Gemeente Rotterdam

Rotterdam-Surat Cooperation on Water Resilience

Report and recommendations
visit Rotterdam to Surat 11-15 March 2019

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Evides waterbedrijf

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Content

1 Context cooperation Rotterdam and Surat

Both Rotterdam and Surat are members of the 100 Resilient Cities Network. Both cities have developed a resilience strategy in which resilient water management and climate resilience are a priority. Collaboration already started in October 2015, when Surat was one of 9 cities visiting Rotterdam during the so-called Water Exchange program. In 2017 the two cities expressed their willingness to cooperate more extensively on resilient watermanagement. Both cities then applied for funding through the European Union International Urban Cooperation programme (IUC). Since december 2017 Rotterdam and Surat were officially paired as part of the IUC programme.

Figure 1-1 Geographical location cities of Surat and Rotterdam

In November 2017 a first Rotterdam delegation visited Surat for a fact-finding mission. The results of this visit were presented during a meeting with the vice-mayor Struivenberg in Ahmedabad. During this meeting mutual interests and commitment were confirmed.

In July 2018 a Surat delegation visited Rotterdam, where experiences on water and climate resilience were shared and discussed. This visit resulted in a long-list of potential actions to be executed to enhance watermanagement in Surat. Surat Municipal Corporation (SMC) selected priority actions to be discussed and elaborated during a second visit

of a (larger) Rotterdam delegation. This report gives the results and recommendations of this second visit from Rotterdam to Surat that recently took place in March 2019.

The cities are focusing their IUC partnership on tackling issues related to water management, such as ensuring the quality of drinking water, mitigating water pollution from industrial and agricultural run-off, protecting against flooding and rainwater harvesting. In chapter 2 the priority topics are described.

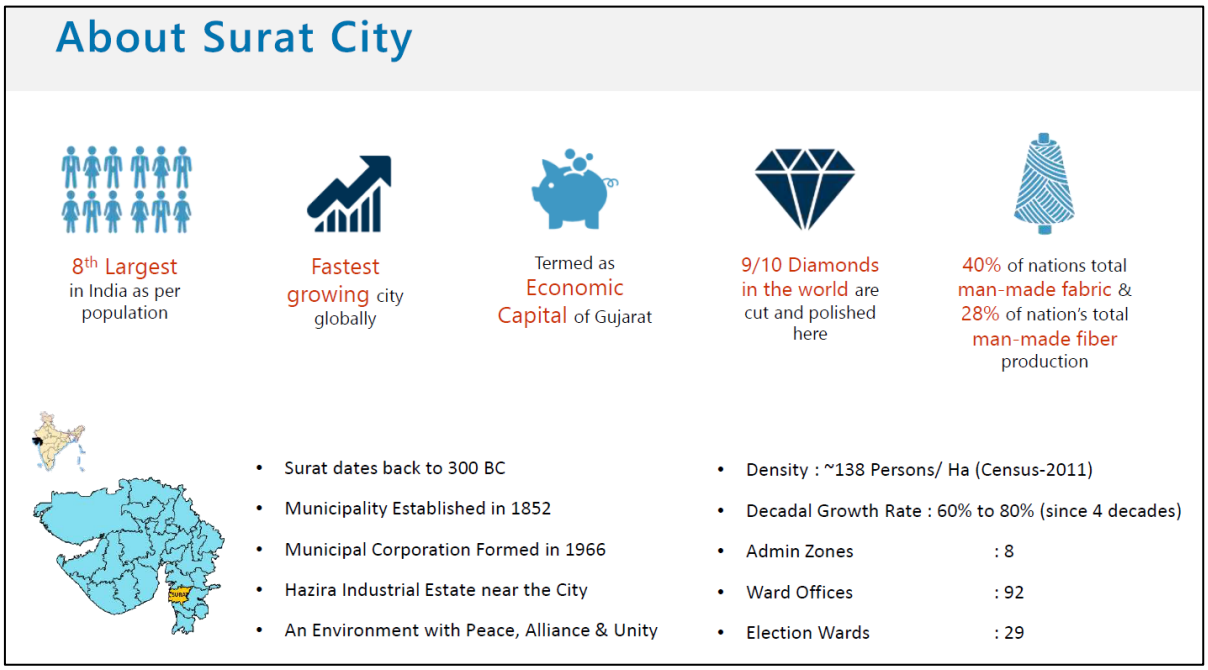


Figure 1-2: Facts & figures Surat

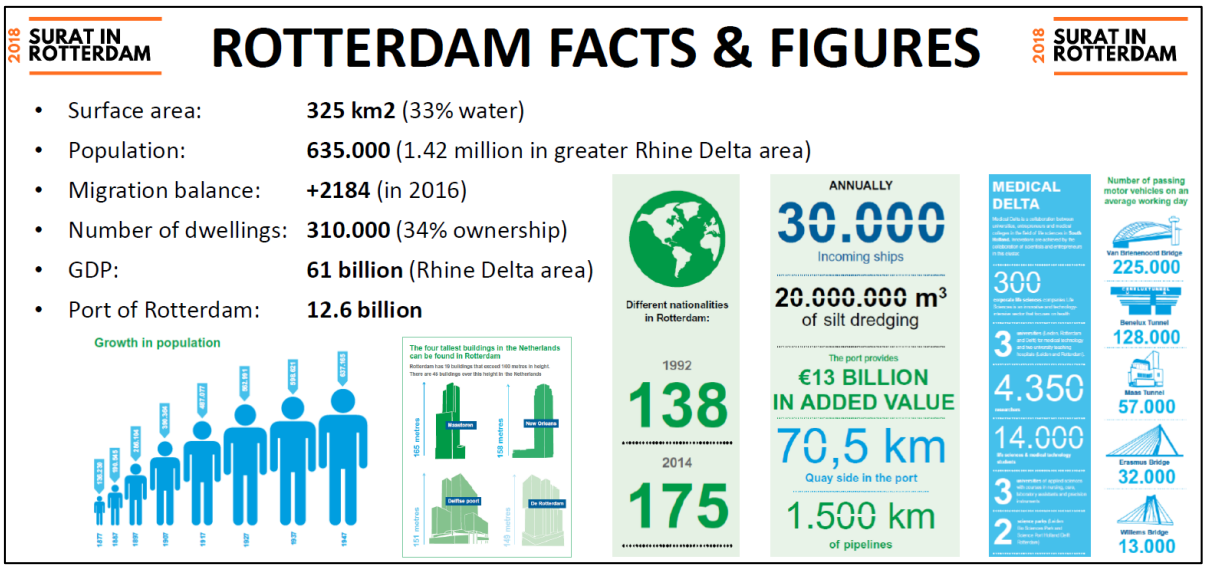


Figure 1-3: Facts & Figures Rotterdam

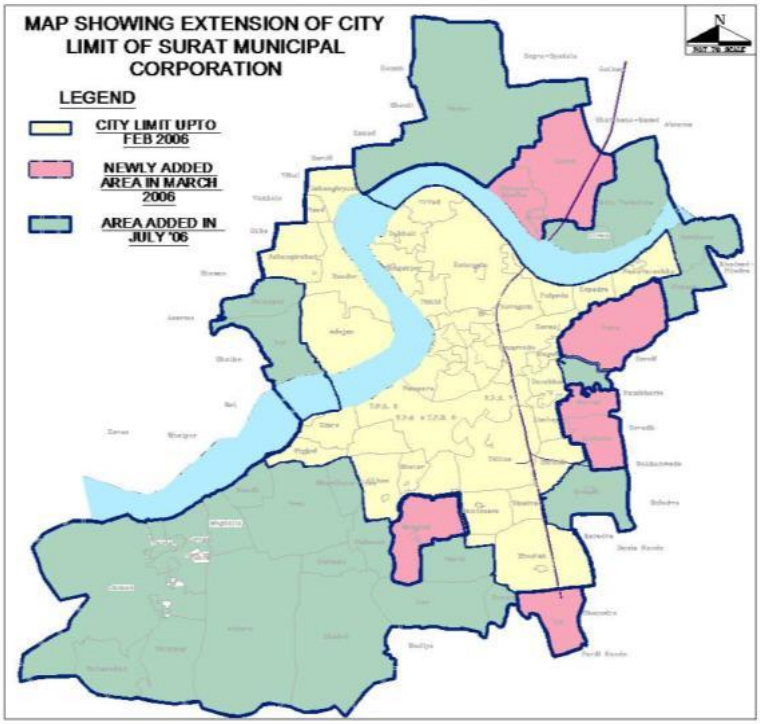


Figure 1-4: City limits of Surat

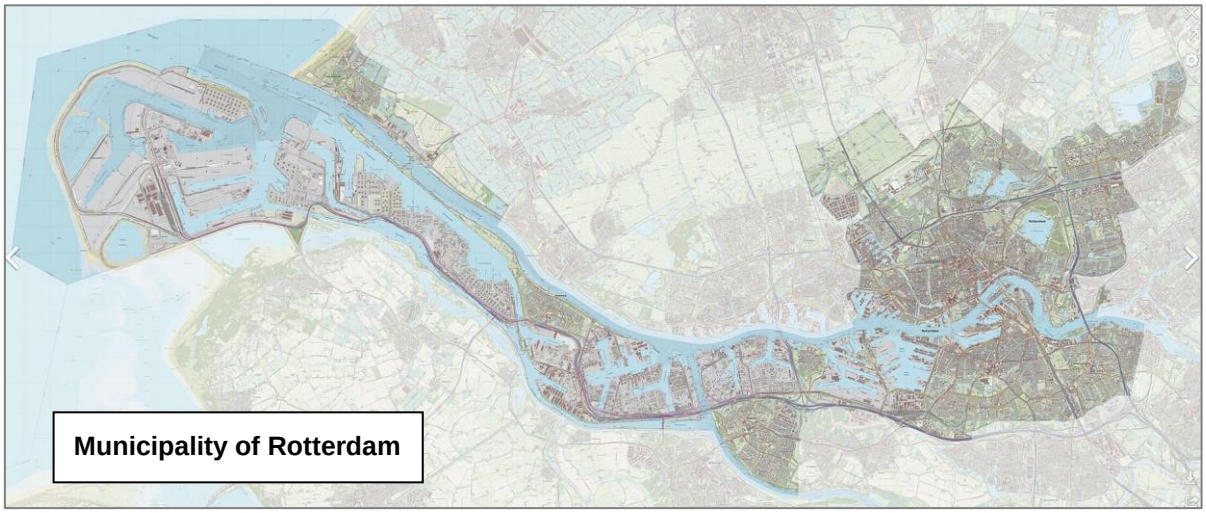


Figure 1-5: City limits of Rotterdam

Historic links between Surat and the Dutch

Surat is a famous trading city on the northwest coast of present-day India, in the state of Gujarat, on the river Tapi. The city of Surat was part of the Mogul empire, which at the time encompassed much of India. As early as 1609 or 1612, the English had a trading post in the city of Surat by battling with the Portuguese.

Links between Surat and Rotterdam date back to the 16th century. Since the city was very important for the trade in cotton fabrics and Indigo, the Verenigde Oostindische Compagnie (VOC) wanted to open an office there. Pieter van den Broeck established a

trading post in Surat in 1616, after a few unsuccessful attempts. (The VOC was forced to do so because the sultan of Atjeh (current Indonesia) no longer allowed her to buy cotton on the local market). Due to opposition from the English, it took until 1620 before Van den Broecke was given leave to expand the factory.

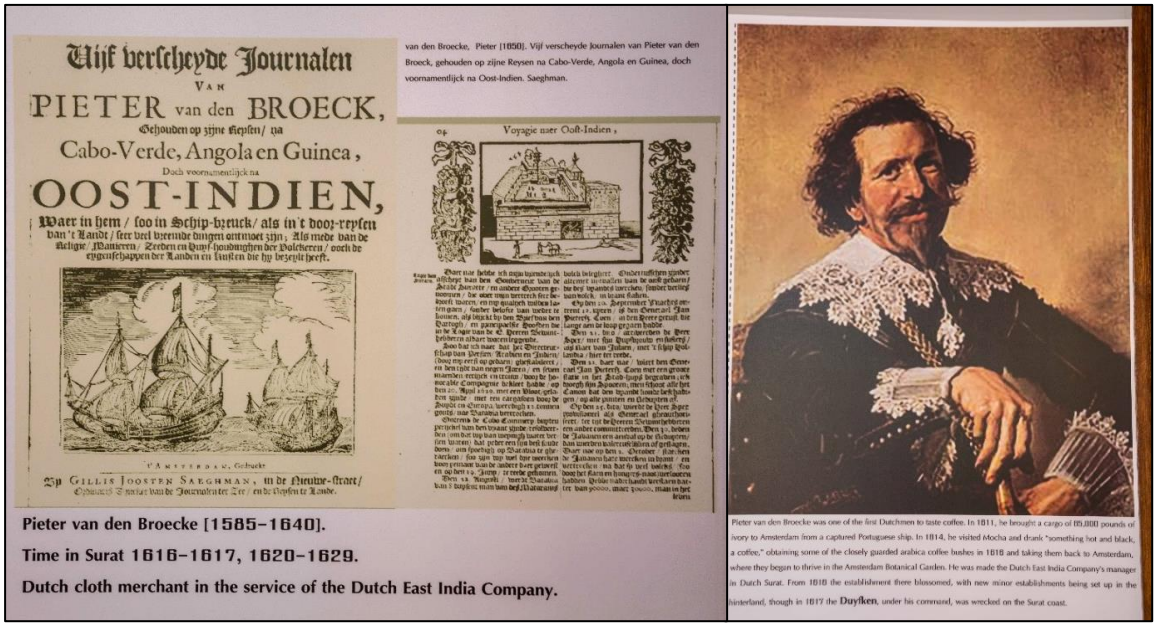


Figure 1-6: VOC trader Pieter van den Broecke

Local traders used the city to transport goods from the interior and Persia. The cotton were traded by the VOC in Atjeh and served as a means of exchange for the trade in spices in the Moluccas. The VOC received a number of trade privileges from the Groot-mogol Nuruddin Salim Jahangir, and in the course of the seventeenth century it was able to gain control of the trade in cotton and speceurs themselves.

