WATER INFRASTRUCTURE:
HYBRIDIZED ARCHITECTURE ALONG THE ARIZONA CANAL

by

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Water Infrastructure: Hybridized Architecture Along the Arizona Canal

by

Alex Atwood

Submitted to the Department of Architecture on January 19, 2012 in partial fulfillment of the requirements for the degree of

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Due to budget issues, the Central Arizona Project (CAP) canal has been left exposed to the arid desert environment since its construction in the 1970s. As a result, 5% of the amount of water diverted from the Colorado River is lost to evaporation and seepage from the exposed aqueduct and Lake Pleasant reservoir. This amount of loss is equivalent to the amount of water required to supply 75,000 households annually.

With increasing pressures on the Central Arizona canal, we should restrategize and reinvest in this infrastructure in order to prevent further inefficiencies and further loss of water. The objective of this thesis aims to engage architecture with water infrastructure in order to transform the canal into a water-efficient repository and recreational venue while recuperating the amount of water loss from the canal. Through the act of hybridization, a regional amenity is created, serving as support for the water infrastructure as well as creating spatial experience of water collection.

A series of architectural interventions along the canal serve as nodes for rainwater collection. These nodes function as public spas that combine the act of swimming with the act of collecting and cleansing water in order to create spatial experience and awareness of the issues of water.

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Title: Associate Professor of Architecture

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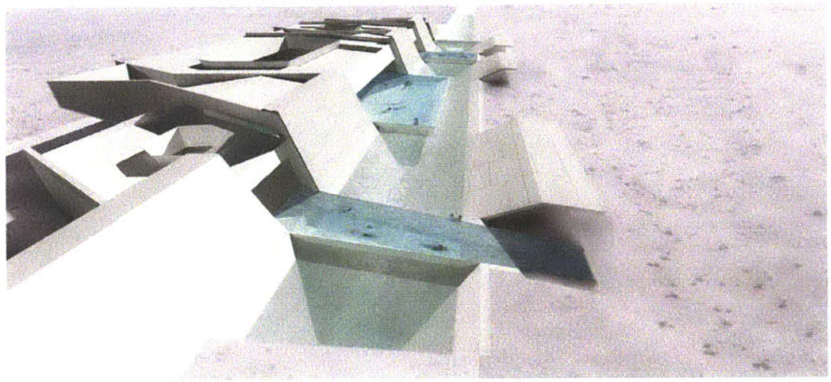
January 19, 2012



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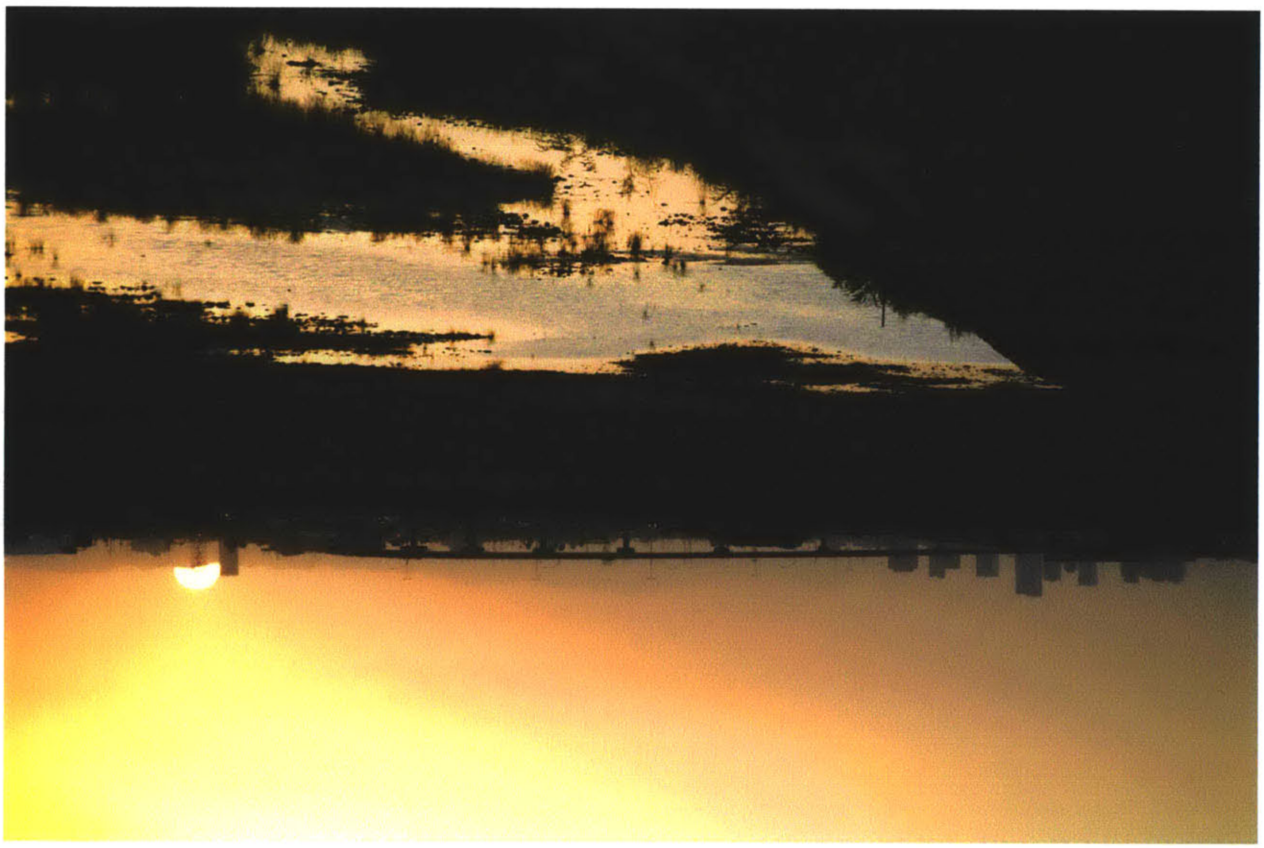


