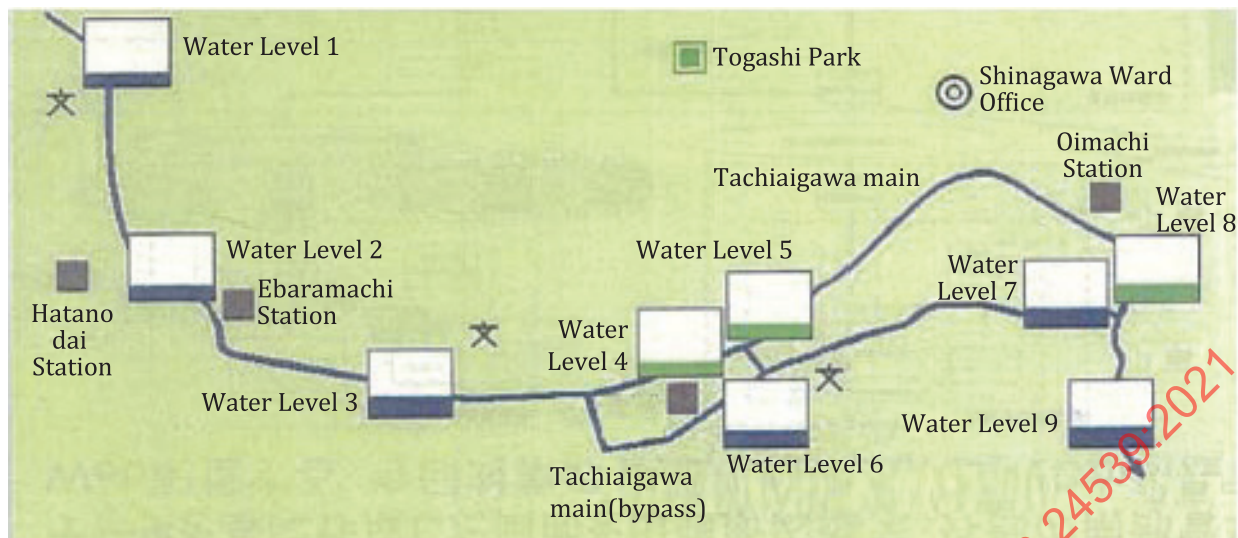


Figure A.31 — Water level information examples (Tachiaigawa Main)

For the most part, only flood control personnel are notified of rainwater flood levels requiring a special warning under the Flood Control Act, mainly for evacuation purposes, but the public will also be informed as needed. However, information on sewer main water levels is disclosed mainly for the purpose of supporting flood damage prevention measures, and as such is provided to flood control personnel and to the public on an as-needed basis.

A.8.4.3.7 Watershed measure initiatives/flood damage reduction initiatives

The Bureau of Urban Development, which oversees urban planning, has taken the lead in promoting watershed measures to control the flow of rainwater into rivers and sewer systems, and housing design and urban development measures to reduce flood damage.

Watershed measures are being installed at both public and private facilities, with the future goal of being able to control rainfall flow equivalent to 10 mm/h.

To encourage residents and businesses to voluntarily improve flood prevention measures in housing design and urban development, information on the dangers of flooding is being more widely circulated, and as previously stated, public notification is being made of districts where flooding is deemed likely. In addition, in 2008, the “Flood Control Guidelines for Tokyo Metropolitan Underground Spaces” were established and distributed to concerned parties, outlining practical flood control measures for underground spaces, which are particularly vulnerable to flooding. Beyond this, to expand flood control measures for large-scale underground urban spaces, partnerships were formed with the administrators of underground spaces, to investigate measures to be implemented in the event of underground flooding. In 2015, the Shibuya Station area was used as a case study for investigating measures in partnership with facility administrators and other concerned parties, and a flood measure plan was created to increase communication among administrators ([Figure A.32](#)).

Chapter 1	Plan outline
Chapter 2	Outline of target facilities
Chapter 3	Flood prediction
Chapter 4	Contact network and information sharing
Chapter 5	Evacuation guidance
Chapter 6	Underground flood prevention measures
Chapter 7	Disaster-awareness education
Chapter 8	Training implementation

Figure A.32 — Shibuya Underground Flood Control Plan (July 2015)

A.8.4.3.8 Further rain control measures based on legal revisions

Under the revised Flood Control Act, “rainwater flooding” from runoff is clearly defined in the purpose of the law. Therefore, it will be more important than ever to promote cooperation among agencies concerned with flood prevention, while also promoting partnerships with the administrators of underground spaces.