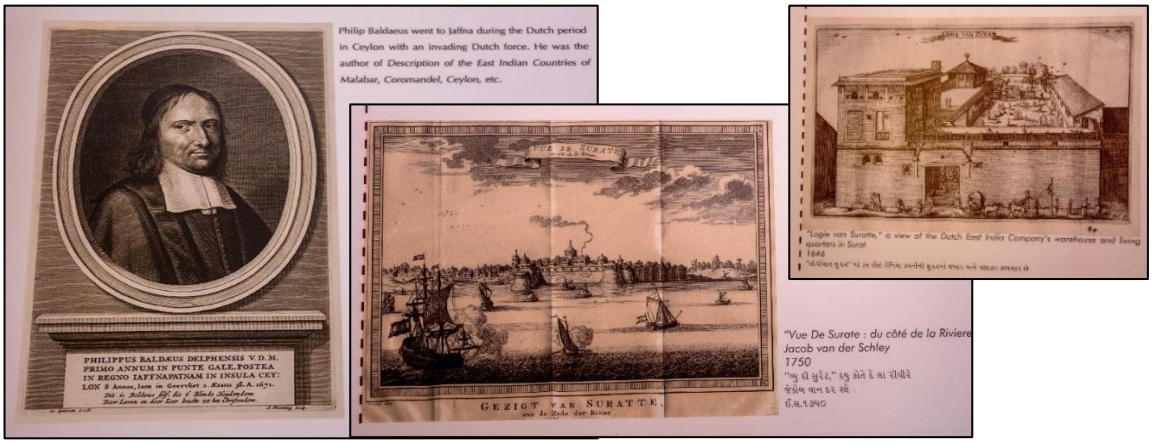


Figure 1-7: Dutch presence in Surat

Because of the privileges obtained, the VOC did not have to force the trade with military means, and as a result there were relatively few VOC personnel in its place. The VOC

also did not have to build forts to protect the trade. In the course of the eighteenth century, trade was endangered by political tensions within the Mogol kingdom. The empire had fallen into disrepair and there were also domestic unrest in Persia, which reduced trading activity. The VOC also had to contend with competition from the British, who partly and later largely took over the trade from Bombay. Between 1781 and 1784 the city was equally British possession. The VOC recaptured Surat, but in 1795 the city finally came into British hands.

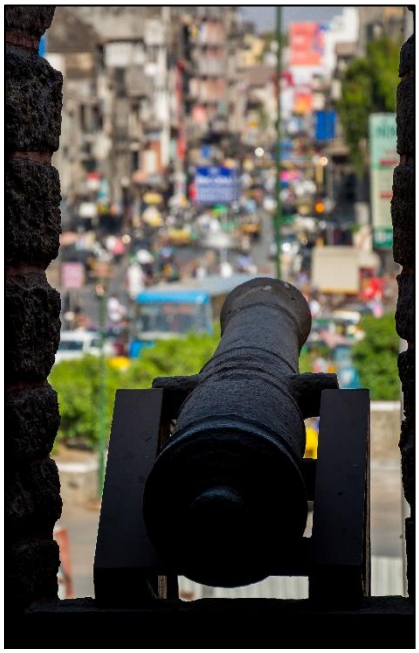


Figure 1-8: View from Surat Fort

However, the trade was profitable during almost the entire period that the VOC was active. Thanks to the privileges, the VOC was able to found many factories in the area and hinterland, up to isolated Agra. Because the Grootmogol was accustomed to much outward display, the VOC directors and merchants behaved in the same way, creating a complete court. They argued that this was necessary if they wanted to achieve something in negotiations. The (Dutch) Council of the Indies has, as is clear from sources, protested several times against this royal behavior of its staff, but without result.

When the trade for the VOC had already collapsed considerably in 1759 and the trade had long since relocated to Bombay, the VOC played a subordinate role in Surat. The trading posts were occupied by the United Kingdom following the Letters of Kew in 1795.

Figure 1-9: Remnants of Dutch presence in Surat

2 Scope of visit March 2019

Building upon the learnings of the Surat delegation during their visit to Rotterdam in July 2018, some priority topics were selected by the city from an assessment of potential topics. These topics are related to urgent questions of the SMC as well are linked to expertise available in Rotterdam.

Topic 1: Water treatment process and river reservoirs
The main source of drinking water for Surat is the river Tapi and extensive water treatment facilities are present. The river Tapi flows out into the Arabian See and tidal movement is present in and beyond Surat city. About 95 km upstream Ukai dam was constructed in 1972, creating a controlled river discharge. To create a source of fresh water for raw water extraction from the river a barrage ('Weir cum Causeway') was constructed in 1995, preventing salt water to flow further upstream. A plan is elaborated to construct a second dam downstream to extend the reservoir capacity.
SMC has identified a need for advisory on treating raw water at the source extraction and usage of chemicals in the final procedure of treatment process, similar to the process/technology seen at Evides facility in Rotterdam. SMC also asked to reflect upon the concept of creating fresh riverwater reservoirs.

Figure 2-1: Kosad Waterworks site

Topic 2: River water quality monitoring and river restoration
Downstream the Ukai dam the river water quality is detoriorating badly, resulting in a low biological and chemical water quality at Surat city and the drinkingwater inlets. with scattered untreated wastewater inflows along the river combined with long dry periods are main causes for this situation. There is the need for a dedicated treatment process, but analyzing capabilities are limited. Never the less a proper analyzing process for standard water quality indicators is present at the treatment plants.
Therefore upgrading of the water quality monitoring is a SMC key priority and the aim is to start a pilot project. SMC expressed that experience of Evides is helpful to give advice on what kind of river water quality monitoring is suitable for Surat. On basis of the visit the pilot project can be further scoped.

Figure 2-2: Tapi river view from Katargam Head waterworks

Topic 3: Flood Forecasting Modelling

After a disastrous flooding event in 2006 due to heavy rainfall at the end of the monsoon season and lack of information about actual dam management at Ukai dam, Surat took several measures to prevent repetition. Physical measures as well as organizational were taken, for instance development of an Early Warning System (EWS). The present available flood forecasting model is not integrated in the EWS and measures flooding based on reservoir catchment capacity. SMC is interested in securing an end-to-end flood forecasting modeling which is integrated with the EWS. SMC has expressed interest to have support from Deltares to review this model and advise on upgrading and integrating it into the EWS.

Figure 2-3: Northern gate in Weir cum Causeway

Topic 4: Blue-green roofscapes and groundwater replenishment

Surat encounters groundwater salinization due to the natural soil conditions, situation near the Arabian sea and un uncontrolled groundwater extraction. For that reason groundwater replenishment with fresh rainwater is stimulated as much as possible. One of the measures is the obligation of building developers to include a rainwater harvesting and groundwater replenishment system in newly build real estate. In the public realm SMC has started projects to harvest rainwater and infiltrate this into the soil. SMC has prepared a pilot design and is interested in getting targeted advisory from the Rotterdam specialists on rooftop initiatives.

Figure 2-4: Rain water harvesting and infiltration system near Science Center

Topic 5: Waterplazas, small lakes and groundwater replenishment

Inspired by the waterplaza concept in Rotterdam, SMC has identified a pilot site location for a waterplaza to store storm water in flooding situations and the monsoon season. Goals are also providing social recreation opportunities during the dry reason and usage during the Ganesh festival for emission reduction of idols to reduce pollution in the river basin. The project is still in the early phase of discussion and SMC is thinking about design options. The experience of Rotterdam can be helpful. Waterplazas as well as several small lakes still present in Surat can be useful for groundwater replenishment. This can be incorporated in the discussion about the purpose and usefulness of a waterplaza in the Surat context.

Figure 2-5: Small city lake at Kavi Kalapi garden

Complementary topics
During the visit of the Rotterdam delegation to Surat several other topics were discussed and locations visited. Learnings from these topics and linkages with the priority topics are discussed in a separate chapter. These subjects are:

- Surat Smart City approach (related to visit of SMC Smart City Centre)
- Approach on renewable energy (related to visit of the Surat Science Center)

Two other very interesting visits were made, that gave the delegation insight and 'feeling' about the main industries and education on spatial design/architecture of Surat:

- Diamond and textile industries (related to visit of Shree Ramkrishna Exports Pvt. Ltd. (diamonds) and Siddhi Vinayak Knots & Prints Pvt. Ltd. (textile))
- Architecture and spatial aspects in urban development (related to visit of SCET faculty of architecture)

This report describes learnings during the visit of March 2019 and gives recommendations on the topics listed above. Besides that, connections between approaches in Rotterdam and Surat are identified as well as take-aways of Surat approach for Rotterdam.

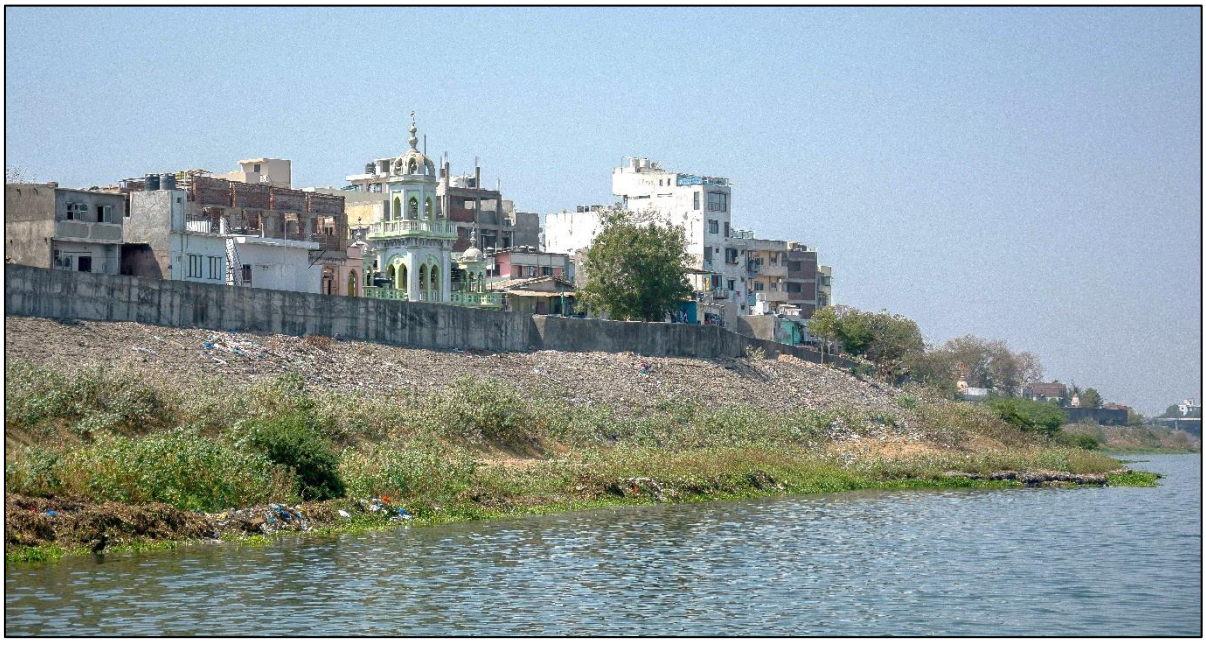


Figure 2-6: Flood protection wall near Weir cum Causeway

3 Water treatment processes and river reservoirs

3.1 Situation and ambition Surat

Drinking Water Consumption
With a current population of about 6 million people in Surat and a large textile industry 1,2 billion liters of drinking water per day is produced (coverage of 96%). 20% of this is used by the textile industries. The average consumption of drinkingwater per day is 200 liters. Goal is to cover 100% of drinking water need in 2020.
The expected drinking water consumption in 2040 is 2,3 billion liters per day for 12,3 million inhabitants.

Figure 3-1: Intake Tapi River water for Katargam drinking water treatment plant

Tapi River
Drinking water is produced from surface water directly abstracted from the Tapi River in the Surat region between the Ukai dam and the Weir cum causeway in Surat city.
The conventional drinking water treatment consists of pre-chlorination, poly-aluminum-chloride-dosing, clarification, rapid sand filtration and post-chlorination.

The Katargam treatment plant is a well operated, well maintained treatment plant using a state-of-the-art SCADA-system. The personnel showed good knowledge of the treatment processes and seem to be in control. Some parameters are monitored on line in the in-coming water and outgoing water of the treatment. Backwash water is re-used, but particle load can be very high and pathogenic organisms can accumulate, thus increasing infection risk for the consumers.

Figure 3-2: Clarification and filtration at Katargam treatment plant

In the present situation the occurrence of the parasitic protozoans Cryptosporidium and Giardia is not taken into account in the treatment setup because chlorine disinfection is absolutely not full-proof to control this potential risk. The protozoan parasites Cryptosporidium and Giardia have been implicated as the causative agents of many outbreaks of waterborne intestinal illness worldwide. Water appears to be an important vehicle for the transmission of these parasites, along with direct contact with infected persons or animals. Both parasites produce a robust (oo)cyst to be able to endure environmental stress and to make the probability of reaching a new, susceptible host as high as possible. The (oo)cysts are shed by infected persons or animals and enter surface water through direct fecal input, discharge of treated and untreated sewage, and runoff from agricultural lands.

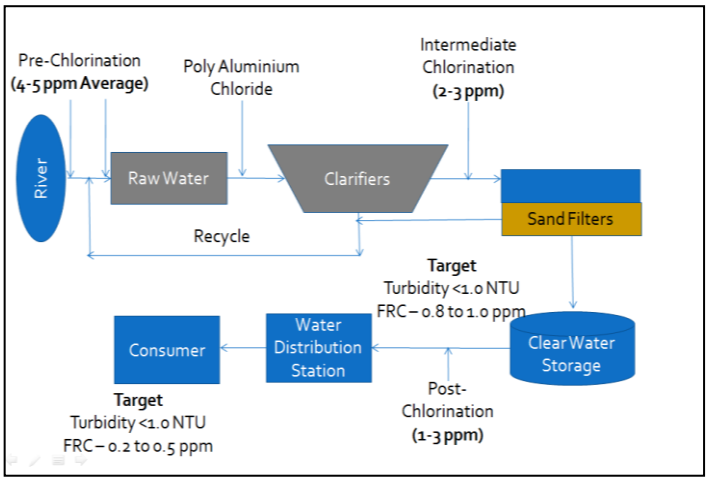


Figure 3-4: Treatment process Katargam treatment plant

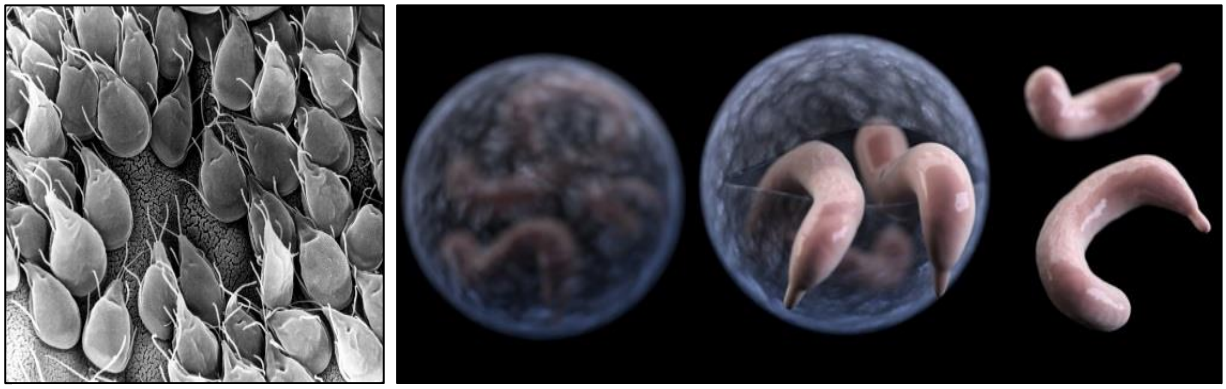


Figure 3-3: Giardia (left) and Cryptosporidium (right) as they appear in the human gut

Some problems exist with respect to the amount of particles reaching the WTP. It is suspected that the particles are of organic origin, algae or debris from water plants. The suggestion was made that micro-sieves are needed to remove the particles.

