المشروع البحثي للمياه الأرضية
GROUNDWATER RESEARCH PROJECT

مـــدرسة حفـــاظ

Conservation School

أضرار المياه الأرضية والأملاح على المواقع التاريخية في المحيط العمراني.

Groundwater and salt damage to historic sites in urban contexts.

13 نوفـــمبر November - 22 ديسمـــبر December

للاستعلام والتسجيل
for inquiry & registration

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وزارة الدولة لشئون الآثار

ARCE AMERICAN RESEARCH CENTER IN EGYPT

محاورة

تكوين TUDelft U.S. Embassy, Cairo UNIVERSITY OF OREGON القاهرة

Contents

1.0 INTRODUCTION

This report covers the output of the last module of the ARCE conservation school: Ground water and salt damage to historic sites in urban context. The module that was specifically focusing on integrated solutions.
The school was organized by the Athar Lina Initiative – Megawra Built Environment. Funded by the American Research Center in Egypt, with additional funding from the American Embassy under the supervision of the Ministry of Antiquities.
In partnership with the Universities of Oregon and Cornell and in collaboration with Cairo Governorate, TU Delft, Cairo University's Faculty of Planning and Takween for Integrated Community Development.
Within the framework of Athar Lina Groundwater Research Project: Integrated solutions for ground water problems in historic contexts.

1.1 About Athar Lina Groundwater Research Project Integrated solutions for ground water problems in historic contexts

A multi-disciplinary research and training program with the participation of an international team of architects, conservation experts, urban planners and experts in urbanism, environment, infrastructure and water resources. The purpose of the program is as follows:

a. Study the phenomenon of ground and subsurface water rise in historic areas and its effect on historic buildings. (Research phases: Aug-Oct 2016 and Jan-Mar 2017).
b. Train a professional and scholars in the field of heritage conservation on state of the art techniques of treatment of historic buildings suffering from salt and water damage. (Conservation School: Nov-Dec 2016).
c. Organize an international school to develop integrated methodologies for treatment of water extracted during dewatering processes to be used as an alternative for supply water for cleaning, industrial, irrigation or irrigation purposes. (International School: April 2017).
d. Pilot one or more proposed methodologies in al-Khalifa. (Piloting and Intervention phase: May-Jul 2017).

The program follows a sustainable methodology through technologies that can be implemented and that are suitable for the social particularity and economic conditions of the area with the aim of transforming ground water from a source of harm to a social resource. It builds on Athar Lina initiative's mandate to preserve the historic city and make sure it is used efficiently as a social resource and driver for development. Athar Lina initiative has been implementing an integrated participatory program of conservation, rehabilitation, heritage education, tourist development, capacity building and urban development in the neighborhood of al-Khalifa since 2012 based on this mandate.

1.2 About the conservation school
Groundwater and salt damage to historic sites in urban contexts

A six week conservation school aimed primarily at Ministry of Antiquities employees. It engages 20 MoA professionals in addition to around 7 employees of Cairo Government, the Ministries of Housing, Environment and Endowments, in addition to the Water and Sewage Companies and the National Institute for Water Studies. Students and young professionals are also given a chance to audit sections of the course. Teaching was Sunday through Thursday from 9 am to 1 pm through lectures, fieldtrips, practical exercises, discussions and peer exchange with a side program of public events. All the course activities took place in al-Khalifa generally with focus on the domes of al-Ashraf Khalil and Fatima Khatun as a case study.
This school was divided into seven modules as follows:

Module (1) introduction and basics (13-16 November):
Conservation theory for historic buildings – introduction to principles of building and material conservation – introduction to structural systems of historic buildings.

Module (2) project 1: site investigation and condition survey (17-23 November):
Preliminary site investigation, background research and damage assessment to the domes of al-Ashraf Khalil and Fatima Khatun

Module (3) material conservation (24 -29 November):
Principles of treating water and salt damage to inorganic material (stone, masonry, mortar and renders).

Module (4) architectural conservation (30 November -5 December):
Architectural solutions for water and salt damage (desalting, grouting, insulation, ventilation, structural support).

Module (5) project 2: conservation proposal (6-11 December):
Conservation project proposal applied to the domes of al-Ashraf Khalil and Fatima Khatun Domes.

Module (6) urban solutions (12-15 December):
Dewatering, extraction, treatment and looking into ways of treating and reusing water with reference to al-Khalifa as a case study.

Module(7) project 3: integrated solutions (18-25 December):
Proposals for pilot projects for water extraction and reuse within historic contexts.

2.0 WORKSHOP SCHEDULE

Conservation School:
Dangers of salts and groundwater to historic buildings in an urban context
8 November - 22 December 2016

WEEK 5 11-17 dec	**T 13**	**22**	**6. Urban Solutions**	**Lecture:** Principles of dewatering in hisoric buildings	**Discussion:** International integrated solutions for ground water reuse	Mohammed Al-Eissawy, Megawra team	to be announced then	Lecture 7 pm: Mohamed El-Sheikha - New directions in infrastructure
	W 14	**23**		**Seminar:** Results of the Athar Lina urban studies of Al-Khalifa area in cooperation with the faculties of urban planning and engineering in Cairo University, the Urbinsight project, and takween		Reda Haggag, Ashraf Khedr, May Al-Ibrashy, Karim Ibrahim, megawra team		
	Th 15	**24**		**Field trip:** Dewatering, greywater reuse, and treatment.		May Al-Ibrashy, Megawra team		
	Sa 17	**25**			**Seminar:** Tailored integrated solutions for Al-Khalifa	Reda Haggag, Ashraf Khedr, May Al-Ibrashy, Karim Ibrahim, Brook Muller, Josh Cera		
WEEK 6 18-22 dec	**S 18**	**26**		**Lecture:** Integrated systems based approaches	**Discussion:** Framework for developing integrated solutions	Brook Muller, Josh Cera, Karim Ibrahim, Ahmed Ebeid	to be announced then	
	M 19	**27**		**Working session:** Divide into groups: Teams investigate optimal strategies given a focus on one key parameter (different teams look at different parameters, for example environmental benefits, cultural benefits, economic benefits, urban space/urban design implications…or possibly the parameters are more specific: dewatering, materiality, other)				Lecture at 7 pm: Josh Cerra - Integrated approaches in landscape architecture
	T 20	**28**		**Participant presentations:** Optimal strategies findings	**Group discussion:** Priorities and most promising approaches; devise integrated solutions schemes			
	W 21	**29**		**Working session:** Integrated solutions				
	Th 22	**30**		**Presentations:** Integrated solutions schemes; Group discussion: What is achievable? What prototypes would be of the most interest and value?	**Group Discussion:** Recap of Conservation School: final comments and observations			

3.0 METHODOLOGY

The participants were divided into 6 teams, two teams for each of al-Khalifa area 3 sections. The goal was to produce solutions for three phases of the project;

- Prevention.
- Extraction, treatment and storage.
- Reuse.