Until now, in Tokyo, the Bureau of Sewerage has worked with the Bureau of Urban Development to implement measures against heavy rains. Going forward, information must be shared among concerned parties, and relationships among concerned parties must be strengthened, while improving information transmission methods, and promoting clear and precise crisis management.

A.8.4.4 Organization

Tokyo Metropolitan, Bureau of Sewerage, Planning and Coordination Department.

A.8.5 Source infiltration promotion in Yokohama

A.8.5.1 Background

Over 150 years since the first stormwater drainage was built in 1861 within the sewerage system of Yokohama city, almost all of the city area is now covered. Previously, the sewerage system has upgraded as the city has expanded.

However, in recent years, as stormwater infiltration function has declined due to further progression of urbanization, resulting from problems such as additional flooding due to an increase in surface runoff volume, and a deterioration of a sustainable water environment due to decreased groundwater level or a depletion of spring water.

To find solutions to these problems, the cooperation of residents was required, due to restrictions on projects costs and premises causing limits to the response by public authorities.

A.8.5.2 Purpose

It is necessary to increase the infiltration of stormwater for reduction of ground surface runoff and groundwater recharge. Therefore, a subsidy system that makes it easier for residents to cooperate in the deployment of infiltration facilities was introduced, aiming to increase the amount of stormwater infiltration.

A.8.5.3 Outline

A.8.5.3.1 Submission of the confirmation document concerning installation of infiltration inlets on the premises is the basic requirement.

Anyone requiring new construction or reconstruction are requested to make necessary entries of the “Adequacy of installing infiltration inlets on the premises,” “With/without wish of installation” in the confirmation document concerning installation of infiltration inlets on the premises for submission to the Civil Engineering Office ([Figure A.33](#)).

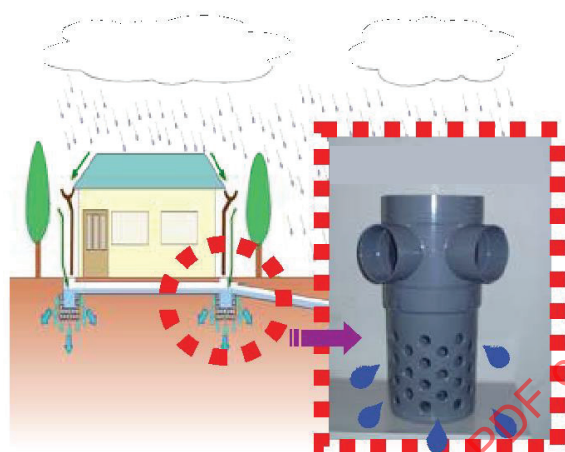


Figure A.33 — Infiltration inlet

A.8.5.3.2 Reduction of the burden on the installers

The subsidies will be increased to reduce the cost burden for installation ([Table A.8](#)).

Table A.8 — Subsidies for installation of infiltration inlet

Inlet inside diameter	Current (Japanese Yen)			After revision (Japanese Yen)	
	New installation	Relocation		New installation	Relocation
150 mm	7 000	22 000	➡	15 000	28 000
200 mm or more	10 000	29 000		18 000	31 000

A.8.5.3.3 The map for determination of whether or not the infiltration facilities are installed is revised.

The map for determination of whether or not the infiltration facilities are installed, which is intended to provide a guide to determine adequacy of installation of the infiltration facilities will be revised, in such a manner that the locations concerned are colour-identified as “Installable location (in green)” and “Non-installable location (in white)” on the basis of combined elements of geological characteristics, topography and so on ([Figure A.34](#)).

A newly revised map can be viewed in the “Daichan Map,” an administrative map information on the Yokohama Municipality website.



Figure A.34 — Permeable suitable map

A.8.5.4 Organization

Yokohama city, Environmental Planning Bureau.

A.8.6 Implementation of the stormwater management of Kitakyushu City

A.8.6.1 Background

Kitakyushu city is a government ordinance designated city with a population of approximately 1 million located in the southwest part of Japan and northern part of Kyushu.

In 1963, five cities merged to create the city, which is the birthplace of a number of large Japanese companies.

The centre of the city is located on the flatland overlooking Hibikinada Sea, and during the western Japan flood disaster in 1953, this suffered great damage and many fatalities. After the development of Kitakyushu city, in order to prevent similar flood damage, improvement of the river and development of sewerage have been promoted. In order to efficiently proceed with flood control and proper sewage treatment, the city centre adopted a combined sewer system, using the parameter of once in every five years rainfall (50 mm/h) as planning standards. By the 1980s the sewer in the central part was almost completed. In 1991, the sewer rainwater plan was amended to include design rainfall events once in every 10 years (53 mm/h). This caused the need to improve the existing combined systems and to promote separate sewer systems throughout the city. However, in recent years, rainfall exceeding 50 mm/h has been increasing each year due to climate change caused by global warming. [Figure A.35](#) shows change of annual number of times rainfall exceeded 50 mm/h in Japan. During the rainy season in 2009 and 2013, heavy rain exceeding 70 mm per hour, 150 to 300 houses were damaged by flooding. [Figure A.36](#) shows flooding situation in 2018 and [Table A.9](#) shows rainfall and flood damage number in 2009 and 2013.