French wells

Presently, there are also three French wells in Sarthana area of Surat city, which abstract 155 MLD of infiltrated ground water from Tapi River. The abstracted ground water has low turbidity and requires according to the officials no treatment other than chlorination.

It is the ambition of SMC to increase the number of French wells. Ground and helicopter based surveys have already been executed. It is suggested that at six different locations water will be available between 60 meters to 200 meters depth. The chemical water quality of the infiltrated Tapi River water is currently characterized poorly, because only a limited set of parameters are measured.

Tertiary treatment

In order to reduce the use of drinking water for industrial purposes, as the textile industries in Pandesara, the Bamroli sewage treatment plant treats waste water with an extensive, state of the art facility with a total capacity of 40.000 m^3 per day. In addition to the conventional waste water treatment a sand filter and an ultrafiltration and reverse osmosis system produce 32.000 m^3 per day water of drinking water quality. 8.000 m^3 of UF –filtered water is treated with active carbon filtration as a last treatment step (see fig. XX). The plant will be enlarged in the near future.

Figure 3-6: Treatment process of Bamroli tertiary treatment plant

Figure 3-5: Reverse osmosis and ultrafiltration in Bamroli tertiary treatment plant

At Kavi Kalapi Lake a 1000 m^3 per day tertiary treatment plant produces water for lake restauration, gardening and irrigation purposes. Goals of the project are reduction of potable water use, reduction of sewage treatment plant load, reduction of pressure on water resources such as bore wells and tankers for gardening. The tertiary system consists of moving bed bioreactor technology, multi-grade fine filtration, active carbon filtration and UV and chlorine disinfection.

Figure 3-7: Treatment plant at Kavi Kalapi Lake

River reservoirs and new barrage project

About 95 km upstream Surat city the Ukai dam was constructed in 1972, creating a controlled river discharge. To create a source of fresh water for raw water extraction from the river a barrage ('Weir cum Causeway') was constructed in 1995, preventing salt water to flow further upstream and creating a fresh water reservoir.

A plan is elaborated to construct a second barrage ('Shinganpor Weir') aprox. 10 km downstream to extend the reservoir capacity (additional 19 MCM). This reservoir will also prevent salinization of the groundwater due to the tidal movement of sea water in the river stretch between 'Weir cum causeway' and 'Shinganpor weir'. The banks of this river stretch will be developed as attractive riverfronts.

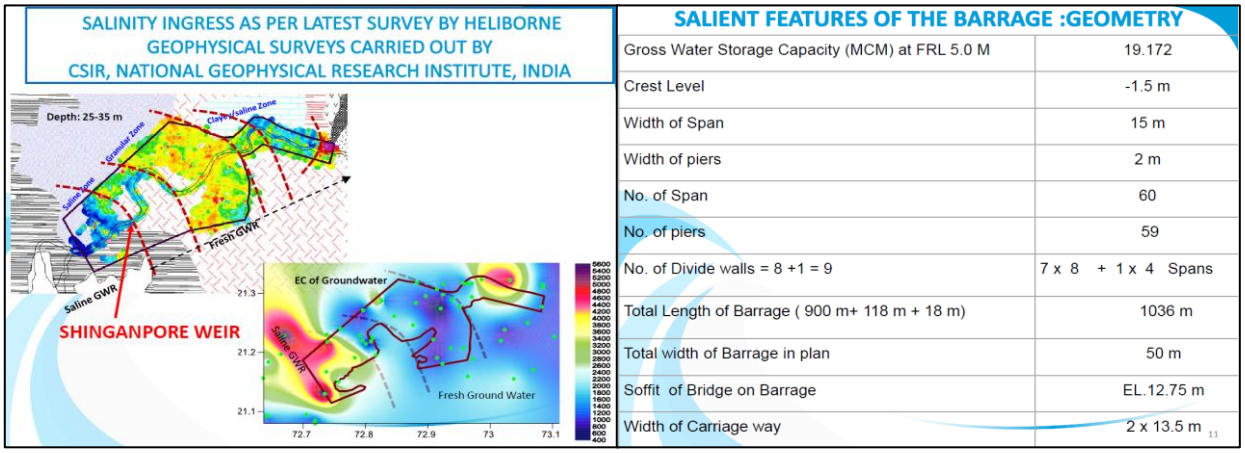


Figure 3-8: Salinity ingress downstream river stretch and geometry figures new weir

3.2 Learnings and review remarks

Based on the site visits and the information provided these remarks can be made:

- The conventional treatment with chlorination is not equipped to inactivate parasitic protozoa and organic pollutants are not removed. The SMC laboratories can only analyze a limited set of parameters.

- French wells seem to be an efficient way of abstracting water from Tapi River, because the river water has already been filtered by the river bottom. The more French wells can be installed the less dependent SMC is on surface water treatment.

- The successful treatment of waste water to water of drinking water quality at Bamroli tertiary treatment plant and the treatment plant at Kavi Kalapi Lake show that it is technically feasible to produce drinking water from any source.

- Salinization of the groundwater under and near the Tapi river is a serious problem in dry periods when the tidal movement causes the sea water to move far upstream without fresh water flowing downstream. In combination with groundwater extraction (legal or illegal) and no rainfall large part of the year it causes a salt groundwater environment.

- At this moment there is limited knowledge of groundwater streaming patterns and the effect of water infiltration and extraction for drinking water production (as is for rainwater infiltration). Questions like what soil layers are present and used and if extraction has effect on land subsidence could be answered.

3.3 Recommendations

Evaluating the drinking water production process, waste water treatment and creation of fresh water reservoirs the following recommendations can be given:

1. *Characterize the 'particle problem' by determining the size frequency distribution of the particles and determine the composition (organic or inorganic).*

   The results from this investigation will give a clue on the possible solutions. If particles in the size range of 50-500 µm need to be removed micro-sieves can be a (very expensive) solution.
   At WTP Berenplaat In Rotterdam 16 micro-sieves with a mesh size of 35 µm are installed to produce 18.000 m^3/h (see Fig.XX). If larger particles need to be removed a more coarse screen can be used, which limits the amount of screens, because the hydraulic loss will be less. At Kralingen WTP Evides uses screens with 2 mm meshsize to remove coarse particles and juvenile fish. The capacity of such a screen is approx. 3600 m^3/h with a pollution grade of 30%.
   If results from the investigation on particle size are available Evides can give an advice on furthersteps.

Figure 3-9: Microsieves at Berenplaat drinking water treatment plant (Rotterdam)

2. *Organize a monitoring program to determine the density of the parasitic protozoans Giardia and Cryptosporidium in the surface water.*

   As the analysis of these protozoan (oo)cysts is complicated and expensive it is recommended that a (foreign) university could be persuaded to perform the investigation. See 4.3 for the need for extended monitoring of chemical pollutants. Results from river water monitoring will indicate if more treatment steps are necessary. Active carbon filtration is a possible solution to improve removal of pesticides etc.

3. *Develop a regional and local groundwatermodel to understand the effects of replenishment and extraction of groundwater*.

   To raise knowledge of the hydrogeological situation of the underground in Surat and plan for the long term a regional and local groundwatermodel combined with dedicated groundwaterlevel monitoring plan is usefull. On basis of this the effects of water extraction for drinking water production, infiltration of salt water and fresh water replenishment flows could be determined.

Figure 3-10: Screens to remove larger particles (1-2 mm) from raw water (Kralingen Rotterdam)

4. *Investigate effectiveness and feasability of compartmentalization of the planned new river reservoir.*

   The fresh water reservoir that will be created by building a new barrage downstream the existing Weir cum causeway is a massive fresh water source. According to reactor kinetics rules compartmentalization is favourable for water quality improvement. Excavation of this river stretch could also increase water storage capacity.
   The effects of both options should be investigated thouroughly because intervening in a natural river system can have unexpected effects bearing in mind that the river will function as a natural river in monsoon periods. Inflatable barriers, which can be lowered during monsoon, could be an option to be investigated.

5. *Investigate (if not done already) the effects of long term sea level rise.*

   Sea level rise can cause an increasing risk of flooding on the long term. Can the Shinganpor Weir also have a function of storm surge barrier and is the proposed height fit for that purpose?
   By building a weir more downstream (10 km) the strenght of the tidal volume could increase causing more erosion in the downstream river stretch. Are these effects modelled and taken into account?

6. *Investigate ecological effects of the new barrage.*

Dependent of the ecological values (or restoring these) of the river Tapi and bearing in mind the expected improvement of water quality through the Tapi river conservation project, it is worth investigating effects of the new barrage for river ecology. Migrating fish for instance could benefit from 'fish steps' to swim upstream and pass the barrage. In the Netherlands a lot of examples of these structures exist, from small to very large (f.i. Afsluitdijk).

Figure 3-11:Birds near proposed location new barrier

4 River water quality monitoring and river restoration

4.1 Situation and ambition Surat

Water quality Tapi River

Many reports indicate that Tapi River is heavily polluted during winter and monsoon season due to industrial and domestic sewage pollution and agricultural runoff. In addition, the pollution level increases due to religious activities, like Ganesh idol immersion. Most river pollution studies focus on traditional water quality like oxygen, BOD, COD, ammonia and turbidity. Also SMC has a limited monitoring program for assessing river water quality. The SMC laboratories can only analyze a limited set of parameters. We were told that more parameters are measured with a low frequency. Results nor which parameters are measured, were obtained. The potential and well-recognized risk which

Figure 4-1: Online monitoring and analyzing equipment at Katargam

Water Quality Monitoring
Testing Parameters & Testing Frequency

Sr.	Location	Frequency	Parameter	Stage
1	Generation (more than 831 samples)	Round the Clock	pH, Turbidity, TDS, Free Residual Chlorine (FRC), Dissolved Oxygen (DO)	Raw Water, Treated / Supply Water from Water Works
2		Hourly	pH, Turbidity, Free Residual Chlorine (FRC)	Raw Water, Treated Water
3		Shift wise	pH, Turbidity, Colour Index, Taste, FRC, TDS, Alkalinity, DO	Raw Water, Treated Water, Supply Water
4		Weekly	pH, Turbidity, Colour Index, Taste, FRC, TDS, Alkalinity, DO, Total Hardness, Nitrate, Iron, Fluoride, Ammonical Nitrogen, Chloride, Chlorine Demand, BOD, COD, MPN Index (17 parameters)	Raw Water, Treated Water, Supply Water
5		Quarterly	All heavy metals, Pesticides, Radioactive elements, THMs, Chloramines, Virological and Bacteriological test as per IS 10500 including above 17 parameters	Raw Water, Treated / Supply water
1	WDS (35 samples)	Twice in Supply hour	Turbidity, FRC	Supply water to consumer from WDS
2		Weekly	pH, Turbidity, Colour Index, Taste, FRC, TDS, Alkalinity, DO, Total Hardness, Nitrate, Iron, Fluoride, Ammonical Nitrogen, Chloride,	Supply water to consumer from WDS
1	Consumer (more than 660 samples)	Daily	Odour, pH, TDS, Ammonical Nitrogen, FRC	Consumer samples

Figure 4-2: Testing parameters water quality monitoring

is not addressed in the monitoring of river water quality is the risk of infection with the chlorine resistant pathogenic protozoa, Giardia and Cryptosporidium. These pathogens are distributed in the environment through feces from both animals and humans. Both E.coli monitoring and chlorine disinfection are not full-proof to control this potential risk. This is one of the reasons why the application of Quantitative Microbial Risk Assessment (QMRA as described in Hijnen, 2010) is incorporated in the Dutch legislation to secure safe drinking water. QMRA is also described in the WHO guidelines on safe drinking water and besides the Netherlands, Australia has adopted QMRA in the national regulation on recycling waste water.

Massive growth of *Eichhornia crassipes*, commonly known as water hyacinth, an aquatic plant native to the Amazon basin, is highly problematic for water abstraction from Tapi River. One of the fastest growing plants known, water hyacinth reproduces primarily by way of runners or stolons, which eventually form daughter plants. Each plant additionally can produce thousands of seeds each year, and these seeds can remain viable for more than 28 years. Some water hyacinths were found to grow between 2 and 5 meters

Figure 4-3: Removal of water hyacinth in the vicinity of an intake for drinking water production

a day. Water hyacinth are vigorous growers and mats can double in size in two weeks. Water hyacinth thus dramatically affects water flow and blocks sunlight from reaching native aquatic plants which often die. The decay processes in thick mats depletes dissolved oxygen in the water, sometimes killing fish.

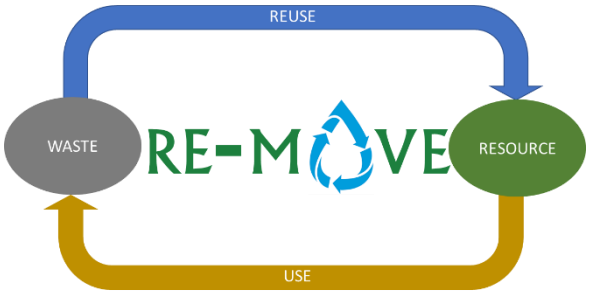
At the intake sites screens are installed to prevent large debris to be pumped to the DWTP. In River Tapi deweeder machines (aquatic weed harvester) are used and plants are also removed manually with dredges. The harvested weeds are dumped on the shore and could be used as biofuel. One hectare (2.5 acres) of standing crop produces more than 70,000 m^3/ha (1,000,000 cu ft/acre) of biogas (70% CH_4, 30% CO_2).

Another interesting feature of water hyacinth is that the roots naturally absorb pollutants, including lead, mercury, and strontium-90, as well as some organic compounds believed to be carcinogenic, in concentrations 10,000 times that in the surrounding water. Water hyacinths can be cultivated for waste water treatment (especially dairy waste water). In addition, water hyacinth is reported for its efficiency to remove about 60–80% nitrogen and about 69% of potassium from water.

Figure 4-4: Water hyacinth

Waste Water Reuse and Tapi Conservation Project

To encounter the issues related to a fast growing population, river pollution through untreated waste water and the need for fresh water for diverse purposes Surat developed a long-term strategy to deal with it.



Basically two tracks are followed. First is extending the sewage and treatment plant network, also outside the bounderies of the city, to prevent ultimately the inflow of waste water into the Tapi river (Tapi Conservation Project). Secondly treated waste water is re-used for appropriate purposes and consequently reducing the needed water extraction for fresh water production. Treated waste water is used for industrial water delivery, gardening, small lake restoration, irrigation/farming and construction works. This contributes well to the goals of Gujarat State that aims to reuse 75% of the treated wastewater by 2025 and 100% by 2030.
The mentioned Kavi Kalapi lake site is an inspiring example of reusing treated waste water, serving several goals and therefore a multi benefit project.

The sources of river pollution extend outside the city bounderies and therefore a larger perspective is needed. This is reflected in the river Tapi Conservation Project, for which Surat City succeeded in making agreements with several higher governments to receive funding. The main goal is to protect river Tapi from further degradation.