The teams produced this on three steps, first through general ideas then through strategies on the area level then interventions on a specific site level. The proposed interventions then were evaluated according to the following goals of the project:

- The significance of the historic fabric and the importance of cultural heritage.
- The need for livability and thermal comfort.
- The desirability of economic enhancement/activity/redevelopment.
- The importance of anticipating potential impacts of climate change (water will become that much more precious).

4.0 OUTPUT

4.1 General ideas exercise

Through this initial exercise, participants brainstormed on general ideas that address the three phases decided for the project.

Phase (1) prevention

- Having meters for each housing unit is essential to address efficient consumption, the measure will have economic benefit for residents and provide a motive. The meters cost about 1000 pounds but the resident will get back this money from what he saves in a couple of months.
- Using low flow caps for taps.
- Using sensory taps or taps that automatically close after a certain period of time.
- Periodic maintenance.
- Putting fines on damages to the water network, in cases where a facility does not fix its sanitary and has a lot of leakage.
- Determining the hot spots for leakage in the network.
- Making signage; boards that explain how to be water efficient, especially in schools.
- Training kids in schools on maintenance of networks and include it in the curriculum with practical exercises, in addition having committees in the schools from students that monitor the state of the sanitation.
- Making direct drainage from sink water to toilet flushing boxes and the excess goes into the sewage.
- Putting laws that enforce new buildings to have greywater reuse systems.
  Separate ablution water in mosques from waste water, to be directed to reuse and decrease the load on the current network.

- Awareness for the local community about efficient water use; in schools, mosques, clubs, restaurants, cafeterias and residential buildings.
- Decrease the water pressure from source to decrease leakage.
- Renew the network by gathering money from residents in addition to investment, the economic and environmental benefit comes from saving water, also there is a community benefit due to the collaborative work and capacity building in fields of maintenance of the network.

Phase (2) extraction and treatment

- Use open spaces as a center that includes spaces for treatment and storage.
- Use the difference in levels of the area and natural slope to move and store water.
- Treat using sand filters, filtering pipes that are on a level below the ablution sinks, where water flows by gravity through sand and gravel for an improved quality.
- Treat and store water from ablution in underground tanks and sand filter tanks, the advantage of being underground are:
  - No need for pumping from the sinks.
  - No structural threats to the old buildings when the tanks are situated beneath courts and yards of the mosque.
- Store the water in old cisterns and tanks under the ground in the area.

Phase (3) reuse

- Reuse in car wash.
- Use water for watering and cleaning of the streets and the public and residential buildings.
- Using water in industries the need water in the area (for example tiles and marbles), or near the area (potters area in al-Fustat).
- Inserting crafts or industries that consume a lot of water, for example pottery or industries.
- Roof farming in roofs surrounding the mosques from ablution water, or using it for irrigation for open spaces next to these buildings.
- Watering existing green spaces in clubs or gardens.
- Creating green spaces, wet lands and water bodies.
- Creating green spaces within the context of cemeteries. Many streets there are very wide, too wide for its current use, by transforming parts of the street to green spaces; we improve the current urban fabric, improve livability, and create opportunity for gathering and economic activity.
- Use water to have fish tanks (fish farms).
- Use water in fire extinguishing tanks in the dense urban fabric; the historical fabric of old Cairo does not allow for easy access by fire cars, by using these tanks we are sensitive to and preserving the historic fabric.
- Use grey water for flushing; some suggested directly some suggested after treatment and pumping to roof to be reused.
- Making streams for water (uncovered) that filters the water along the way and make it accessible for use.
- Irrigate trees for wood production.
- Create fountains.
- Gather water and transport it to the nearest desert area for irrigation.

4.2 Area level strategies and site specific interventions

The study area was divided into three smaller section. Two groups worked on each section.

4.2.1 Northern section: groups 1&2

Main sites of intervention in this section	Other notable sites that will not have interventions	Observations
• Safiyy al-Din Jawhar Dome; a historic dome suffering from ground water rise. • Ahmad Kuhya Mosque; a historic mosque with an existing dewatering system. • Shajar al-Durr School; a public school that was forced to stop operating this academic year due to water problems, Cairo Governorate decided to install a dewatering system for the school.	• Ibn Tulun Mosque; a historic mosque of a very high value on the level of Egypt.	• Two residential buildings Next to the Shajar al-Durr School suffer from water problems in their basement floors, they pump the water but it keeps flowing again. • Ibn Tulun Mosque has had a broken pipe for 10 months. • There is an empty land plot next to the school that is disputed between residents and the Ministry of Endowments. • The wide spread problems in the region of network water loss is the main reason for the rise in the ground water level in buildings and monuments. • Another smaller reason is the Water Coolers (the modern alternative for *sabil*) on the sidewalks that lack maintenance and therefore leaks all day.

To understand the topographic differences refer to the topographic map in annex 1, the areas east and west of al-Khalifa street (middle going north-south) are sloping in its direction, all of the area is also sloping to the north direction.