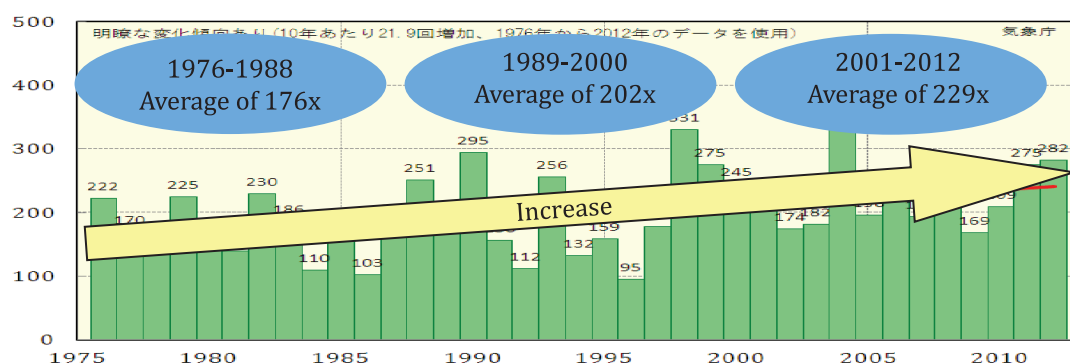


Figure A.35 — Annual number of times rainfall exceeded 50 mm/h



Figure A.36 — Flooding situation in 2018

Table A.9 — Rainfall and flood damage number in 2009 and 2013

Date	Maximum rainfall intensity mm/h	Total rainfall mm	Flood damage number houses
July 24–26, 2009	79,5	451,5	319
July 3, 2013	73,0	—	147

A.8.6.2 Purpose

In Kitakyushu city, in order to reduce the damage caused by floods with short-time concentrated heavy rains in recent years, we have formulated a comprehensive stormwater management plan which includes asset-related solutions and non-asset-related solutions. The asset-related solutions include implementing sewerage facilities such as sewer and pumping stations. The non-asset-related solutions involve distributing disaster maps and conducting disaster drills in collaboration with citizens.

A.8.6.3 Outline

The comprehensive stormwater management plan formulated by Kitakyushu city consists of asset-related solutions and non-asset-related solutions.

A.8.6.3.1 The purpose and method of asset-related solutions and non-asset-related solutions are as follows.

Control of inundation by asset-related solutions:

- efficient removal of stormwater: construction of new sewer and pumping stations;
- control of runoff of stormwater: construction of stormwater storage facilities and infiltration facilities.

Non-asset solutions in cooperation with citizens:

- disaster maps and disaster prevention drills to promote cooperation with citizens;
- preparation of sandbags and flood defence barrier by citizen's self-help.

A.8.6.3.2 Comprehensive stormwater management plan

The comprehensive stormwater management plan consists of both asset-related solutions and non-asset-related solutions, and specific concrete techniques and measures are shown in [Table A.10](#).

Table A.10 — Stormwater management plan

Area	Techniques/method		Target
Asset solutions	Improvement of downstream capacity	New/increased construction of facilities	Pipes, pumping stations
	Control runoff	Collection	Stormwater reservoirs
		Infiltration	Pavement, inlets, others
Non-asset solutions		Instruction/guidance on land development	Housing development
	Cooperation with residents	Information sharing	Hazard map, information on web
		Voluntary activities	Flood defence barrier, sandbags

A.8.6.3.3 Case (1): Improvement of downstream capacity

In order to avoid traffic congestion due to construction, the construction of a new stormwater sewer is adopted a non-excavation method. [Figure A.37](#) shows the construction of the sewer main by the shield construction method. The inner diameter of the sewer is 3 400 mm, the extension is 1 500 m and the installation depth is 20 m underground. Also, in order to respond to sudden rainfall, we are moving forward with renovation to a pre-standby type pump. The pre-standby type pumps operate the pump at full speed before stormwater inflow, so it is a pump that can drain immediately when stormwater flows in. [Figure A.38](#) shows a stormwater pump of the pre-standby type.