The project deals with the Tapi River from Kakrapar weir to the ONGC bridge at Magdalla, south west of Surat. The project stretches over 85 km along the Tapi river. SMC is cooperating with Surat Urban Development Authority and the State Government.

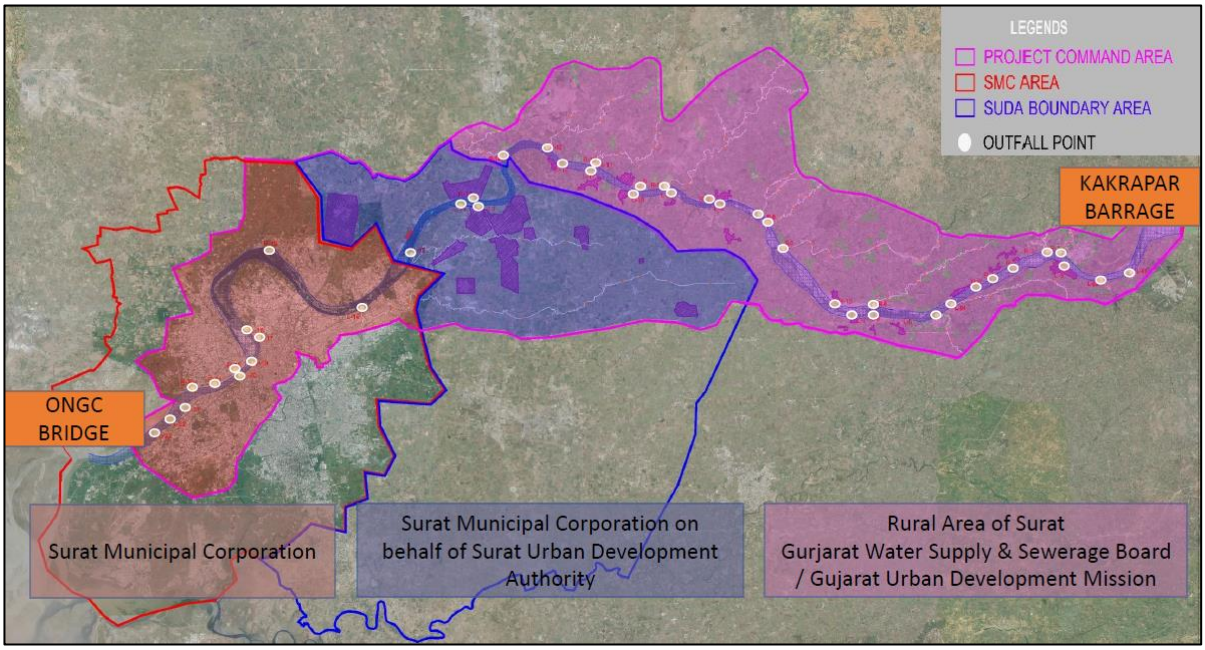


Figure 4-5: Institutional responsabilities in Tapi conservation project

Goals of the project are upgrading water quality by the provision of a comprehensive sewerage system in un-sewered areas and the treatment of all sewage water, including industrial effluents. By re-use of treated waste water it is also aimed at that river flow continues in dry periods.

There are 73 settlements in rural and SUDA area and 44 outlets (creeks) flowing into the river. The project will prevent the discharge of 370 million liters/day of residual material. Over 3,9 million inhabitants will receive improved sewage facilities. Installations will be placed to treat an additional 250 million liter/day residual material (Surat area currently: 150 MLD). Re-use of treated waste water is aimed at a total of 275 MLD used for several purposes. Additional goals are:

- 4 riverfront park developments (outside of Surat)
- 100.000 trees to be planted on 6 locations
- Purchase of 1 aquatic weed harvester
- Install 8 organic composting installations, which produce fertilizer
- Online monitoring on 4 locations using 2 laboratories.

The project spans 3 years and has a budget of 150US$ (97.124 crores rupees). 15 years of maintenance and operation is included in the project as well.

Figure 4-6: Some of the creeks discharging on Tapi river

4.2 Learnings and review remarks

The extensive site-visits at Katargam Head and Kosad Waterworks and discussions led to these remarks and learnings:

- Monitoring of the river water quality is done regularly for standard parameters and less frequently on extra parameters. More organic as well as inorganic pollutants than are measured currently are probably present in the river water. Current monitoring also doesn't give insight in the toxicity of the river water. Toxicity measurements add value because it is expected that the presence of unregulated sewarage inflows upstream contain toxic elements.

- Extensive growth of water hyacints, due to the very eutrophic environment caused by unregulated inflow of waste water, is a serious problem in the river reservoir upstream of the Weir cum causeway. It takes a lot of work to remove the plants to prevent too low oxygen ratio in the river.
  Currently the removed bio-mass isn't re-used for other purposes.

- The Tapi River Conservation project is a very ambitious program. It is well based on a strategic vision aimed at prevention by eliminating the sources of river pollution. Different phases are well described and considering the executing power and ambition of SMC to provide adequate solutions for the challenges of Surat many improvements will be made in the near future.

- The strategy of re-using treated waste water takes well into account the needs of Surat city for the near future with a fast growing fresh water need. It also contributes to the city goals and goals of Gujarat State with reusement of water. In fact this practise contributes to circularity of natural resources.
  A challenge is treated waste water (up to drinking water quality standards) to be accepted as drinking water source. This is a psychological and communicational issue.

4.3 Recommendations

Based on the information stated here, these recommendations can be given on the topic of water quality monitoring and river restoration:

7. *Execute a survey on the occurrence of Giardia and Cryptosporidium in source water and produced drinking water.*

   It is highly recommended to evaluate the risk of waterborne diseases for these pathogens also in connection with the critical aspect of recycling back-wash water in the water treatments. Evides Watercompany could give advise on this.

8. *Extend the monitoring program with a broad variety of organic and inorganic pollutants.*

   Knowledge about occurrence of pollutants like pesticides, industrial substances (e.g. carcinogenic perfluorinated compounds, trihalomethanes, benzene) and heavy metals can give basis for an extended treatment program. To make this possible the laboratory facilities need to be extended.
   To be able to identify pollution sources water quality should be monitored at different sites along the river.

9. *Extend the water quality monitoring with a total toxicity assessment.*

   A total toxicity assessment can be done on line by effect directed analyses. To get knowledge about pollution sources along the river stretch from Kakrapar Barrage and Sardar Bridge some strategic locations for monitoring could be selected. A total toxicity assessment could be done e.g. with the TOXControl (Microlan).

   A consortium of three Dutch SME's, amongst them MicroLan, prepares a proposal for funding through the Dutch NGO Partners for Water. The topic is *'An integrative approach for quick, simple and affordable water quality monitoring for chemical and microbiological and AMR (Anti Microbial Resistance) parameters'.* They are looking for an Indian city to start a pilot project. This could be matched with the aim of SMC to develop a more integrated and extended water quality monitoring system.

10. *Investigate the usefullness of the water hyacints for eather bio-fuel generations or waste water treatment.*

Figure 4-7: Removal of water hyacinths

At this moment massive amounts of water hyacints have to be weeded from the river which could be used in a bio-gas generator. Such a generator could also be feeded with other available biomass and be used for instance for generating (part of the) power for the DWTP.
Another, more uncertain, option is to create a controlled situation for cultivated water hyacints for specific flows of raw water to be treated. The feasability should be thouroughly investigated.

11. *Develop a communications strategy for convincing citizens that treated waste water is a safe source for drinking water*.

Knowing that the pressure on drinking water production will increase with the fast growing population, having a second source of drinking water is resilient. Treated waste water is already used for other purposes like gardening and irrigation, but also meets drinking water standards. Creating a situation in that citizens are convinced that this re-used water is safe begins with a well-thought communication strategy. Of course also selection of city district to start pilot projects and ways of distribution to citizens has to be thought of.

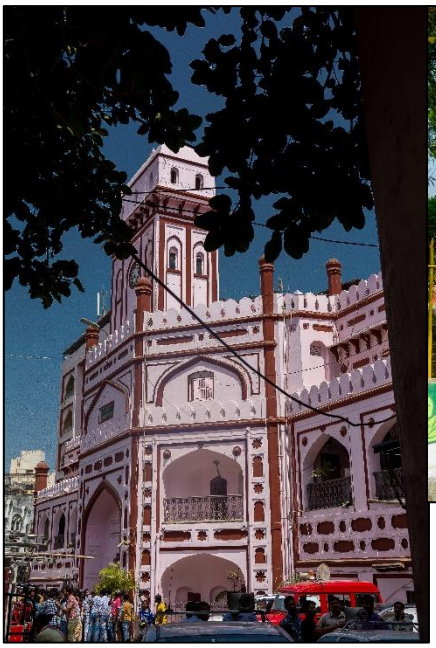


Figure 4-9: SMC Head Quarters

Figure 4-8: Dutch garden in Surat city center

5 Flood forecasting modelling

5.1 Situation and ambition Surat

Tapi river basin

The municipality of Surat covers an area of 326 km^2 and currently counts more than 5.5 million inhabitants. Coincidentally the area of the municipality of Rotterdam has about the same size. River Tapi flows though Surat for a length of 32 km.
From the city centre to the upstream Ukai dam, constructed in 1972, is 95 km. About 10 km downstream the Ukai dam the Kakrapar weir is present. From there to the Weir cum causeway near Surat city center Tapi river flows freely. The average annual rainfall in Surat is around 1400 mm (55 inches).

The total river basin area of the river Tapi covers more than 65.000 km2 and is part of three states: Madhya Pradesh (15%), Maharashtra (79%) and Gujarat (6%). Two other dams are build in the cathment area: Girna dam and Hathnur dam, both are smaller than Ukai dam. Also three dam authorities are active and responsible for dam management. Other stakeholders are the Irrigation Department, CWC, IMD and SMC.

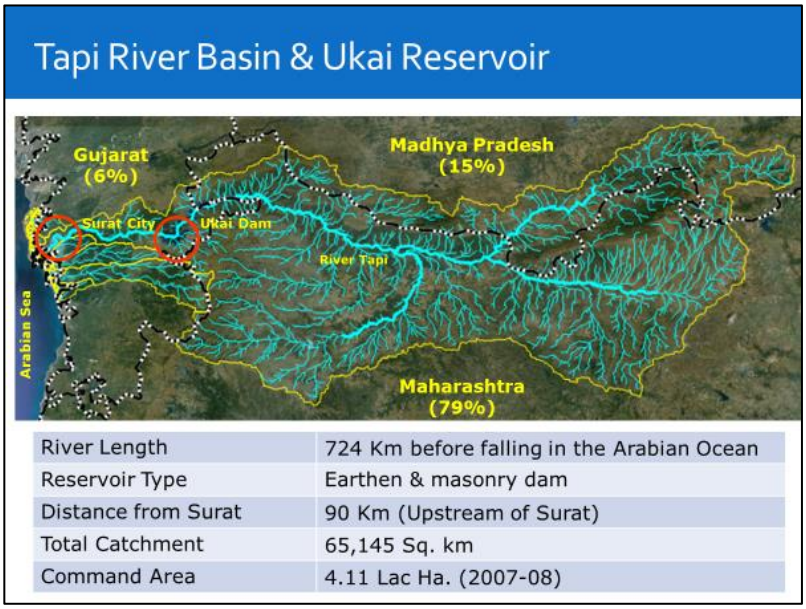
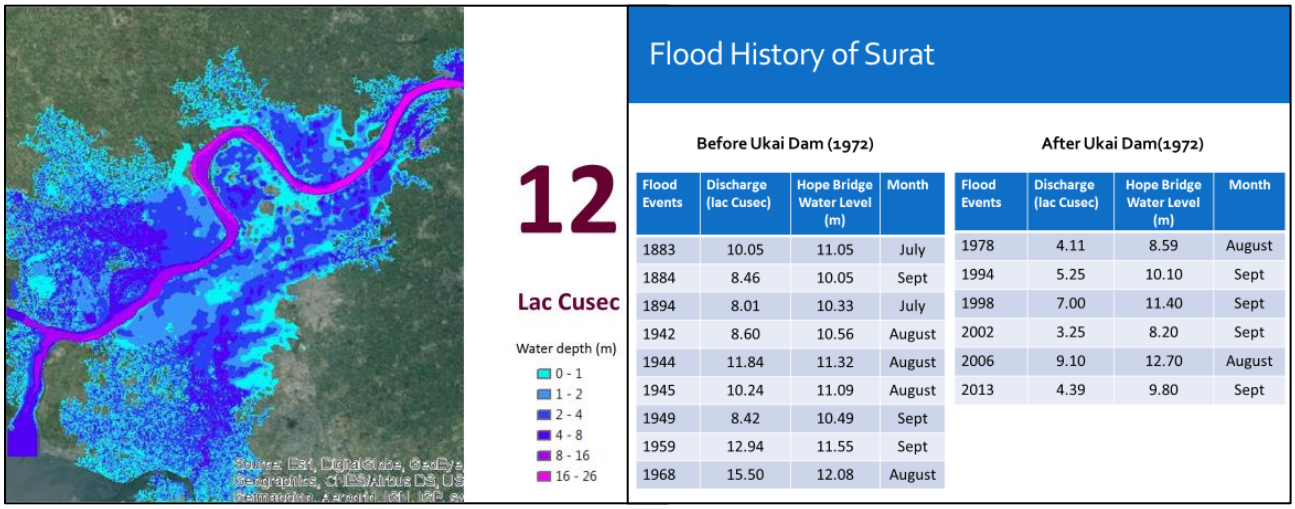


Figure 5-1: Tapi river basin

Since Ukai dam was constructed the flow of Tapi river is controlled by the Ukai dam management authority. The release of water is based on 'dam rules'. The stored water volumes in the dam reservoirs are mainly used for irrigation and power generation.

Flood event 2006

In august 2006, after very heavy rainfall in the antecedent period, the maximum reserIoir dam level was transgressed and a further quickly rising water level was foreseen. To prevent a dam breach a lot of water was released, finally causing massive floods in Surat untill depths of 8 meters. 128 km^2 of the area was flooded affecting 27.000 people, 157 people died and a total economic loss of 160.000.000.000 Rupees (at current rate: 2,3 billion USD) was estimated.



Flood History of Surat

Before Ukai Dam (1972)

Flood Events	Discharge (lac Cusec)	Hope Bridge Water Level (m)	Month
1883	10.05	11.05	July
1884	8.46	10.05	Sept
1894	8.01	10.33	July
1942	8.60	10.56	August
1944	11.84	11.32	August
1945	10.24	11.09	August
1949	8.42	10.49	Sept
1959	12.94	11.55	Sept
1968	15.50	12.08	August

After Ukai Dam(1972)

Flood Events	Discharge (lac Cusec)	Hope Bridge Water Level (m)	Month
1978	4.11	8.59	August
1994	5.25	10.10	Sept
1998	7.00	11.40	Sept
2002	3.25	8.20	Sept
2006	9.10	12.70	August
2013	4.39	9.80	Sept

Figure 5-2: Flood history of Surat

A massive rescue and relief action was set up and due to extensive actions, in which SMC played an important role, main utilities in the city were functioning again within 48 hours. After a month the city was functioning as before.
After evaluation a whole set of remedies were put in place, among others: a ward disaster management plan (ward wise micro level planning), establishment of an Early Warning System, constructions of new embankments, augmentation of storm drainage network and installing color poles to help citizens take action in case of flooding.