Introduction

My thesis originated with a curiosity in the desert landscape coupled with an interest in the importance of water in our culture. With the majority of my life spent in Florida, and living on the East Coast, I was surrounded by water and the numerous activities utilizing water, such as surfing, fishing, boating, recreational swimming, etc. Further, water plays such an important role in society's daily routine. The ease of access of such a precious resource is usually taken for granted with the numerous activities and countless things that we do with water daily. In dealing with the desert landscape, there's an issue of water scarcity and overdraft of limited supplies. While researching issues of water in the dry/arid states of the American southwest, I became fascinated with the Central Arizona Canal as it presented issues of a mediocre-planned and constructed water infrastructure.

Central Arizona Canal: History

Ancient Origins of Canal

Origins of the concept of the Central Arizona Canal can be traced back to the irrigation ditches created by the Hohokam culture. Modern canal ruins found mainly along the Gila and Salt Rivers of the Southwest have provided insight into ancient Irrigation and farming systems. The Hohokam culture adapted to their surroundings using local resources conservatively and left only a minimal impact on the environment. The Hohokam used several canals to aid in their agriculture by building extensive irrigation networks off of the Lower Salt and Middle Gila Rivers.

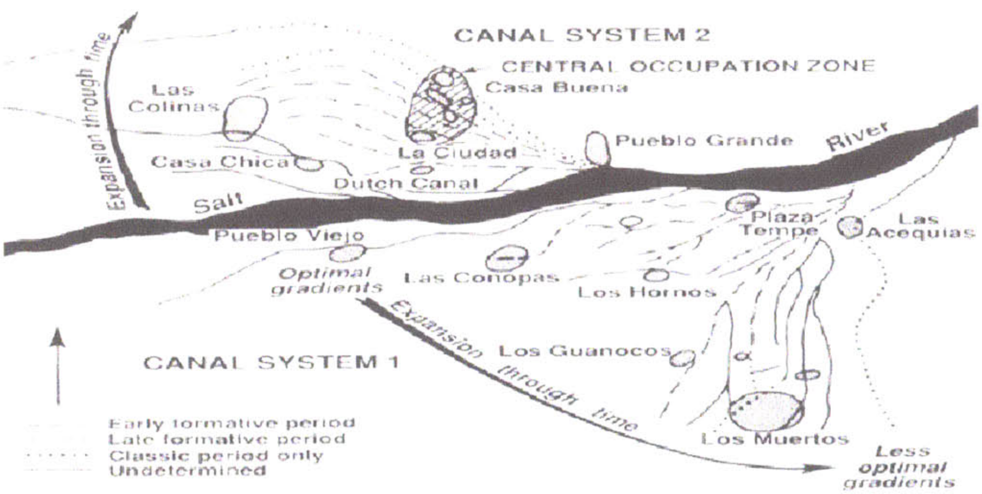
Hohokam Canal Ruins:

Arizon-Sonora Desert Museum, The Sonoran Desert's prehistoric Hohokam Canal, http://www.desertmuseum.org/books/nhsd_human_ecology.php
(accessed, May, 8, 2011)

Arizona Museum of Natural History, Recording a set of narrow but very deep prehistoric canals at the Riverview site http://azmnh.org/arch/riverview.aspx (accessed, Dec, 27, 2011)

Even without the benefit of advanced engineer technologies, the Hohokam were able to excavate and construction these expansive networks of water. The canals branched 30 miles east of the Gila River. The size of these canals was roughly 30 feet wide and up to 10 feet deep; this allowed for less water to evaporate at surface. (Nabokov, Peter and Easton, Robert, Native American Architecture, (Oxford: Oxford University Press, 1989), 355)