**Figure A.37 — Construction of trunk sewer****Figure A.38 — Improvement of pump**

A.8.6.3.4 Case (2): Control of stormwater runoff

A.8.6.3.4.1 Asset-related solutions

In order to control the amount of stormwater runoff from the catchment basin, we are using a flood control reservoir and an existing reservoir to develop a multipurpose rainwater reservoir.

[Figure A.39](#) shows a flood control reservoir underground in the park.

[Figure A.40](#) shows multipurpose utilization of open reservoir.



Figure A.39 — Underground stormwater reservoir



Figure A.40 — Multipurpose utilization of open reservoir

A.8.6.3.4.2 Non-asset-related solutions

In order to control the amount of stormwater runoff from new development housing area, Kitakyushu city enacted instruction and guidance on development for developers.

This instruction/guidance regulates that the developers should provide stormwater reservoirs when housing areas are developed.

A.8.6.3.5 Case (3): Measures by cooperation with citizens

The government is in charge of the following actions:

- Create and distribute a flood disaster map by flood simulation of the area.
- Deliver real-time information related to flood disaster, such as live images of rainfall observed in the city, water level of river and flood condition of river via the internet.

Figure A.41 shows information provided by government.



Figure A.41 — Information (hazard map)

The activities that the residents implement together with the administration are as follows:

- preparation of sandbags and flood defence barrier and installation of them before rain;
- preparation of evacuation regime at the time of flood damage and implementation of evacuation drill.

Figure A.42 shows residents activities.



Figure A.42 — Residents activities (flood defence barrier, instruction)

To the end, in Kitakyushu city, the only model in the Asian region has been selected by the United Nations from the OECD in April 2018 as the “model city of the world for promoting SDGs”, promoting civic safe and secure city planning. Using the know-how of sewage service accumulated over the years, we are actively working on solving the water problems especially for the Asian region.

A.8.6.4 Organization

Kitakyushu city, Water and Sewer Bureau.

A.8.7 Implementation of an early flood warning system in Toyama City

A.8.7.1 Background

The Kureha district of Toyama City, Toyama Prefecture (area 200 ha, [Figure A.43](#)) has experienced repeated damage from heavy rains. In particular, the heavy rains on July 25 2013 caused heavy damage. Various measures must be taken to reduce damage, such as upgrading river infrastructure and increasing sewer capacity. However, because these measures incur high costs and require a long time period for implementation, a policy was also considered whereby residents are encouraged to take part in self and mutual aid. In 2015 MLIT (Ministry of Land, Infrastructure, Transport and Tourism) has been promoting a sewer innovation technology project targeting the Kureha district entitled "Stormwater Management Technology for Localized Heavy Rains in Urban Areas." Part of the project includes the creation of an information notification system in which residents support self and mutual aid.

Flood damage in Kureha District (Rainfall intensity 44mm/h and 23mm/10min)