Figure 5-4: Flood protection along Tapi river

Figure 5-3: Flood communication poles

This event gave lessons in preparedness. A lot of power supply units and ICT systems were not in the right place to withstand a flood. An interesting measure to give citizens information to act is the establishment of an end user communication system, By installing automatic weather stations actual information is gathered about rainfall and

other parameters. Citizens get an SMS alert when rainfall exceeds 50 mm in 15 minutes or if the river level at the causeway exceeds 12 meters.

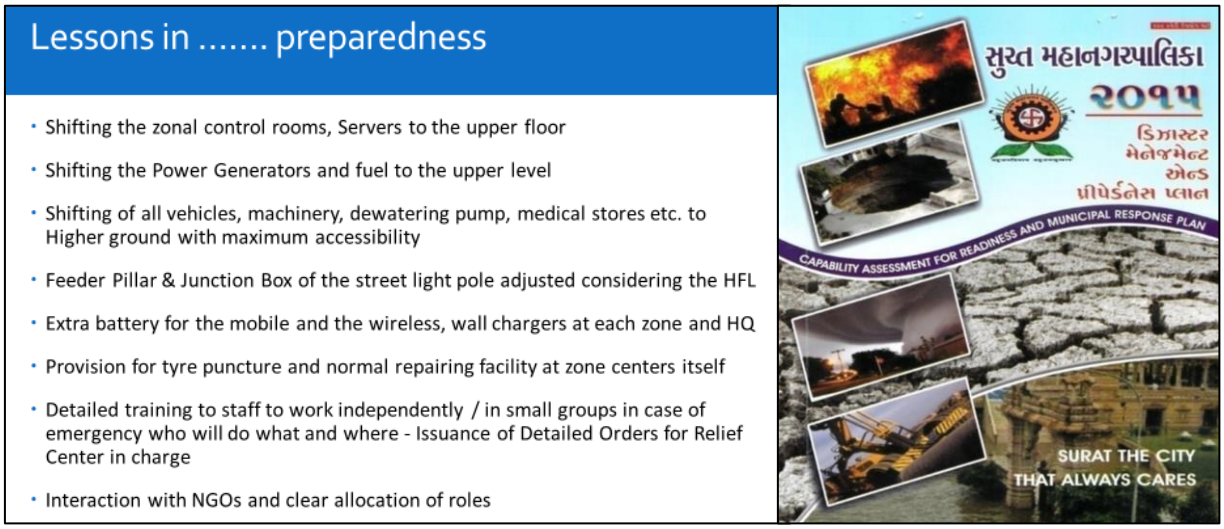


Figure 5-5: Lessons in preparedness

Learnings communication and coordination

The event made clear that a need existed for better flood forecasting and reservoir management. The information level for Surat concerning predicted and actual rainfall in the river basin as well as about the water release from Ukai dam had to be upgraded. Timely and effective information on flood hazard was needed. Agreements were made with the Irrigation department and CWC. Part of this was a revision of the Ukai dam rule level and development of an a*dvance depletion strategy* considering upstream rainfall and coordination among Ukai Dam Superintending Engineer, Surat District Collector and Municipal Commissioner.

Part of the taken measures was installing an Early Warning System (developed by ITT Delhi) to reduce the intensity of floods and resultant flood damage to Surat city. In flood forecasting several issues play a role: a control room, the reservoir authorities, IMD data monitoring, rain gauge station data and the moon calendar. The present available

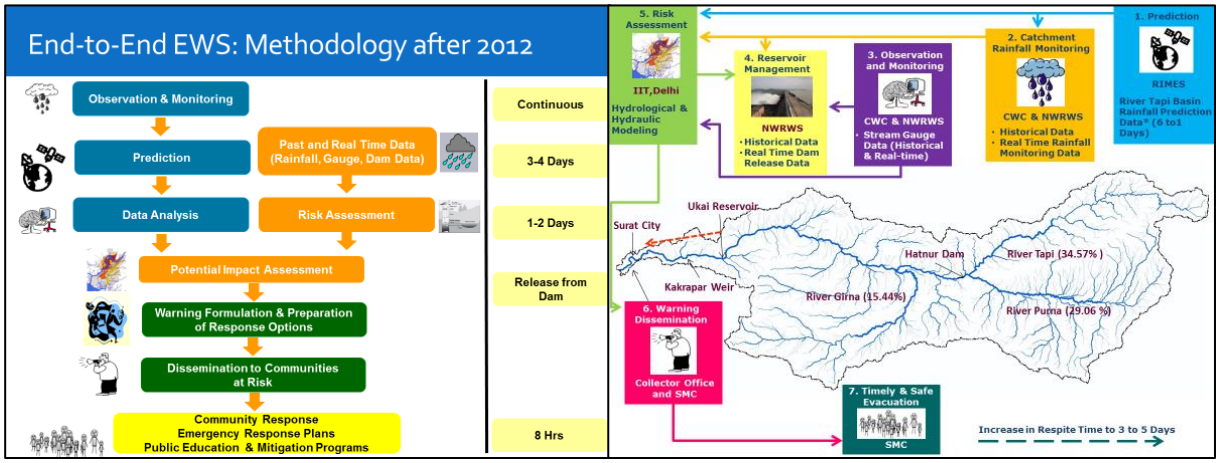


Figure 5-6: Methodology Early Warning System

flood forecasting model is not integrated in the EWS and measures flooding based on reservoir catchment capacity. SMC is interested in securing an end-to-end flood forecasting modeling which is integrated with the EWS.

5.2 Learnings and review remarks

Some remarks about the explanation of the flood risk and forecasting in Surat:

- It is very clear that the (pluvial) flood risk in Surat, located almost at the end of the Tapi river basin, depends on weather events and (on the longer term) on climate change affecting the whole Tapi river basin. A second determining fact for flood risk is the management regime of the Ukai and other dams in the river catchment area. Thirdly there is also a risk of flooding from the sea (fluvial flooding).

Figure 5-7: Weir cum Causeway

- The city of Surat has a limited role in preventive action in case of heavy rainfall in the catchment area. The dam management (primarily from Ukai dam) in cooperation with the Irrigation department determines the release of water from the reservoirs. Surat, specifically SMC, does have an important role in preparation of the city and it's citizens for a possible flooding event.

- The developed discharge and flood model (by ITT Delhi) for the Tapi river basin isn't yet accurate enough (as was stated). The inflow prediction from the model has a 30% variation (plus or minus) from the real inflow. How does this affect the prediction of water levels in Surat?

- It is not clear how the management rules of the dams in the catchment area relate to each other and which priorities are chosen. Storage of water further upstream in the river basin could be helpful to prevent the Ukai reservoir to fill to quickly. Optimazation of the whole river and reservoir management for the Tapi river basin could be a first step (but perhaps already done). Ofcourse this asks for a lot of coordination of several authorities. Developing an integrated flood model that can predict high waters as well as low waters and diversion of rainwater over the river basin can persuade several authorities because the model is multifunctional then.

There is an anology (although very different type of river basins) with the international coordination concerning the Rhine and Meuse rivers between Netherlands and Germany, Belgium and France.

5.3 Recommendations

The following recommendations can be done:

12. *Let the Early Warning System including the flood model(s) be reviewed.*

    As is requested already by SMC, Deltares can review the EWS and flood modelling related to the goals Surat aims for. Besides a technical review of the EWS set-up and flood model, the governance of flood forecasting and dam management should also be taken into account. Developing a model that can serve different purposes could be helpful in getting support and finance for developing it.

13. *Investigate the flood risk caused by the sea and climate change.*

    As stated before it is important to know what can be expected from storm surges from the Arabian sea now and in the future with sea level rise. How could a possible risk be mitigated and could the new barrage, which main goal is to create a fresh water reservoir, also have a protective function?

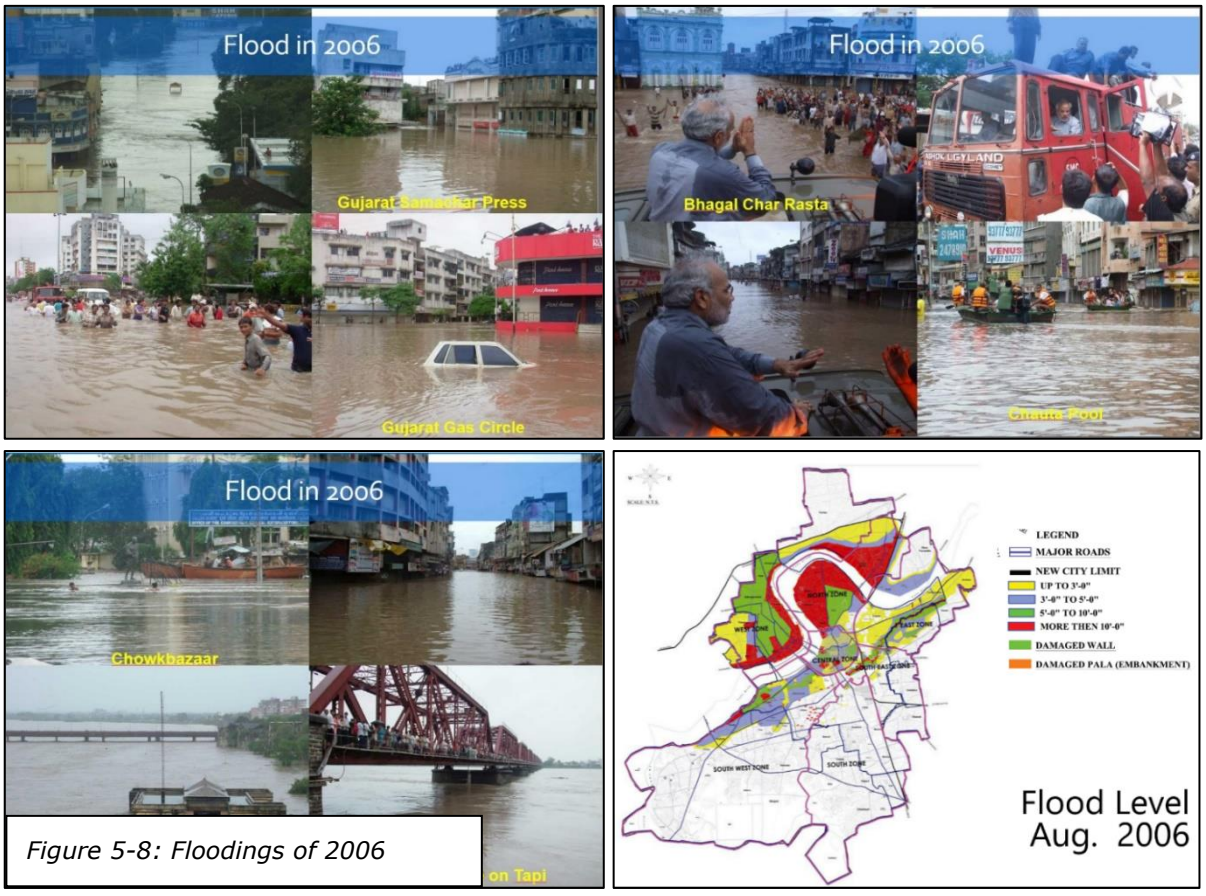


Figure 5-8: Floodings of 2006

6 Blue roofscapes & groundwater replenishment

6.1 Situation and ambition Surat

Blue roofs are used to collect rainwater on the exact rooftops where it falls. Common terminology is rainwater harvesting.
In Surat the main purpose is not to prevent flooding, but this practice has been combined with water infiltration, in order to replenish ground water. The city encounters groundwater salinization due to the natural soil conditions, situation near the Arabian sea and un uncontrolled groundwater extraction. For that reason groundwater replenishment with fresh rainwater is stimulated as much as possible. The aim is also to use replenished groundwater for drinking water in case of drinking water shortage.
Also, in the face of climate change that increases long periods of drought and salination of ground water urge the city to act.

Surat is well underway when it comes to rainwater harvesting on rooftops. Since 2008, the city made blue roofs obligatory for new buildings over 4.000 m2. Water is infiltrated untill a depth of about 30 meters. The building owner have the responsibility to install the systems and must maintain the system. Recently, the SMC has started inspecting the existing systems on proper functioning. In the public realm SMC has started projects to harvest rainwater and infiltrate this into the soil.

10/7/2018 SMC to engage residents in rainwater harvesting - Times of India

Printed from
THE TIMES OF INDIA

SMC to engage residents in rainwater harvesting

TNN | May 11, 2018, 04.00 AM IST

Figure 6-1: Rainwater harvesting in the media

At this moment, over 1350 rain water harvesting (RWH) systems have been installed. SMC has installed 332 on their buildings. Their aim is to install 2000 RWH systems per year.

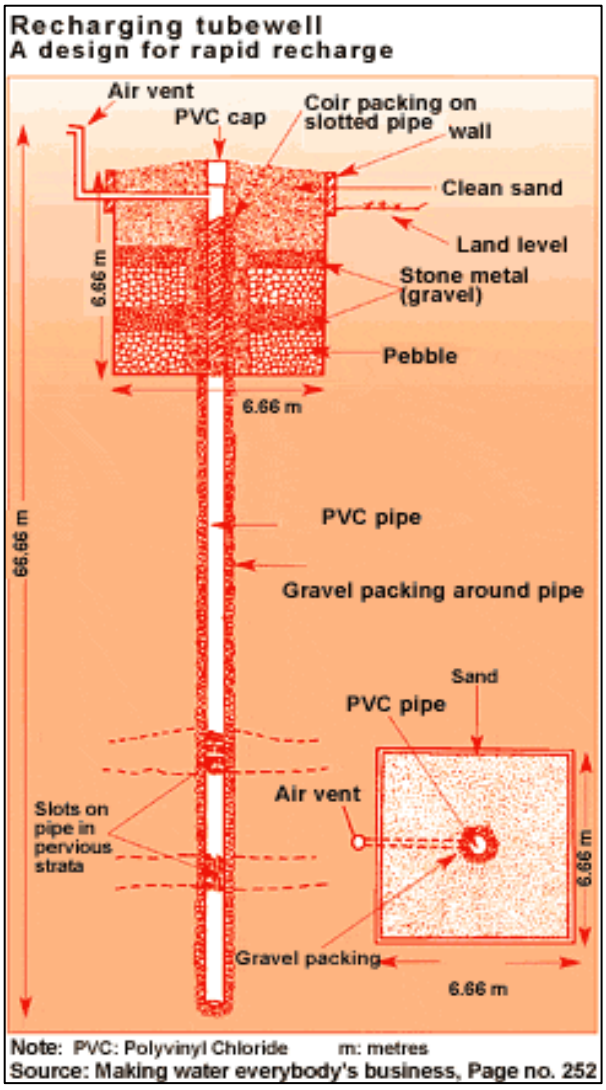


Figure 6-2: Rain Water Harvesting system in the public space

The municipality has installed a centralised window, a digital counter where citizens can go for assistance. As the RWH systems do not have an economic business case, SMC provides a subsidy. The subsidy is paid in 5 years to ensure the proper functioning of the system. More info on: http://www.rainwaterharvesting.org/urban/thepotential.htm

The potential for rain water harvesting can be found mostly in 'land-locked' districts and in districts downstream of the river, as the first will have most difficulties replenishing their ground water and the latter suffer most from salination.