Group 1

a. Area level strategies

Economical, simple and practical recommendations for a dense residential area to turn up negatives to positives. Recommendations included:

- Repair the bathrooms of the Shajar al-Durr School and the Ibn Tulun Mosque and repair networks.
- Schools and mosques are good candidates because water can be extracted and reused on the same site that has a concentration of uses

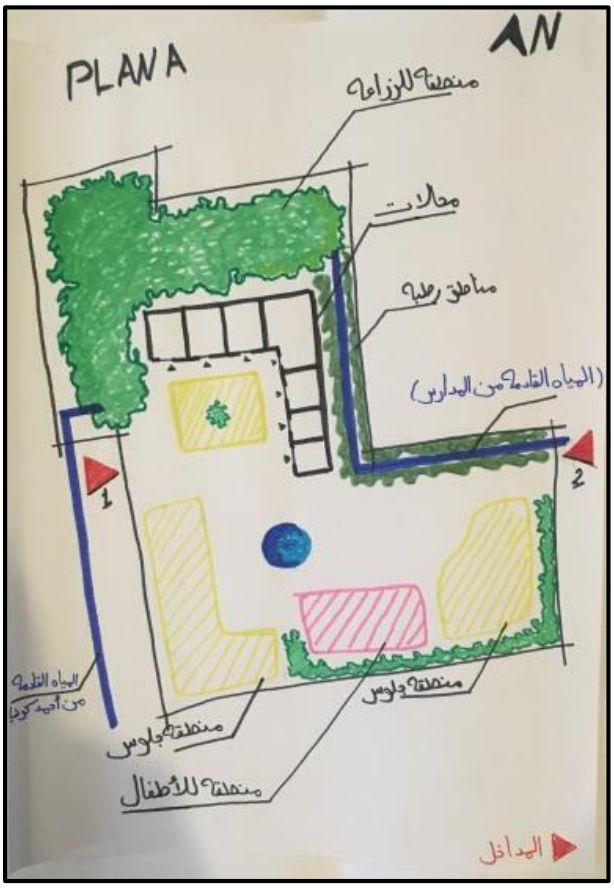
b. Site specific interventions

This group used the school, Ahmad Kuhya Mosque and the plot in between as their sites of intervention. Recommendations included:

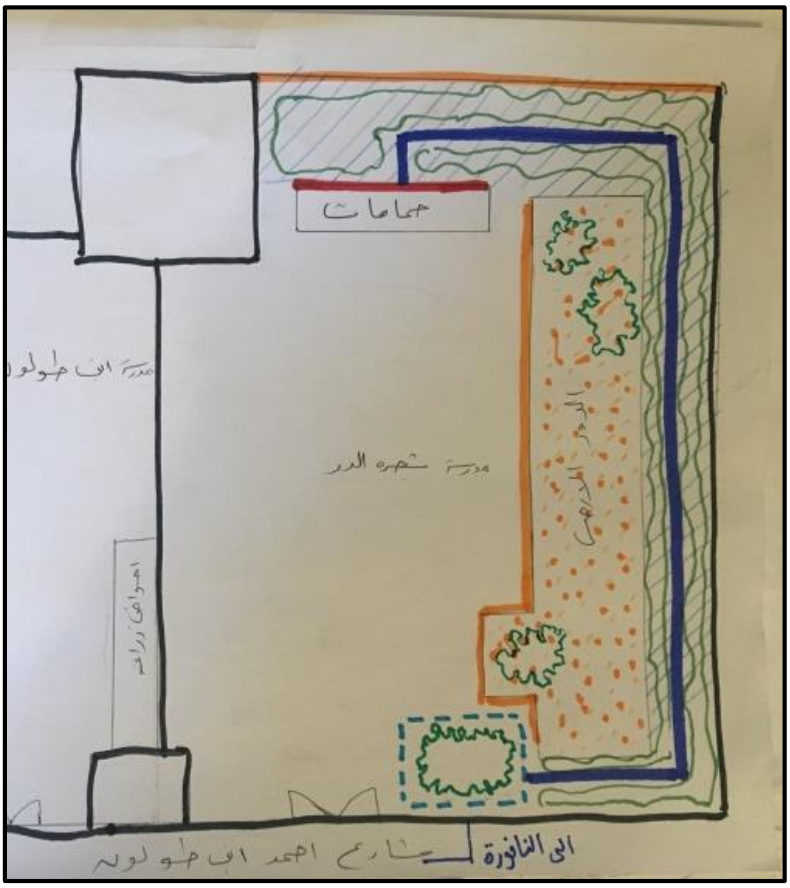
- To use the existing dewatering system at Ahmad Kuhya Mosque, we can add cisterns for water treatment with sand and coal, to be re-used in toilet flushing and car washing.
- There is land plot neighboring Shajar al-Durr School and near Ahmad Kuhya Mosque whose ownership is disputed between the Ministry of Endowments and one of the families, if the problem of the land was solved, it can be used for storage and water reuse for the water coming from both the school and the mosque as follows:

  - Make wetlands in the part of the land for water treatment (the part right next to the school).
  - Designate part of the land for the cultivation of water-loving and productive plants.
  - Make shops for selling agricultural products grown in the land to increase the economic return.
  - Create recreational areas for residents and children.
  - Agreeing with an NGO to participate in the implementation of the project.

The disputed land plot (striped grey), the school (yellow left) and the mosque (yellow middle)



The proposed plot, wet lands at the corner neighboring the school to the right, plants in the north side and stores next to it, and recreational activities in the middle



A map of the school proposing wetlands in the yard to the right of the school plan

Group 2

a. Area level strategies

Plots highlighted in blue in the above map are empty and hold potential for use, there are buildings with good structural conditions that can have roof farming (some highlighted in blue stripes) and the slope next to Ibn tulun Mosque (left) allows for water transport and storage

Uses

There are various functions in the region, such as residential, commercial, archaeological buildings, and some schools and other various activities as workshops, bakeries and shops selling some of the services needed in the region.

- As a result of the nature of the ground slopes around the mosque of Ahmad ibn Tulun, we can propose action points to collect the water for reuse that can be pumped into buildings for reuse as processed water with lower price than the supply water in:

  - Planting residential rooftops that are in a good structural condition.
  - Flushing toilets.
  - These actions will be more accepted when the supply water prices gets higher.

- There are many empty lots in the region that belong either to private owners or the state that can be used in a number of activities, including:

  - Planting some areas with plants high in water consumption to attract part of the ground water, to improve the air quality in the area, and to create recreational areas for the residents.
  - Making greenhouses on school yards.
  - Using them as fish farms.
  - Using one of the area's state-owned land to make recreational activities for children and residents (Amusement Park).