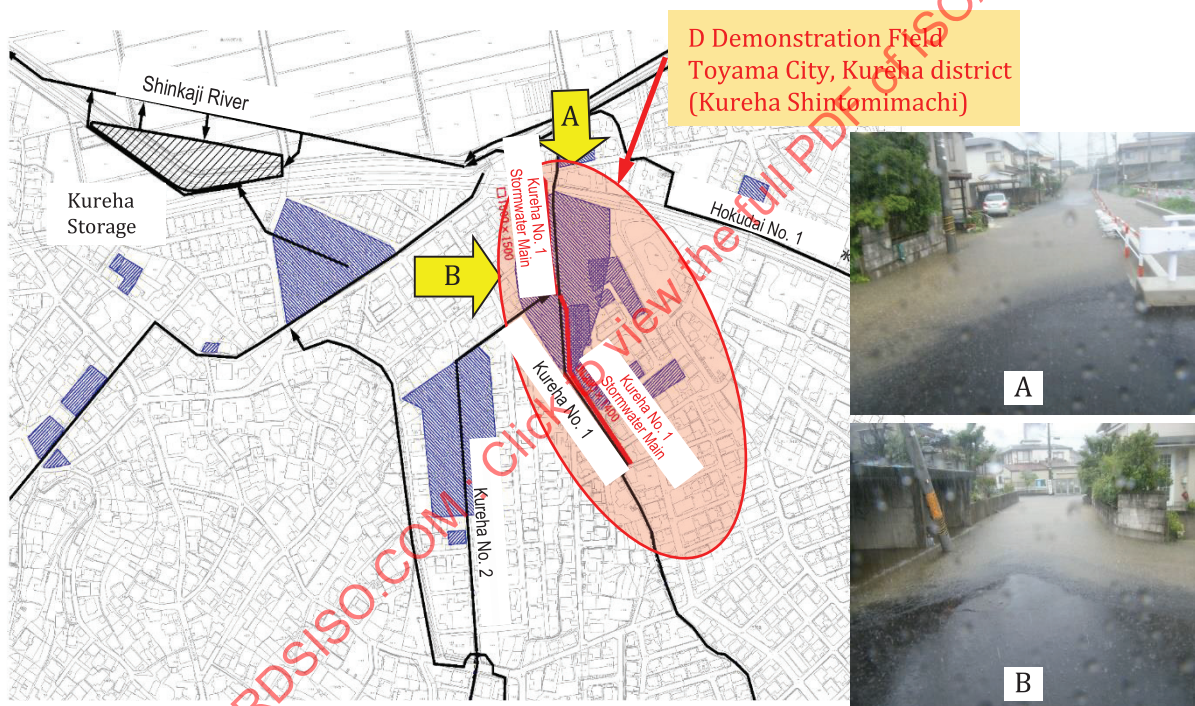


Figure A.43 — Overview and flood map of Kureha, Toyama City

A.8.7.2 Purpose

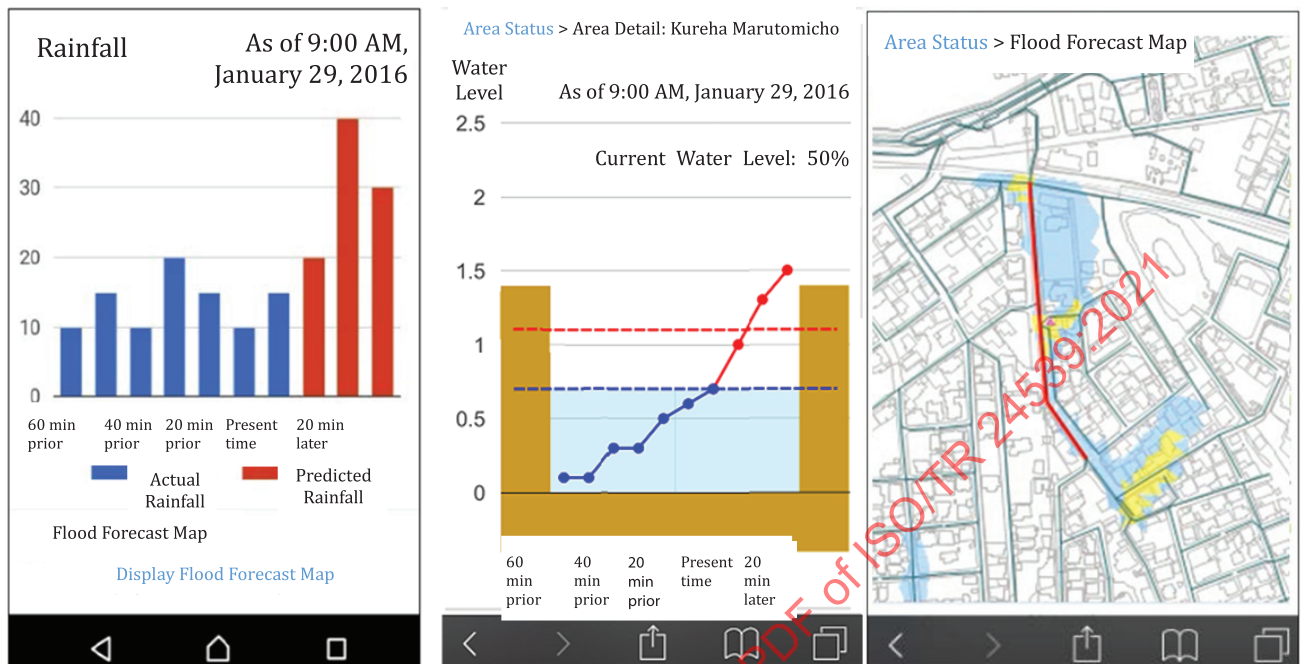
This project has two purposes. The first is to develop an information notification system for the Kureha district of Toyama City. The second is to use the system to provide information that can support residents engaging in self or mutual aid, thereby reducing flood damage.

A.8.7.3 Outline

A.8.7.3.1 System development

The information provided by this system is shown in [Figure A.44](#). The system provides three types of information: rainfall information, water level in sewer conduits, and flood predictions. Rainfall information is based on readings from three small-scale radar units installed in Toyama City. The

radar-based rainfall information is used to issue short-term rainfall forecasts for the next 10, 15, and 25 minutes.



a) Rainfall measurement graph b) Water level measurement graph c) Flood forecast map

Figure A.44 — Information provided

A.8.7.3.2 Information notification method

Residents were issued tablets to support resident-initiated self and mutual aid, as shown in Figure A.45.