6.2 Learnings and review remarks

Remarks and learnings about rainwater harvesting en replenishment system are:

- Due to the rainfall pattern with a limited, wet monsoon period of about 4 months, rainwater harvesting is only effective in a limited period. On the other hand in the monsoon period intensive rainfall is present and large volumes of water have to be drained. Only small part of the water is directly infiltrated in the subsoil through rainwater harvesting systems, but there is potential to store more water.

- In contrary to the Dutch situation rainwater is not collected to store water temporarily and retard the inflow of the drainage system. The main purpose is replenishment of groundwater.

- In public space presence of RWH-systems is still limited. A pilot project is present at the location of Surat Science Center. There is yet potential to install more RWH-systems in public space.

Figure 6-3: Green wall at Science Centre

- The functioning of the RWH-systems depends on proper installation and maintenance. To reach the public goals with these systems, a controlling procedure is indispensable. SMC has started this.

- The existence of a combination of RHW-system and solar panels on the same roof is not known, although the second function is widely installed on rooftops (more in paragraph 8.2).

6.3 Recommendations

The following recommendations about blue roofs and groundwater replenishment can be made:

14. *Investigate the effects of the replenishment of groundwater through the RWH-systems.*

    Because the main goal of the current RWH-systems is groundwater replenishment with fresh water, knowledge about the effects on groundwaterlevels and -flows on a local and regional scale is usefull. If there is also an aim to use the groundwater for water supply in dry periods it is even more needed to have insight in the groundwater volumes and -flows. This recommendation can be merged with recommendation 3 (*Develop a regional and local groundwatermodel to understand the effects of replenishment and extraction of groundwater*.)

15. *Make use of the bore hole information to build and calibrate a groundwater model.*

Upscaling and registering of the bore hole details (soil structure, groundwater levels, salt transport) contributes to the design of a geohydrological model. Register ground composition each time a drillhole for a RWH is made. This way you produce an integral mapping tool to monitor ground water levels & quality. With continuous and online monitoring (linking with data room and model) you can signal illegal withdrawals earlier and possibly stop them (limit land subsidence).
Use the model to substantiate certain assumptions (for example, that the aquifers are replenished from the river). The RWH-systems can be used as monitoring stations for ground water levels and -quality. It is also recommended to capture the first flush, so it will prevent the RWH well to block.

16. Investigate the usage of groundwater for cooling systems in public space.

Rain water harvesting in Surat is now mostly used for replenishing ground water levels. An additional function of the systems could be cooling. The water infiltrated in the soil, can be reused for cooling. By means of pumps cool groundwater can be pumped up and heated water can be pumped down again. There is experience with this kind of systems in the Netherlands. Thorough information on the soil composition is needed.

A Rotterdam innovation that is now in a pre-pilot phase is the 'Coolkuip'. A system that uses the flow of cold(er) groundwater to cool down hot air from outside and the cooled air is used for cooling a space (public area, small building).

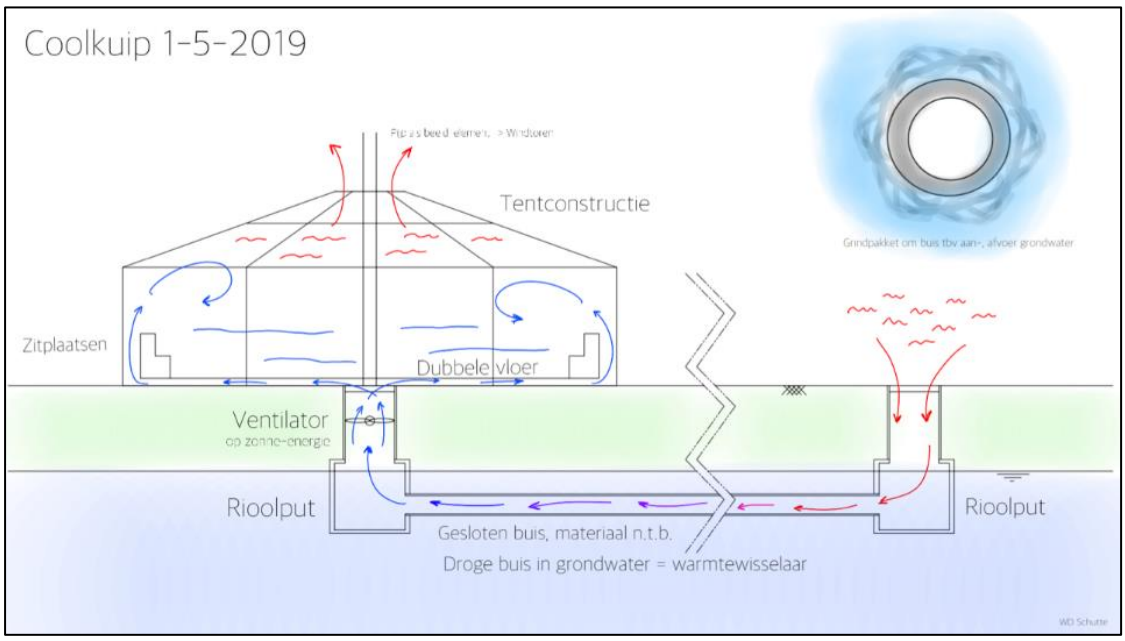


Figure 6-4: Innovative concept for cooling small areas of public space

17. *Develop a broad vision on the use of rooftops.*

Roofs are space! They provide space for a broad variety of functions, which becomes unavoidable in even denser cities. Looking at Surat, the growth of the city seems to be the biggest disruptive challenge the city faces. Roofs won't save the day, but the can provide large quantities of additional urban space.
Surat already uses roofs for rain water harvesting and solar energy. Both combining functions and adding additional functions is recommended. Rooftop space can be used then as efficiently as possible and it could even result in cost benefits.

The city of Rotterdam has started a rooftops programme: Rotterdam Roofscapes. The aim is to use rooftops in a multifunctional way. Surat has its own challenges to cope with, so a specific approach is at place. Possible functions that could land on Surat's roofs are: cooling, water retention, solar energy, greening and social/recreational use of roofs.

Figure 6-5: Rooftop gardening at Dakakkers Rotterdam

Multifunctional Roofscape

Rotterdam focusses on a mix of functions that are relevant for the city. These include sustainable energy production (yellow roofs), water retention (blue roofs), nature & bio-diversity (green roofs) and social functions on rooftops (red roofs). The impression be-low shows the ambitions of Rotterdam. Future functions that will be added to the mix are mobility over rooftops (orange roofs) and living on roofs (purple roofs).
Rotterdam found that combining functions on rooftops builds better (business) cases.

Figure 6-6: Rotterdam Roofscape

Figure 6-7: Combinations of rooftop functions

7 Waterplaza, city lakes & groundwater replenishment

7.1 Situation and ambition Surat

In earlier times a lot of small ponds ('city lakes') were present Surat of which more than 200 remain. These lakes had several functions, but water storage was evidently one of them. Today the city has 'discovered' the city lakes again beacause they also can contribute to groundwater replenishment.
A very good example of such a lake is situated at Kavi Kalapi garden. Alongside this city lake, Kavi Kalapi lake, a small tertiary waste water treatment plant is build and the treated waste water flows into this small lake. The water is used for gardening water among others.

Another type of lake, but artificial, are the temporary ponds that are build for the Ganesha festival. To prevent the remains of thousends of idols (> 75.000) to be thrown into the river Tapi and pollute the water, what was the practice for a long time, artificial ponds are build to be used as 'idol dipping' means.

Figure 7-1: Artificial pond for Ganesha festival

Inspired by the waterplaza's in Rotterdam, the idea came up to build a waterplaza and use it also for the Ganesha festival, so for ceremonial purposes. Other purposes that is thought of are recreation and temporal waterstorage.
A location for a first pilot project has been chosen, an area of about 5500 m^2. Some artist impressions of the proposed waterplaza are shown below.

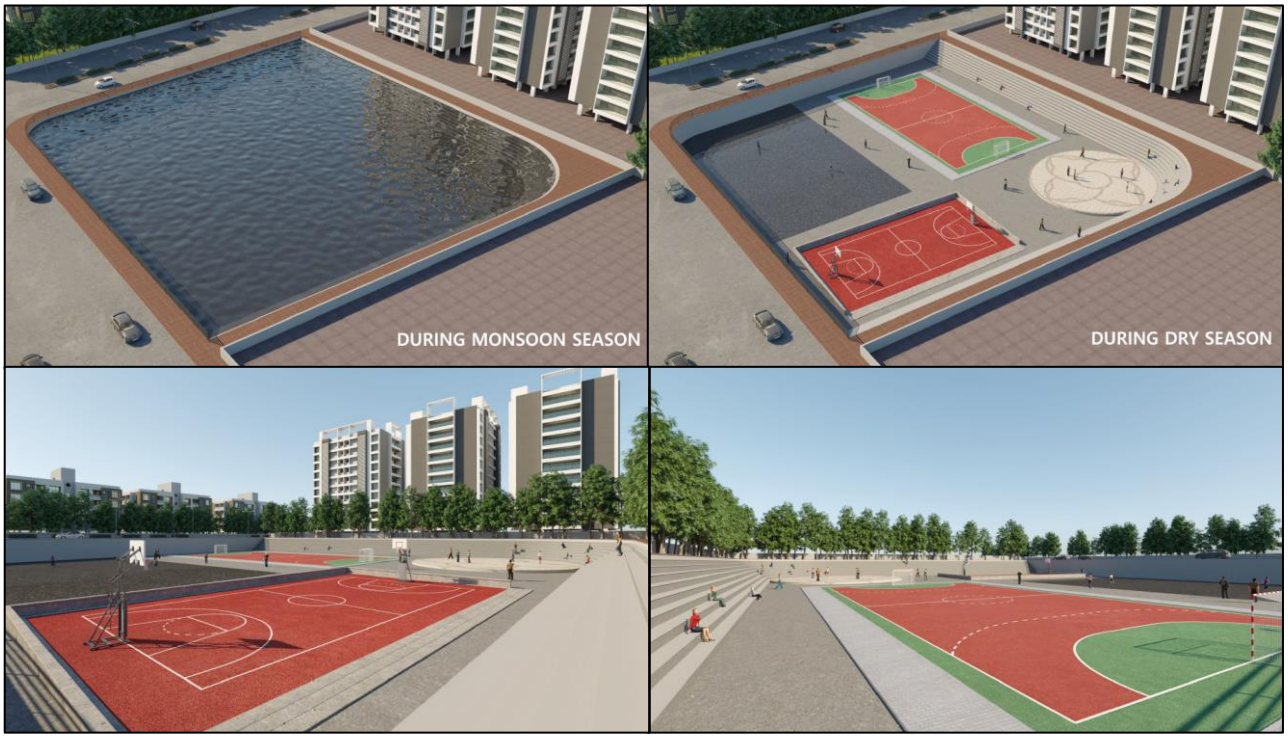


Figure 7-2: Artist impression proposed waterplaza

7.2 Learnings and review remarks

Remarks and learnings about small city lakes and the proposed waterplaza:

- The existence of the small city lakes are a big potential for water related functions like water storage and groundwater replenishment, recreation and greening. It has not become clear where the plus 200 small lakes are located, but they can contribute to the watermanagement of Surat. It is usefull to know how these lakes were filled in the past, where the water came from and if these were filled whole year round.

- The proposal for a waterplaza is impressive! The link with the cultural ceremonies for Ganesha festival is resourceful, a good example of resilience. It is clear that a waterplaza in Surat can have different functions and can contribute to different goals. One of them is evidently also replenishment of groundwater, which is one of the aims of SMC. Besides rainwater in the monsoon period treated waste water could be used for this purpose although a communication strategy is needed then to get this accepted by the public.

- Technically the waterplaza system (as are the RWH systems) are well designed. Integration of functions (multifunctional approach) and good design of the public space could further improve the solutions. When well designed, placemaking could

be actiever. Landscape architect and urban planners could be involved to add esthetic quality and enhance the participation of citizens.

Figure 7-3: Rainwater harvesting

7.3 Recommendations

The city lakes in Surat are a potentially useful asset of the city to encounter water challenges. Also the concept of the waterplaza can contribute to a resilient city. The following is recommended:

18. *Map the (former) locations of the city lakes and investigate how they can be revitalised and become part of an integrated (natural) waterstorage system.*

    Combining maps of the (former) locations of the city lakes and of storm water floodings and natural drainage patterns could give insight in how as much water as possible can be drained towards the lakes. In this way the city lakes can contribute to the watermanagement of Surat and have an important social as well as a recreational function. They can be used as storage facility for rainwater as well as treated wastewater and meanwhile replenish the groundwater. At the same time, if the surrounding public space is well designed can serve as meeting places for citizens. These places can become 'green longs' of the city helping it to cool down and support biodiversity. Aim to make a square that is used all year round. If residents start using the square, they may also help with maintenance and management. Rotterdam can counsel in the support of Dutch designers and landscape architects.

19. *Investigate which additional functions can be combined in the (pilot) waterplaza.*

    Besides the recreational function and the ceremonial function related to the Ganesha festival, groundwater replenishment could be thought of. With the support of public space designers greening can be added and thus create cooler places in the city. Perhaps it is possible to create underground storage near the waterplaza to be used in dry periods for watering the green.