Hohokam Canal System:



Chaco Anasazi Facts, The Hohokam Canal System, http://canyonsworldwide.org/chacoanasazifacts/canal_system.html (accessed, May, 8, 2011)

CENTRAL ARIZONA CANAL: HISTORY

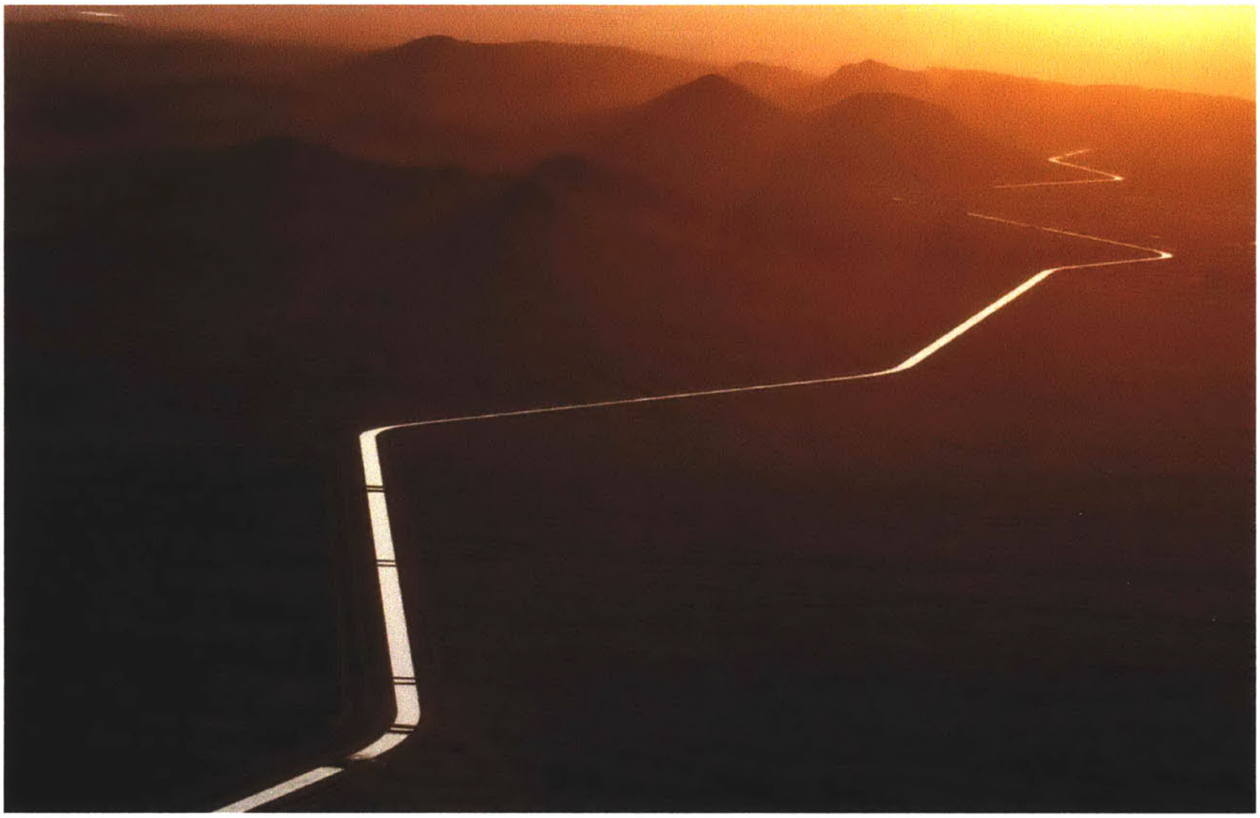
Arizona Department of Water Resources, Central Arizona Project Canal
Pool 24 subsidence mitigation project
http://www.azwater.gov/AzDWR/Hydrology/Geophysics/
(accessed, Dec, 27, 2011)

Launch of the Central Arizona Project

In negotiation for shares for the water of the Colorado River the Colorado River Basin was enacted in 1922, which divided the seven states (Arizona, California, Nevada, New Mexico, Wyoming, Colorado, and Utah), into an upper and lower basin. Each basin is allotted 7.5 million acre-feet of water to apportion. Arizona, California, and Nevada are sectioned into the lower Basin, with California receiving 4.4 million-acre feet of Colorado River water per year, Arizona receiving 2.8 million acre-feet, and Nevada receiving 300,000 acre-feet per year.