Prevention

- Repair and maintenance of networks in general to ensure that no leaking into the soil happens and raise the water level.
- Installing meters in each residential unit instead of depending on estimates or whole building meters.
- Pumping less water in the supply water network to reduce losses from leakage of networks.
- Raising environmental and archaeological awareness of the people to ensure their behavior becomes responsible towards the water and monuments.
- Install low flow caps for tops.
- Install economic flushing boxes.
- Make guidelines, regulations, and strict laws for buildings that are newly created to identify water amount consumed and install grey water reuse systems.
- Organizing a day of water as a workshop for the population to raise awareness of the importance of water (a drop of water equals life).
- Work in plumbing courses to train students and housewives on the maintenance of sanitation, as well as plumbing used in houses and schools.

b. Site specific interventions

This group chose Safiyy al-Din Jawhar Dome as their site of intervention

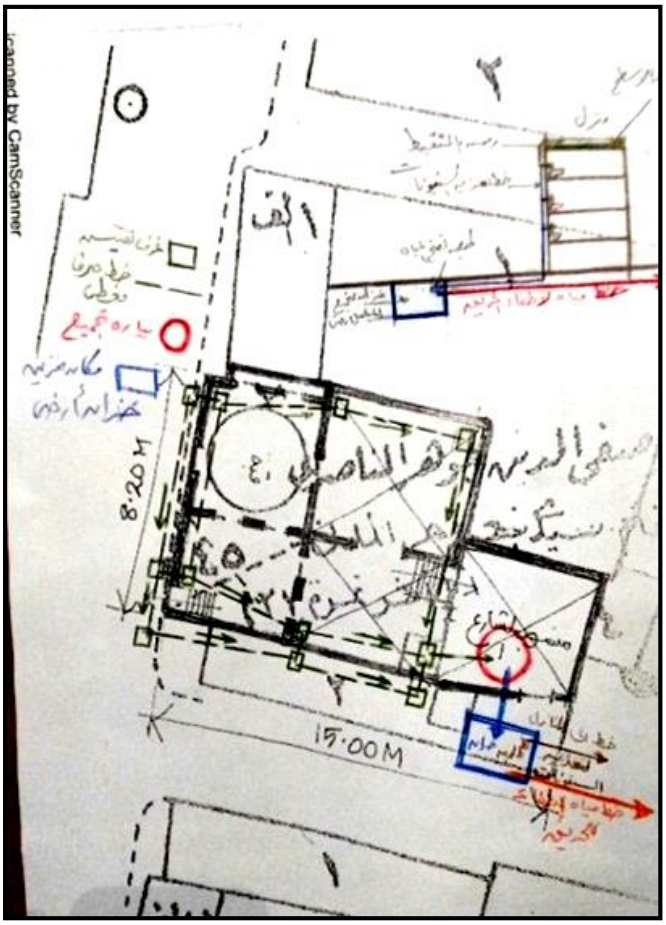
Dewatering phase

- Studying the structural condition of the monument, stabilize it, and work to protect the ancient dome before starting a dewatering project.
- Starting the dewatering project as shown in the drawing (Figure 1) and collecting the water in pipes inside the site and into a tank for use.

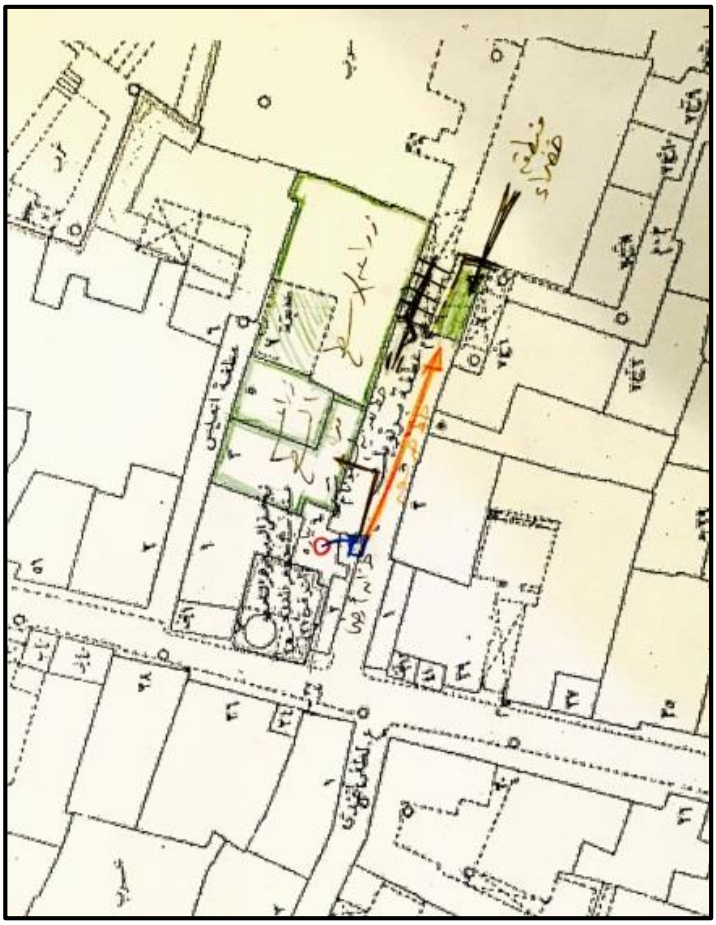
Uses

On the monument level (Figure 2)

- Make a fire tank with hoses attached instead of pipes to reduce its cost.
- Make separate processed water lines for following uses:
  - Flushing.
  - Planting rooftops.
  - Vegetation in the vicinity of the staircase at the end of the street.



A proposed solution to the ground water problem on the monument



Proposed solutions on the monument level (Safiyy al-Din Jawhar)

Benefits

- Saved water losses.
- Reduced family expenses.
- Cultivated rooftops with ornamental plants that give shield to the family and that are shared by all the residents of the house.
- Decreased government expenditure on water.
- Improving the living conditions of the individual as a result of the return of planting rooftops and decreasing the amount of water consumed.
- Improving air quality that leads to improving the environment.
- Cultivation of rooftops reduces the heat content in the higher floors and reduces the use of air conditioners.
- Create a low cost fire line that serves the area.

4.2.2 Middle section: Groups 3&4

Main Sites of intervention in this section	Other notable sites	Observations
• S. Ruqayya Dome; a historic dome suffering from ground water rise. • 'Atika and al-Ja'fari Domes; a historic dome suffering from ground water rise. • The New Ruqayya mosque: a mosque that will be built by the ministry of housing next to the historic domes, an agreement with the ministry of housing states that the new project will include a dewatering system for the historic domes and possibly a reuse system	• Zaynhum neighborhood housing project: a relatively newly constructed area that suffers from bad water and sewage networks. • Al-Ashraf Khalil ridge; a high altitude unused land plot with panoramic views.	• There is a history of springs and cisterns in the area; one spring (now covered) in the Zaynhum area, and cisterns next to the historic domes • A tile workshop (with high water use) exists nearby

To understand the topographic differences refer to the topographic map in annex 1, all the domes and the new mosque lie on a low level, while the Zaynhum area and the ridge are about 8 meters higher.