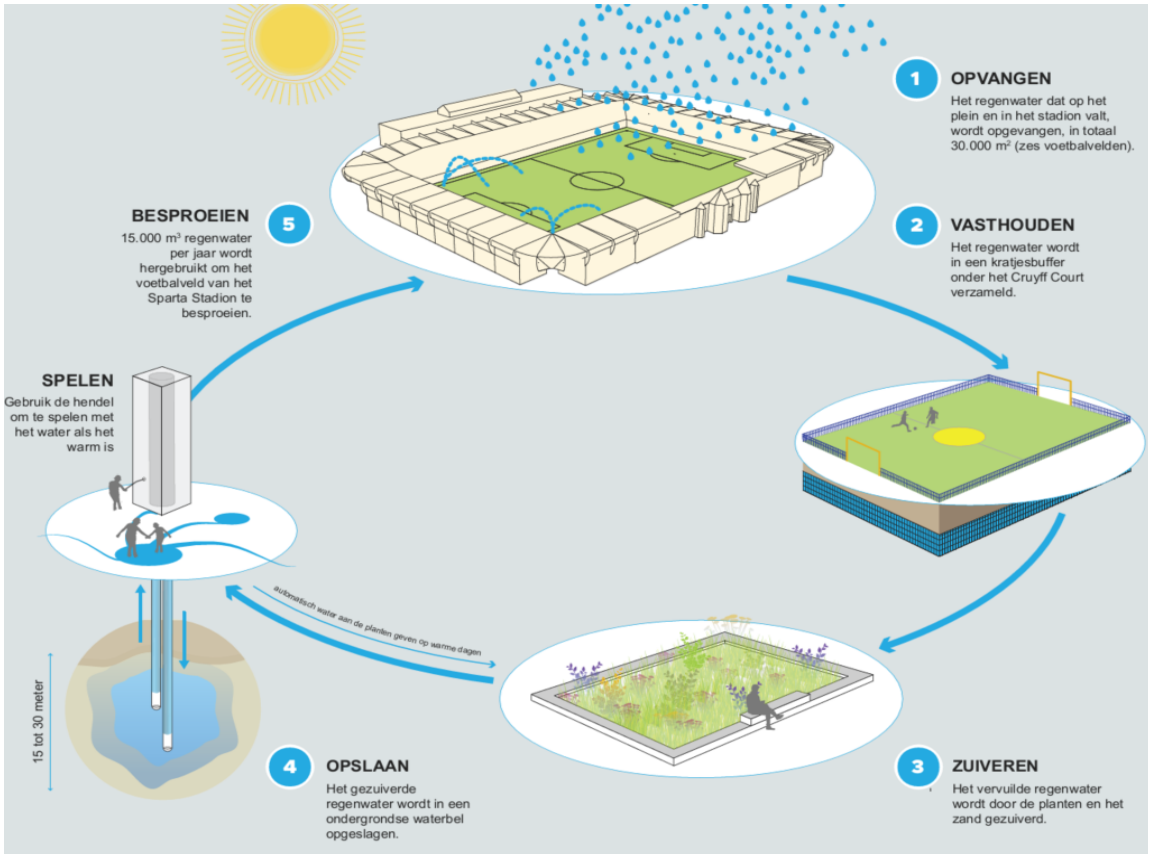
20. *Develop a communications and partipation strategy that makes citizens and companies to support the design and construction of water plaza's and 'city lake parks'.*

    Make it interesting for people to participate in watermanagement and greening of the city. Like companies that 'adopt' green walls and decorations of roundabouts, companies could be inspired to adopt a city lake park or waterplaza. A catchy name for the project(s) would also help.

Figure 7-4: Projected location of pilot project waterplaza

Rotterdam: Urban Waterbuffer

An example of multifunctional use of rainwater in Rotterdam is the Urban Waterbuffer in the district of Spangen. Rainwater is harvested from a plaza and in a large soccer stadium (total area: 30.000 m^2) and stored underground under a small soccer playing field. The rainwater is cleaned through vegetation and sand before it is stored in the subsoil. This water is used for watering the football playing fields of the nearby stadium of the Sparta football club (15.000 m^3/yr). Before this installation was build they used tapwater to spray over the fields. Also kids can play with water by means of a tap in the plaza.



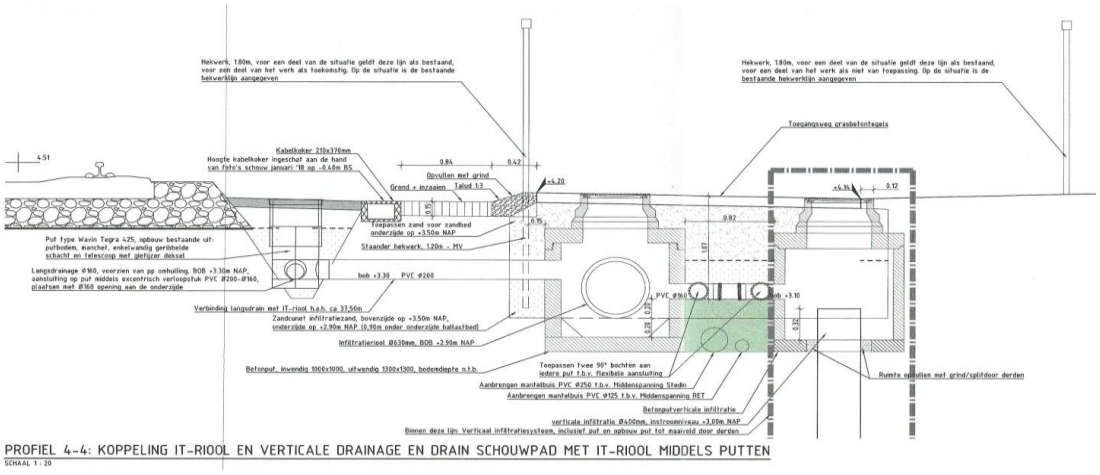


Figure 7-5: Urban water buffer at Sparta soccer stadium

8 Complementary topics

8.1 Smart City approach

Surat is really building a smart city! In the Smart City Centre (SMAC) it was shown that Surat built an integrated system of connected applications and as a second step fill these apps with data and information. It is quite impressive to see that all the app's are integrated with each other and that citizens can be informed on a diversity of topics. They also can 'discover' new types of information.

This approach has the advantage of having an integrated system. In Rotterdam and other cities we see often the opposite: collect data first and then try to bring it together in a digital framework.
In Rotterdam, open source data are provided on an open platform, encouraging organisations and companies to build business around them. We call this approach 'De Digitale Stad' (The Digital City).

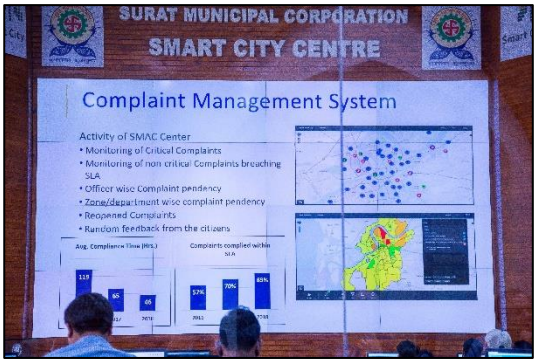


Figure 8-1: Surat Smart City Centre

Some examples of information provided through the SMAC are a solar rooftop app with posibility for a contractor to apply for subsidy, a complaint management system and all kind of public information like taxes, maintenance of street lighting etc. (Surat.data.gov.in). A challenge for Surat is the development of more and more (type of) data and of course cyber security.

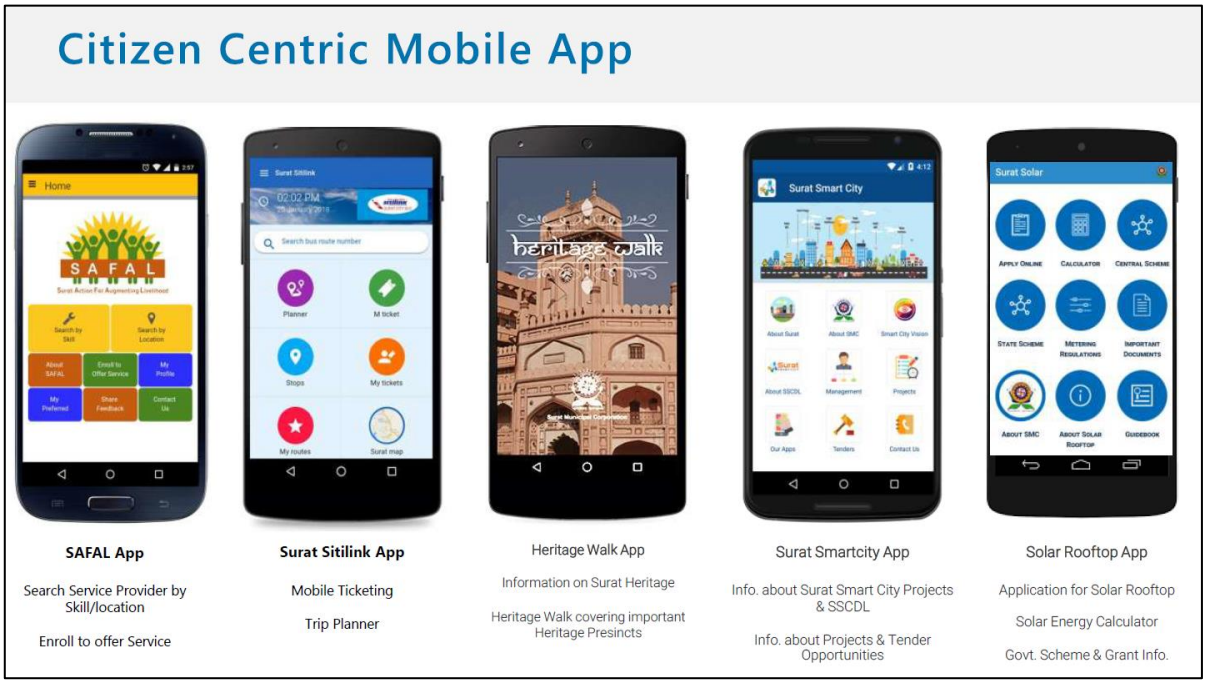


Figure 8-2: Mobile apps for citizens service

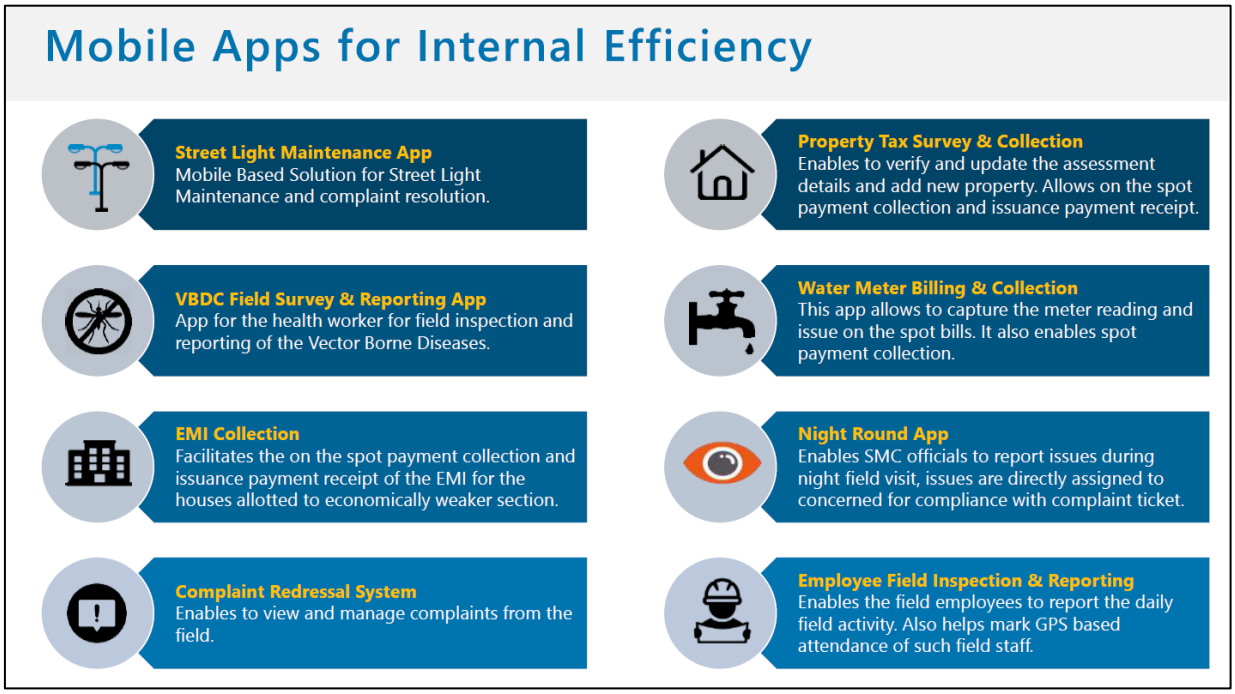


Figure 8-3: Mobile apps for civil servants

8.2 Renewable energy

Since 2011 Surat has been one India's 60 'solar cities'. The city has a green energy policy, in which they aim to provide 10% of their own energy demands by reducing energy consumption and by producing energy in a sustainable way. Up till now, the policy has

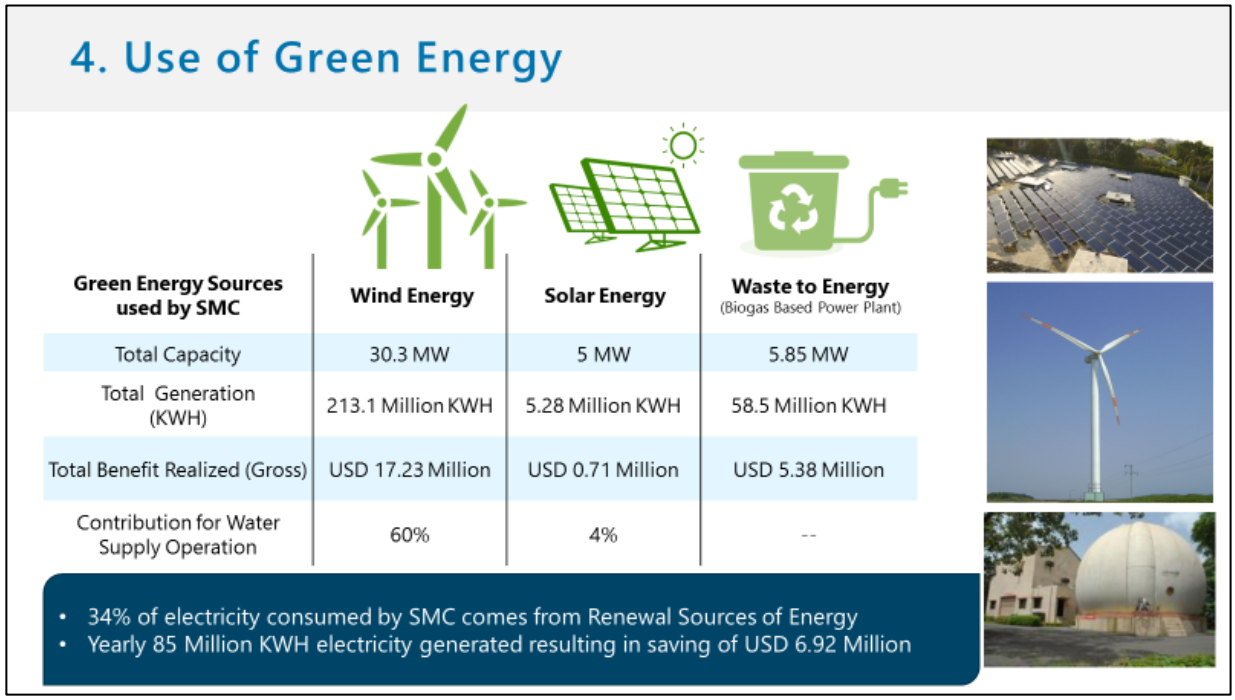


Figure 8-4: Use of green energy in Surat

resulted in a combined installed power of 30MW in wind energy, 5MW in solar energy and 6MW in energy from waste.
Since 2012, solar panels haven been installed on 55 municipal buildings (resulting in 5MW installed power) and the 2022 goal is 100 buildings with a combined installed power of 10MW.