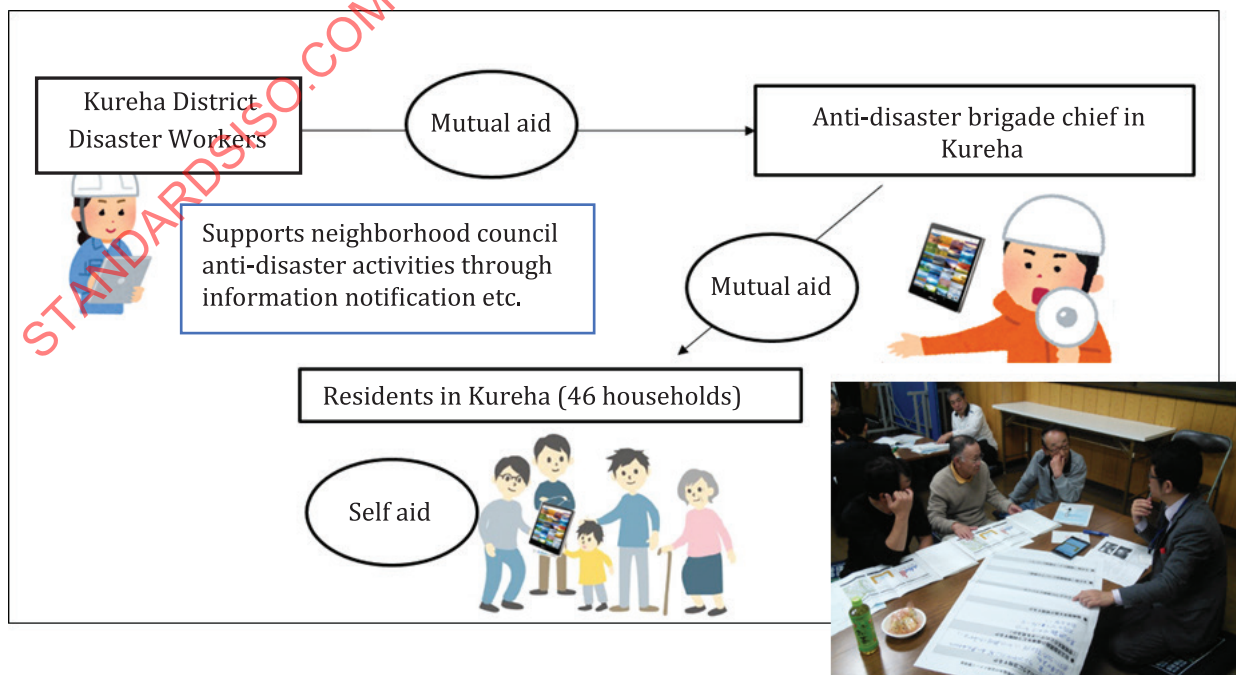


Figure A.45 — Self and mutual aid by residents

It is hoped that the residents will use the rainfall, water level, and flood predictions to conduct mutual aid, such as setting up flood defence barrier (Figure A.46), moving automobiles, and warning neighbours.



a) Prevents water seepage into under-floor ventilation holes in home foundations

b) Prevents water seepage under the front door

NOTE 1 Waterstop plates provided by Toyama City, in addition to sandbag waterstops.

NOTE 2 Used to prevent flooding from seeping in through under-floor ventilation holes and under the front door.

Figure A.46 — Flood defence barrier setup

A.8.7.3.3 Information notification system evaluation

Residents were asked to fill out a questionnaire on self-aid activities before and after the introduction of the information notification system. Only 35 % of residents reported setting up sandbag waterstops before the introduction of the system, but after introduction of the system, the number rose to 80 %. Before introduction, only 53 % of residents reported moving automobiles, while after introduction, the number rose to 100 %.

A.8.7.4 Organization

This project is being led by MLIT and the National Institute for Land and Infrastructure Management, with participation by several companies, Kobe University, Fukui City, and Toyama City. Residents of the Kureha district of Toyama City helped with the application of this system.

Toyama city, Water and Sewer Bureau.

A.8.8 Stormwater storage tank and reuse in Hiroshima City's new stadium

A.8.8.1 Background

The urban centre of Hiroshima is clustered on the delta region of the estuary of the Ota River, which runs through the city from north to south. It is the largest urban centre in the Chugoku region, supporting political, economic, and cultural development.