Group 3

a. Area level strategies

Work plan

Monitoring and searching for the glitches and flaws with the aim of reforming and developing both the place and the population at the same time as follows:

- Asserting the significance of the historic fabric and the importance of cultural heritage.
- Improving livability and addressing the need for thermal comfort.
- The importance of economic enhancement/activity/redevelopment.
- The importance of anticipating potential impacts of climate change (water will become that much more precious).
- Raising awareness and belonging.

Prevention

A preview of the sites mentioned below and monitoring of them as possible sources for ground water:

- Flow of supply and sanitation water from the networks of the housing in the Zaynhum area which is higher in altitude than the study area.
- An ancient spring of water at Zaynhum area which is expected to be a source of water.
- A well or cistern next to 'Atika and al-Ja'fari Domes.
- Car wash in Zaynhum next to the ridge.
- Water appearing above surface on the land of the new mosque.

To prevent or reduce the water consumption follow the following:

- Repair networks.
- Inform the population about the need and the importance of rational water consumption and use.
- Decrease pumping of water in pipes to reduce the amount of water.
- Installing meters in all units and avoid estimated values and whole building meters to monitor consumption properly.
- Preventing the use of potable water in cleaning areas in front of shops, irrigating plants in the streets, car wash or watering playgrounds.
- Separating greywater pipes from blackwater pipes.
- Installation of low consumption sanitary parts, such as small volume flushes or faucets with little drainage.

Extraction, treatment and storage

- Making sure that buildings especially archaeological and important buildings are not affected during the dewatering process.
- Use empty land plots in area to store water.
- Using existing wells and cisterns in the storage and treatment processes.
- The possibility of using schools backyard or mosques in the establishment of tanks for storage and treatment.

- Preferably, fragmentation of the dewatering, treatment and storage to several places to reduce costs and rationalize reuse lines and using the site topography.
- Select a method for the storage of ground water in 'Atika and al-Ja'fari site by using perforated pipes under the ground and higher than the level of foundation of the monuments to collect groundwater and transport it to collection places.

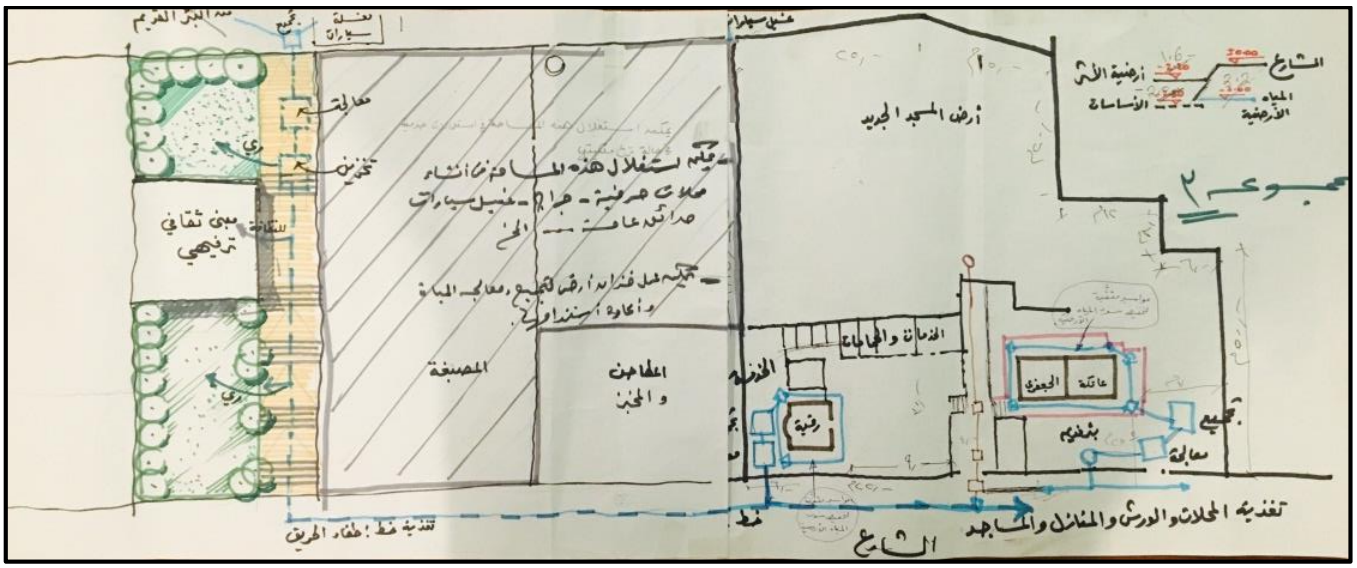
b. <u>Site specific interventions</u>

- For the site of al-Sayyida Ruqayya:
  - Use perforated pipes to reduce groundwater.
  - Transfer water with Pipes to collection tank in the service area and from there to the treatment tank and then to the tank next to the street for storage.

- For the site of the new mosque:
  - Connecting a line of water from dewatering and sewage systems in the mosque to the sewage network of the region.
  - The line will be modified to supply processed water lines later.
  - Use the roof of the mosque as a storage tank, being almost on the same level of Zaynhum area.

- For the car washing place, the old well and the leaks in Zaynhum area:
  - Collect water from all those places and through a dewatering system that acts as a defense line top of the ridge to separate between the two levels.

- For all sites<u>:</u>
  - Connect the collection tanks with the treatment tanks and then to the storage tank on the same line then have a single processed water line along the street that serves different uses to reduce the costs of operation.