For residential buildings, SMC has been playing a facilitating role. They installed a single window clearance system, through which applicants will be unburdened for the process of installing solar panels on their buildings. SMC will arrange permits, subsidies (up to 50% of costs fort installation) and will contact contractors. Applicants can use the solar rooftop app, that the city of Surat has implemented. This is a very useful and modern way to unburden citizens. More info on: suratsolar.suratmunicipal.gov.in

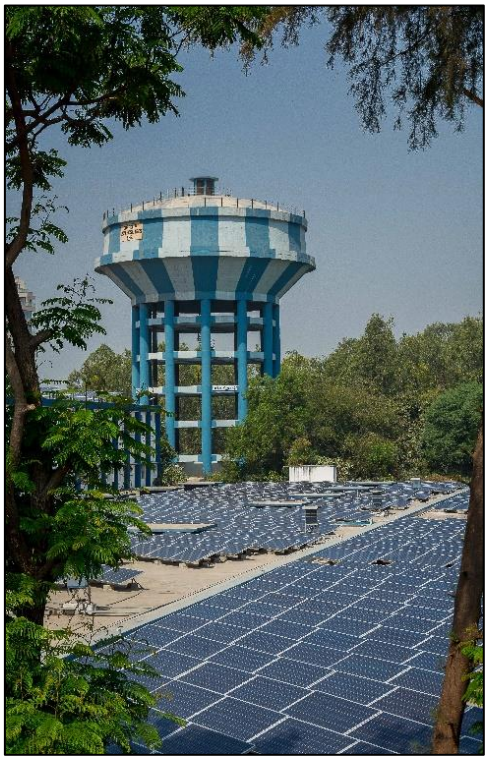


Figure 8-5: Solar panels at Katargam water treatment site

At present, over 6000 buildings have been provided with solar panels, with a cumulated installed power of 39MW. Wind power is not limited to municipal use only. Over 40MW of wind power has been installed by third parties.
All in all, almost 3% of the cities energy need is met by renewable energy sources.

For comparison: Rotterdam is investing in renewable energy as well. Until 2030 750 MW is planned to be installed. So far, over 100.000 solar panels have been installed by which 24 GWh is produced on almost 6500 roofs.

A good way of monitoring solar panels on residential buildings, has been developed by the Rotterdam based start up Sobolt. They managed to write an algorithm for the city of Rotterdam which enables the Rotterdam municipality to remotely monitor the number of solar panels on a yearly bases. The algorithm uses aerial photos, satellite picture, a 3D pixel cloud and GIS-info and can be updated yearly by providing recent data sets.
The municipality of Rotterdam can connect SMC to this company, if requested.

Furthermore, both cities could cooperate on investigating sustainable district cooling as an option to make the cities energy demand future proof. Rotterdam Central District will start it's investigation shortly.

9 Integration and follow-up

9.1 Topics reviewed from a resilience perspective

Urban Growth and Water Resilience
Surat is one of the fastest growing cities in the world; now the population counts around 6 mln. people and within one decade Surat will double in size. Rotterdam counts 640.000 people on exactly the same area, which makes Surat not only a fast growing city but also a very dense city.
From resilience perspective one can conclude that this strong urbanization is a "stress" for Surat resulting in challenges regarding drinking water supply and having enough and a diverse range of drinking water resources. Also because the current economy of Surat depends for a considerable part on good water quality (textile industries). Full dependency on just one resource, the river Tapi, makes drinking water supply vulnerable, now and especially in the future.

Climate Change and Water Resilience
Already today during the monsoon rains urban flooding now and then occurs. Creating flood resilience in a dense city like Surat therefore results in additional challenges. Besides rapid urban growth climate change also is happening and will increase the challenges if no action is taken. Climate change calls for measures in drainage and (temporal) storage capacity, (possible) flood risk measures to encounter storm surges as well as a long term strategy for drinking water resources.

Worldwide sea levels are rising, although there are regional differences. Sea level rise could be a risk for Surat, located about 30 km from the Arabian sea, due to storm surges. At this moment there is a lack of information about short and long-term consequences.

Due to climate change rainfall in the Surat region and upstream will decline. Consequently the role of river Tapi as a drinking water resource is under pressure. Nowadays the Ukai Dam is facing high levels of water, in the future there also might be an increasing chance on a deficit, as the dry 2018-2019 season is an example of.
Climate change also results in salinization of river Tapi from the Arabian sea and consequently salinization of groundwater that is partly used as a fresh water resource.

Energy resilience
Surat is building a renewable energy infrastructure, currently primarily based on solar and wind power. The location and climatical conditions of Surat offers opportunities especially for solar power. The dams in the rivers in Gujarat state also provide power generation. This situation offers a good starting position for Surat to become less dependant on fossil fuels, especially beneficial in the light of the fast growing need for energy in the city.

Interconnection of topics

A quality of resilience is integratedness. Connecting different areas of interest, like water management, energy supply, social goals, can add value and make a city more resilient. In the paragraphs above several examples of this integration and recommendations are already mentioned. Some additional remarks:

- Creating a new fresh water reservoir by building a new barrage is, for the time being, a solution in the growing need for drinking water. Combining this with water front development will add additional urban quality.
- A new multifunctional barrage will connect communities on both embankments in a sustainable way, especially when the design is taking into account different traffic modalities, including pedestrians and bikes.
- The new barrage will block fish migration (if present). Investing possibilities to install "fish stairs" might be worth while to do. An ecologically healthy Tapi River will contribute to drinking water quality, which both is relevant as it is a resource for drinking water ànd it becomes part of new urban quality related to river front development.
- Restoring the old city lakes and combining several functions, as mentioned in paragraph 7.3 could be a new selling point for Surat: "Surat the city of Garden Lakes". This depends on a integrated vision on how use these lakes and combine functions, as well physical as social.
- Both the design of waterplaza's and garden lakes require timely involvement of landscape architects and community involvement. The latter is important in order to create ownership. And maybe this can be combined with community subsidy related to the maintenance of the objects. Connect roofscapes, waterplaza's and city lakes in an integrated vision on watermanagement, greening and recreation and community

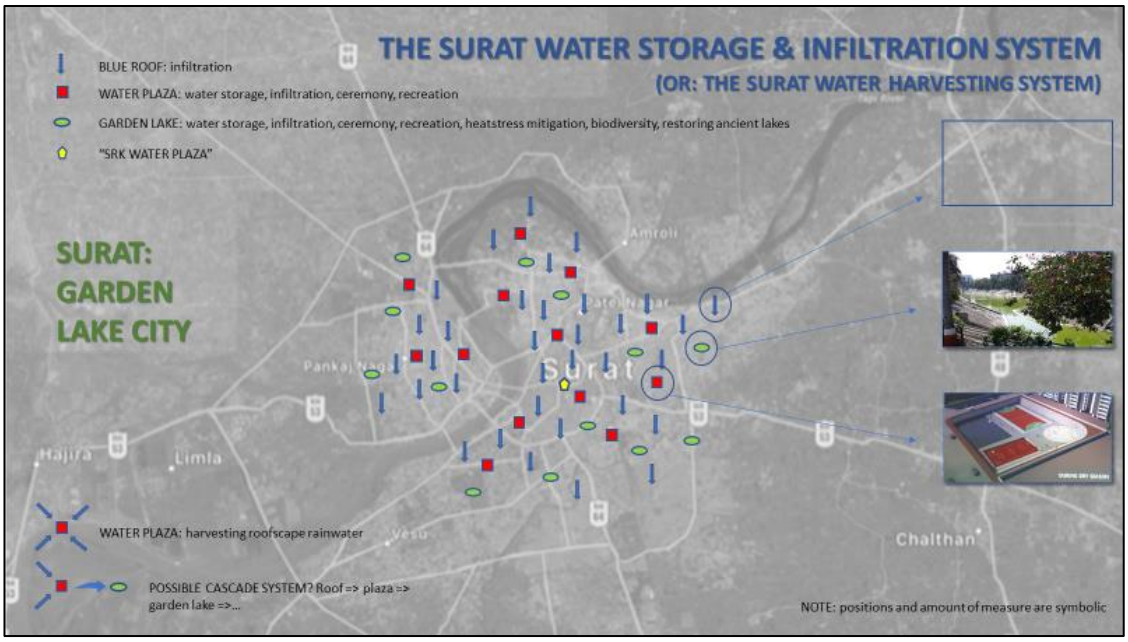


Figure 9-1: Schematic view of integrated approach for rainwater harvesting, storage and infiltration

involvement. It is recommended to use the blue roofscapes in the direct neighborhood of plaza's and lakes, to collect the rainwater. This will create small 'catchments' of rainwater harvesting: a multi layered rain water harvesting system.

9.2 Options for continued cooperation

It is clear that Surat is preparing for current and future challenges in a very pro-active and energetic way. SMC is aware of the risks mentioned in this report and plans for the future. The results and plans are impressive and the visit has resulted in more knowledge about the challenges and approach of Surat.
Surat's approach also gives Rotterdam some entry points for thought, specifically:

- The Anudan scheme: living communities can receive a monthly subsidy in order to be able to keep their environment clean. So far, Surat has reached over 600 communities. This approach can be useful for the city of Rotterdam, regarding its aims on social resilience.
- Surat has installed an extensive system of poles indicating the expected water height in case of a flooding. Although floodings are not expected to reach Rotterdam city in the near future, this method can be a great way to raise awareness in Rotterdam's low-lying areas.
- The two cities have similar challenges, on a different scale. Surat's pace is much faster, especially in execution of measures and projects, which shows most of all in its growth (both economical and for population). It would be interesting to learn more about policy development and executive processes in Surat.
- For Surat the religious Ganesha ceremony is an entry point to address water management issues. The approach on waterplazas is a good example. This approach is useful in Rotterdam as well and already practised on a small scale. A different entry point can enable a municipality to start a dialogue with its citizens on a bases of interests of citizens. Social goals might be easier to reach.

The city of Rotterdam is content with the partnership with Surat and both cities are aiming for tangible results of the partnership. As a result of the visits and continuation of the cooperation these issues, among others, are open to discussion with Rotterdam or its partners:

1. The expertise of Evides Water company is available for reviewing new projects or specific topics.
2. In water technology, like water quality monitoring, a lot of Dutch companies and research institutes have knowledge and experience in international context (also India). Dependend on the needs of SMC collaboration can be explored. MicroLan, for instance, is part of a broader network of companies in water technology (see also page 25).
3. The expertise of Deltares is valuable for the EWS and flood model review. It is advised to make a clear request of issues to be reviewed or investigated and discuss it with Deltares.

4. Several Urban Design firms in the Netherlands have specific expertse on the combination of watermanagement and public space design. For instance, urban design firm 'De Urbanisten' (the designer of the first waterplaza in Rotterdam) could give advise on the design of waterplaza's and 'city lake gardens' in Surat, specifically for design of the public space.
5. Advisors and engineers from Rotterdam municipality could advise on a 'multi layered rain water harvesting system' for Surat and on specific design issues.
6. As mentioned in paragraph 8.2 the start-up firm Sobolt has developed a system to remotely monitor solar panels on residential buildings. Mapping of solar roofs in Surat, using remote sensing, could be an interesting action. Linking it with the smart city activities is an ooportunity.

We are well aware that the context of Surat is really different from Rotterdam, therefore the advise is: 'translate, don't copy'. Surat needs its own solutions in it's specific local context. The recommendations in this report are based on a visit of five days. These have to be discussed and explored into more detail to decide on starting projects.

The city of Rotterdam cooperates with all kind of public and private partners to build climate resilience of the city. Several of them are united in the Rotterdam Centre for Resilient Delta Cities (RDC). A lot of expertise can be found in RDC.
Besides RDC the Dutch NGO Netherlands Water Partnership (NWP) can advise on other private and public knowledge partners for watermanagement and watertechnology (www.netherlandswaterpartnership.com).

Rotterdam Centre for Resilient Delta Cities
Rotterdam Centre for Resilient Delta Cities (RDC) is a public-private network organisation consisting of leading companies, knowledge institutions, design firms and the Municipality of Rotterdam. They joined forces to accelerate the transition towards safe and sustainable delta cities worldwide. In these cities, water safety, ecological resiliency and a sustainable economic development are inseparably intertwined. To face the challenges of the 21st century, delta cities need to find sustainable solutions to enhance water safety and supply, but also to add value in terms of spatial and ecological quality, social outcomes and economic potential. With a world renowned track record of knowledge and experience in the realisation of innovative concepts, RDC members can help your city or your company in raising awareness and expertise on climate change adaptation strategies. RDC can help you find the best business and knowledge partners for the (re)design and development of your resilient delta city. The members are connected to a broad network of national and international partners to ensure a tailor-made approach that meets your needs.

Information at: www.rdcrotterdam.nl

Figure 9-2: Textile industry (Siddhi Vinayak Knots & Prints Pvt. Ltd.)

10 Summary of recommendations

1	*Characterize the 'particle problem' by determining the size frequency distribution of the particles and determine the composition (organic or inorganic).*	Page 17
2	*Organize a monitoring program to determine the density of the parasitic protozoans Giardia and Cryptosporidium in the surface water.*	Page 17
3	*Develop a regional and local groundwatermodel to understand the effects of replenishment and extraction of groundwater*.	Page 17
4	*Investigate effectiveness and feasability of compartmentalization of the planned new river reservoir.*	Page 18
5	*Investigate (if not done already) the effects of long term sea level rise.*	Page 18
6	*Investigate ecological effects of the new barrage.*	Page 19
7	*Execute a survey on the occurrence of Giardia and Cryptosporidium in source water and produced drinking water.*	Page 25
8	*Extend the monitoring program with a broad variety of organic and inorganic pollutants.*	Page 25
9	*Extend the water quality monitoring with a total toxicity assessment.*	Page 25
10	*Investigate the usefullness of the water hyacints for eather bio-fuel generations or waste water treatment.*	Page 25
11	*Develop a communications strategy for convincing citizens that treated waste water is a safe source for drinking water.*	Page 26
12	*Let the Early Warning System including the flood model(s) be reviewed.*	Page 31
13	*Investigate the flood risk caused by the sea and climate change.*	Page 31
14	*Investigate the effects of the replenishment of groundwater through the RWH-systems.*	Page 34
15	*Make use of the bore hole information to build and calibrate a groundwater model.*	Page 35
16	*Investigate the usage of groundwater for cooling systems in public space.*	Page 35
17	*Develop a broad vision on the use of rooftops.*	Page 36
18	*Map the (former) locations of the city lakes and investigate how they can be revitalised and become part of an integrated (natural) water-storage system.*	Page 41
19	*Investigate which additional functions can be combined in the (pilot) waterplaza.*	Page 41
20	*Develop a communications and partipation strategy that makes citizens and companies to support the design and construction of water plaza's and 'city lake parks'.*	Page 42

11 List of abbreviations & figures

List of abbreviations

AWS	Automated Weather System
Crore	10 Million (10.000.000)
Cusec	Cubic Feet per Second
DWTP	Drinking Water Treatment Plant
MLD	1 Billion (1.000.000.000)
Lakh/Lac	1 Hundred Thousand (100.000)
LPCD	Liters per Person per Day
RWH	Rain Water Harvesting
SUDA	Surat Urban Development Area
WDS	Water Distribution Station
WTP	Water Treatment Plant

List of figures