Construction of the sewer system for JR Hiroshima Station and the surrounding area (Ozu watershed) began in 1964 as a combined flow sewer, and is now nearly complete, covering a 533 hectares area

catchment. However, in recent years, urbanization and increasing incidence of localized heavy rains have increased the volume of rainwater runoff, which raises the risk of flood inundation and resultant damage (Figure A.47).

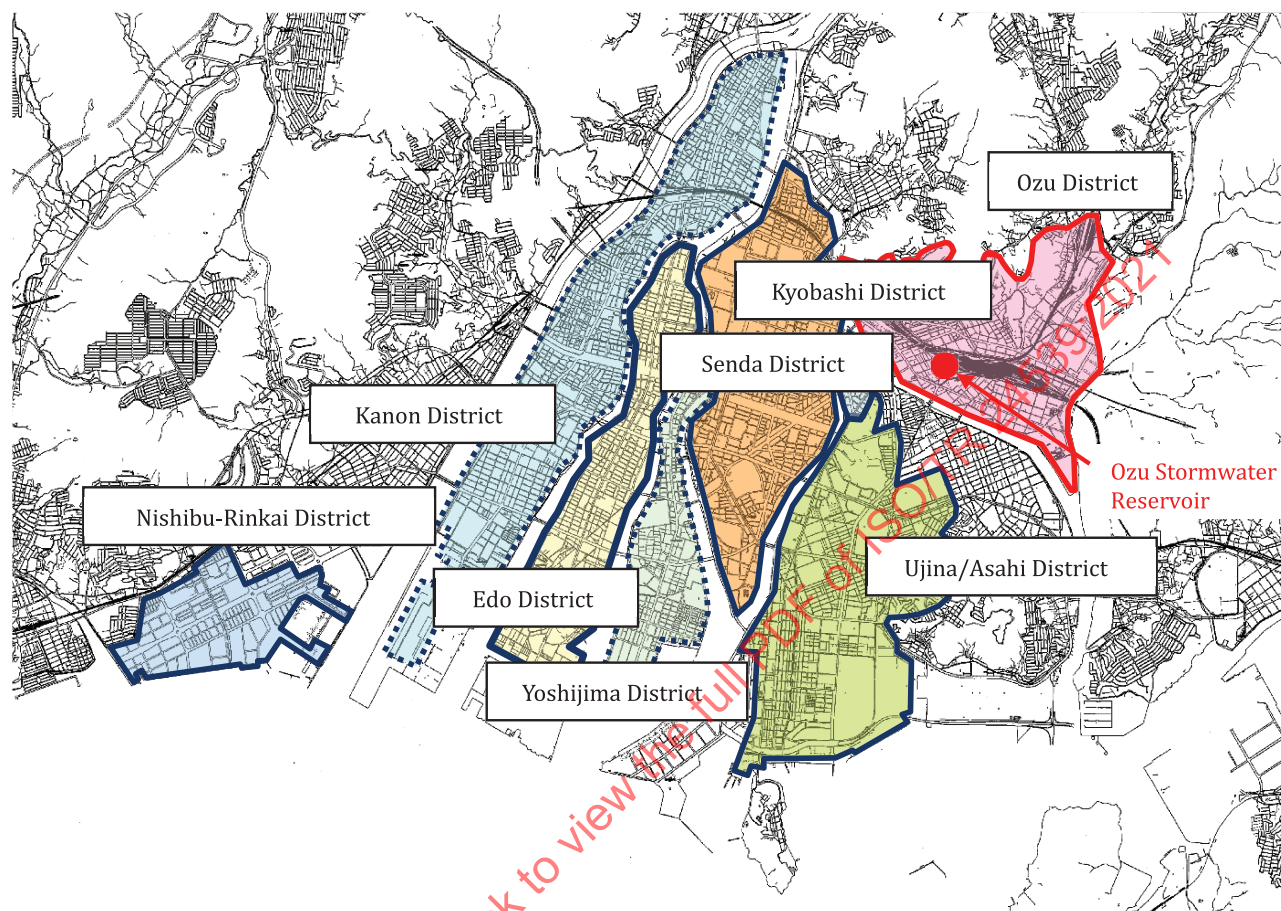


Figure A.47 — Hiroshima City flood prevention plan

A.8.8.2 Purpose

Due to this, to improve flood safety in Hiroshima's urban centre, large-scale stormwater management facilities are being installed in central urban areas, designed to handle a 10-year storm target level of rainfall.

A.8.8.3 Outline

A.8.8.3.1 Ozu stormwater reservoir

The Ozu stormwater reservoir was installed in the Ozu watershed as a flood measure for the area around JR Hiroshima Station (approximately 52 hectares), where many urban functions are clustered.

The stormwater reservoir is located underground under the new Stadium Hiroshima (hereinafter, "the new stadium"), which is the new home stadium of a professional baseball team.