The diagram of uses shows the strategy of connecting the different elements of the system as well as using part of the ridge for vegetation (left)

Reuse

Reuse of the treated and stored water in the three locations as follows:

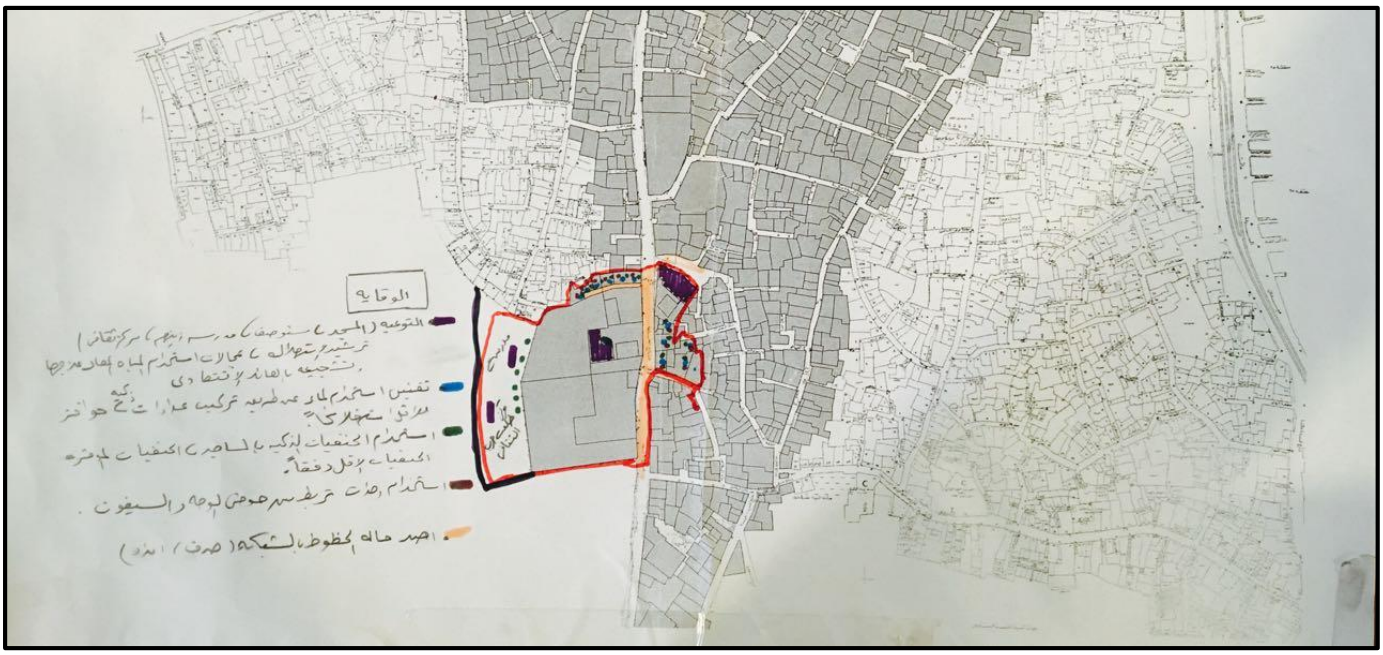
- For 'Atika and al-Ja'fai Domes location:
  - Using the water to irrigate trees in front of the shops and supply workshops with high consumption such as the tile factories and pottery workshops. Also, use it for cleaning purposes in cafes and shops selling poultry.
  - Using water for washing floors of mosques and schools.
  - Using water at residential buildings in toilet flushing, stairs washing and growing ornamental plants on rooftops.

- For S. Ruqayya and the new mosque:
  - Part of the water used for the same previous purposes.
  - Another part in the fire line.

- For Zaynhum Housing:
  - Use the treated water to water plants on the slope between the two areas of different levels.
  - Use the water for cleaning and washing floors and supply flushes in the newly constructed mosque and its cultural and social extensions.
  - Use to supply a fire line, to be created in the region.

Thus benefiting from ground water to become a resource for development rather than being a burden on the budget and being beneficial rather than harmful and damaging buildings, monuments and population in the region.

Group 4



The diagram illustrates sites and uses in the area

Prevention

- Awareness at the mosque, Zaynhum School and the nearby cultural center about decreasing consumption and about the purposes that could use treated water and the Economic benefits that come with it.
- Rational water use by installing smart meters and giving incentives for Least-consuming residents.
- Using smart taps in mosques, saving taps and low flow taps.
- Connecting sinks for washing to toilet flushes.
- Observing the condition of sewage network and clear water network to avoid leakage.

Storage

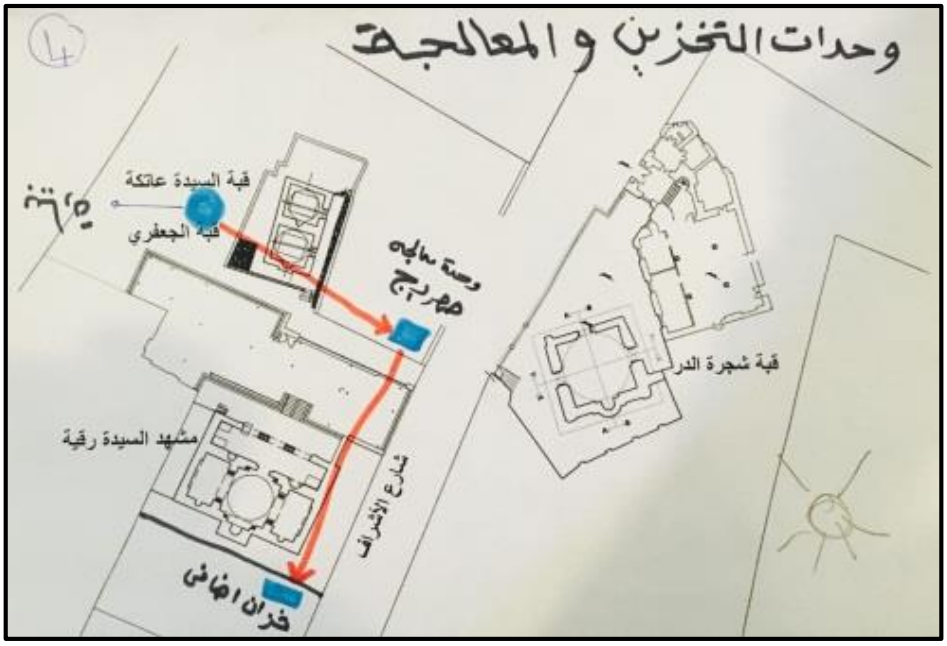
- The empty land of the old mill (owned by the government).
- The cistern under S. Ruqayya mausoleum.
- Dewatering plantation in the land of the new mosque.
- Transfer water to the nearby cemetery and store it.

Treatment

- Use wetlands to treat the water coming from Zaynhum area with higher altitudes.

Reuse

- Cleaning at the mosque, shops and houses.
- Supply flushes in the mosque and houses.
- Irrigate Plants in the street and in gardens that exist between houses in Zaynhum.
- Supply water to Firefighting Network.
- Encourage people to set up projects with an economic return such as roof gardening and Aquariums.
- Building a car wash station.

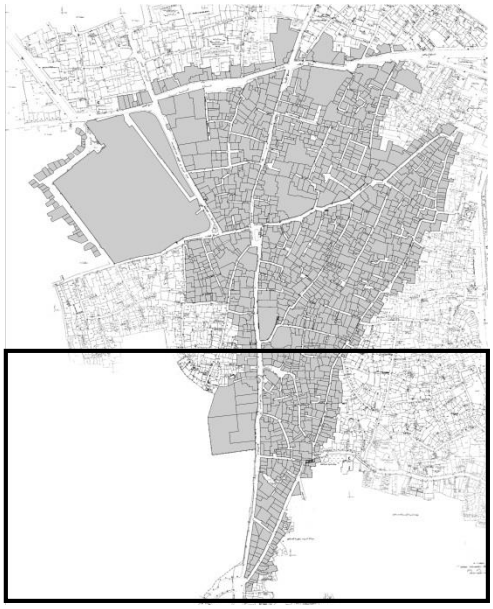


The diagram illustrates proposed storage and treatment units and connections between them

4.2.3 South section: Groups 5&6

Main Sites of intervention in this section	Other notable sites	Observations
• Al-Ashraf Khalil Dome; a historic dome suffering from ground water rise. • Fatima Khatun Dome; a historic dome suffering from ground water rise. • Al-Ashraf Khalil Ridge; a high altitude unused land plot with panoramic views.	• Zaynhum neighborhood housing project: a relatively newly constructed area that suffers from bad water and sewage networks. • The cemetery; south and east of the study area with very low density and vast land plots.	• Most activities has low water use except for a tile factory. • The tile factory causes usual clogging to the neighbouring municipal sewage manhole. • The area has a wide amount of open spaces; in the ridge and the cemetery specially.

To understand the topographic differences refer to the topographic map in annex 1 the areas east and west of al-Khalifa street (middle going north-south) are sloping in its direction, all of the area is also sloping to the north direction.



Group 5

a. Area level strategies

Prevention

- Check the networks of sewage and supply water in the study area.
- Rational water consumption through installing low flow caps and low volume flushing boxes.
- Increase the population awareness about rational water consumption and its economic return.

Extraction and Storage

- Create a dewatering system around monuments.
- Use the empty lots in the study area for water storage.
- Benefit from the topography of the area in transporting water.
- Using the roof of the new mosque for storage.
- Orchard + storage basin beside Fatima Khatun (as a part of dewatering system).

Reuse

- Build a water network with collection points for agriculture, street wash and for residential buildings uses.
- Planting the ridge area.
- use the water in toilets and mosques.

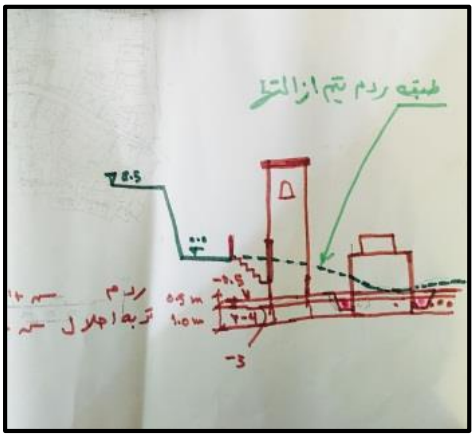
b. Site specific interventions

Dewatering, treatment and storage of water

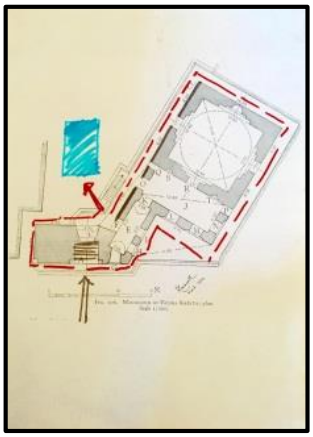
- Remove accumulated soil inside the building and fill with impermeable layer 0.5 m above water level to prevent the rise of water.
- Dewatering for the historic building and collect water in a small tank in the neighboring open space.
- Transfer water mechanically by water wheels, this traditional method brings awareness of the history of water engineering in Cairo.
- Transfer water from the top of the previous system to the top of the ridge on a surface pipe then to a filtration system.
- Filtration with preliminary gravel filter on the top of the ridge then water move from the top to the bottom of the ridge on wetlands by the gravity.
- Collect water in tanks for reuse.

Water reuse

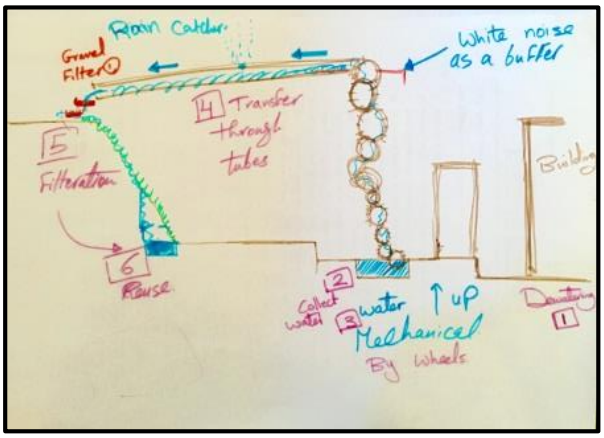
- Planting in front of the historic building and on the ridge.
- Extend a water line to a nearby Pottery workshop.