The storage capacity of the reservoir is 15 000 m³, of which 1 000 m³ is reused for irrigation and toilets at the stadium, and the nearby landscaping waterway.

During rainstorms, rainwater which exceeds the capacities of the original sewer pipes is temporarily stored in the stormwater reservoir, allowing the sewer system to handle about 2,5 times more rainfall (53 mm/h) than its previous capacity (20 mm/h).

During dry weather, the stored rainwater is then sent via the nearby Ozu pump station to the eastern prefectural purification centre, where it is treated and purified before being discharged into the environment ([Figure A.48](#), [Figure A.49](#)).

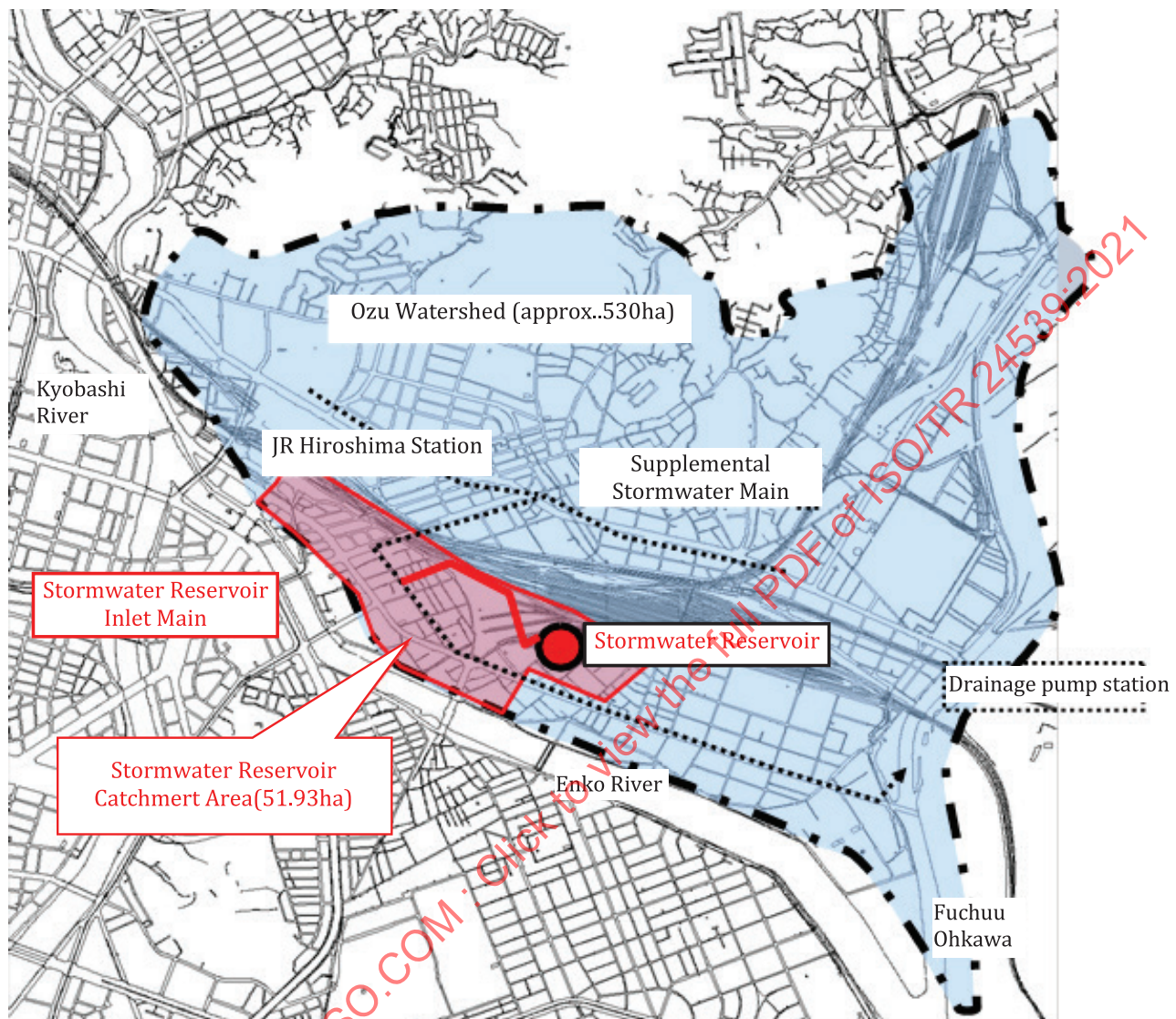


Figure A.48 — Stormwater system plan of Ozu district