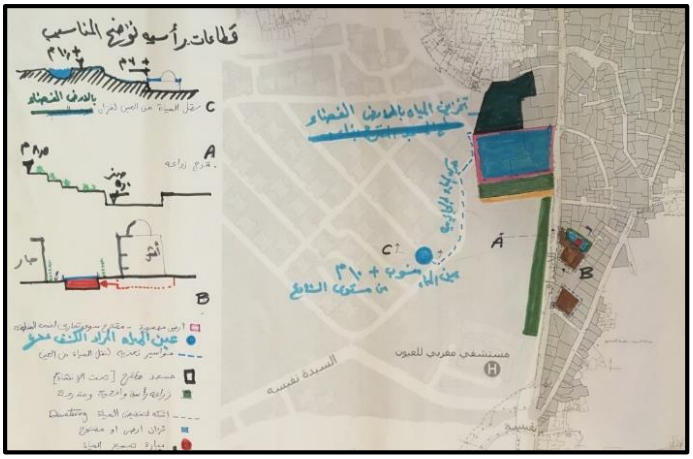
Levels of the domes and the ridge



Dewatering and storage



Water wheels system



Zones of interventions and sections for vegetation and storage

A proposal for processed water networks in Zaynhum and the cemetery

Group 6

a. Area level strategies

Prevention

- Check sewage networks and repair connections.
- A tile factory in the area, causes usual manhole clogging, the group proposes moving the tile factory or disconnecting their network from the main network.
- Community development environmentally friendly.

Extraction, treatment and storage

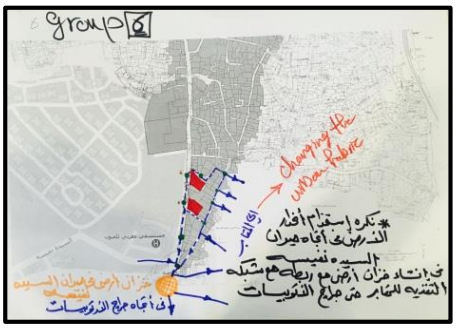
- Collect water in the ridge, empty lots and S. Nafisa Square (using topography).
- Make physical treatment by sand and gravel and biological treatment by plants.
- Use the region featuring Low population density and building construction in the cemetery.

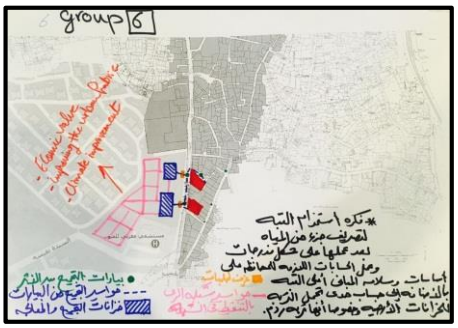
Reuse

- Planting rooftops and elevations.
- Plantings the ridge.
- Planting and creating a fountain in S. Nafisa Square.
- Use water in workshops and car wash.
- Planting the cemetery (change the urban fabric) or parts of the cemetery streets.
- Use in cleaning and toilets in mosques.
- Shrimp farming.
- Mushroom planting.
- Firefighting.

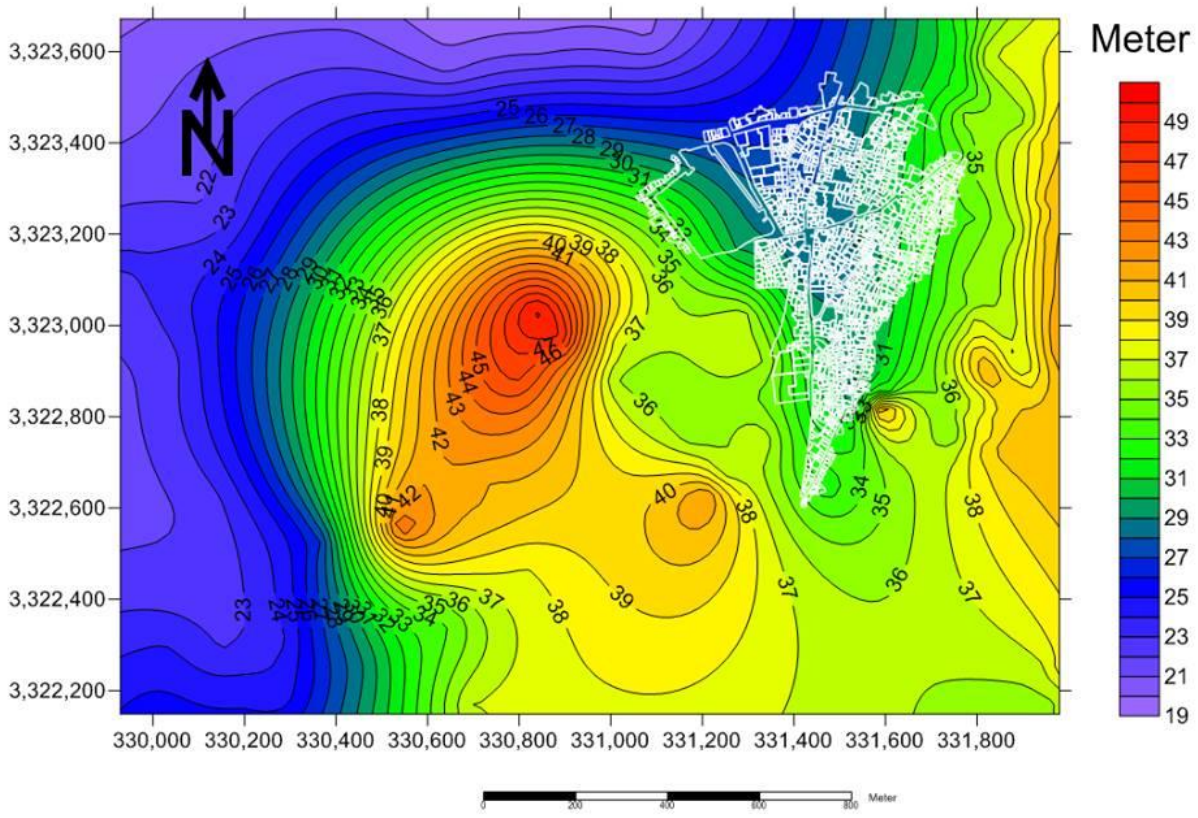
b. Site specific interventions

- Collect water from historic buildings (Fatima Khatun and al-Ashraf Khalil) by collection pipes then to pump rooms and then to tanks for treatment and to drip irrigation network to cultivate the ridge as steps.
- Make a network that connects water from the groves to cemetery area to use in cultivation some ornamental plants and flowers and Shrimp farming.
- Use the slope of the land in the way to S. Nafisa Square to make ground tank under the square and this tank connected to the cemetery water network to the bus station.





5.0 ANNEX 1: TOPOGRAPHIC MAP



General observation; Al-Khalifa street (middle of the study area) is the lowest between lands both to the east and to the west, also the street is higher in the south than in the north.