Arizona is suffering from a 2.5 million acre foot groundwater overdraft, causing serious structural damage to homes, agricultural lands and industry. The planning and construction of the canal was initiated to counteract the overdraft by providing an alternative source of surface water. (CAP 2011)

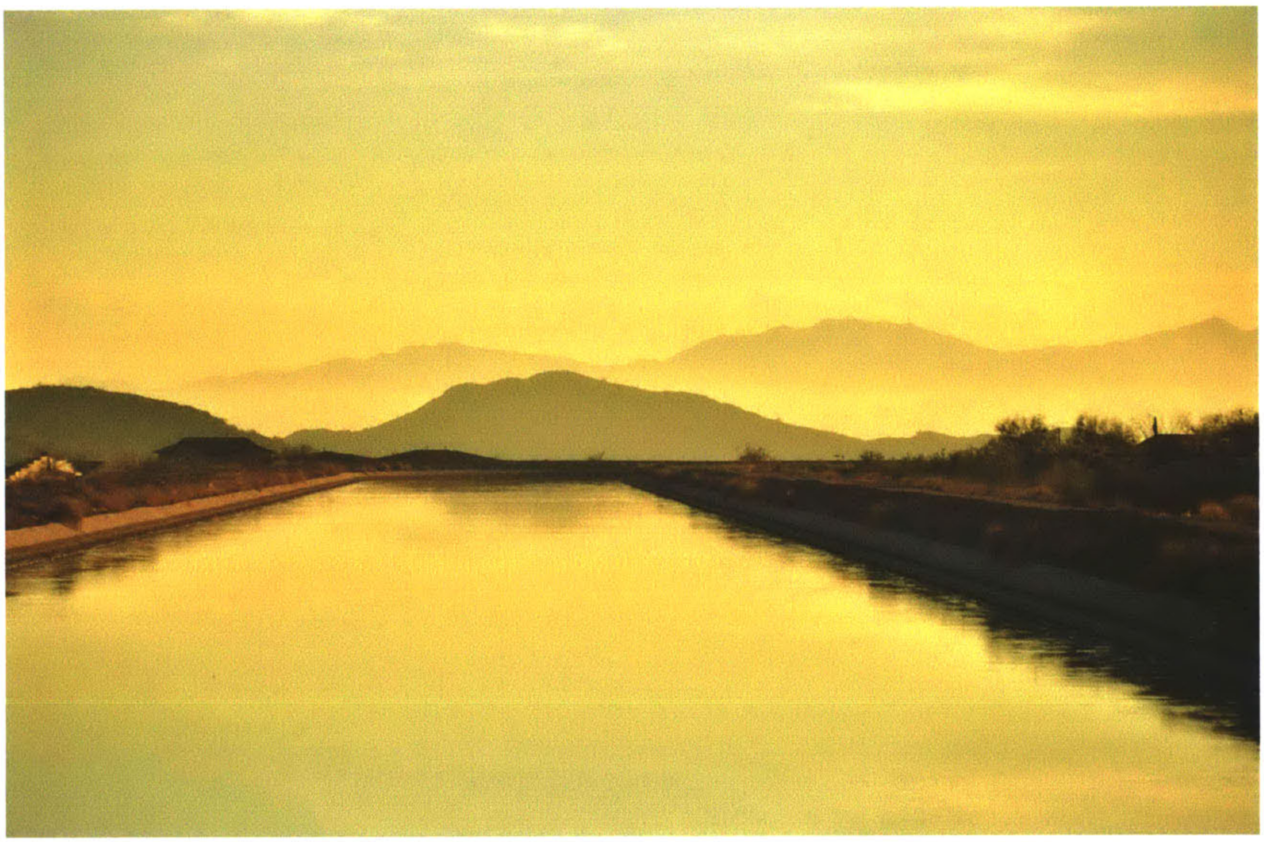
Central Arizona Project Association was initiated in 1946 to lobby congress in order to authorize construction as well as to educate Arizonians the importance and need for CAP. Construction of the CAP was approved after the signing of bill by President Lyndon B. Johnson in 1968. To provide a means for Arizona to repay the federal government for the reimbursable costs of construction and to manage and operate CAP, The Central Arizona Conservation District was created in 1971. Construction of the canal was launched in 1973 at the Lake Havasu starting point and was substantially complete in 1993 at the terminus 14 miles south of Tucson.



Pete McBride, Central Arizona Project,
Arizona, JPEG
http://www.petemcbride.com/#/COLORADO%20RIVER/Selects/13/caption
(Accessed November 1, 2011)

The canal is currently used solely for the diversion of water from the Colorado River to urban areas and agricultural districts in Central Arizona. However, there is potential for the canal to be a corridor through the landscape, capable of capturing, manipulating, and storing water. Further, this element has the potential to be an alternate transportation route through the desert linking Phoenix, Casa Grande, and Tucson.

The canal is an artificial mechanism that has altered the natural waterway of the Colorado River as well as the ecosystem and diversity of the environment. Fully exposed to the desert environment, water loss through evaporation and seepage is an increasing threat; every drop of water is precious and can't be lost.



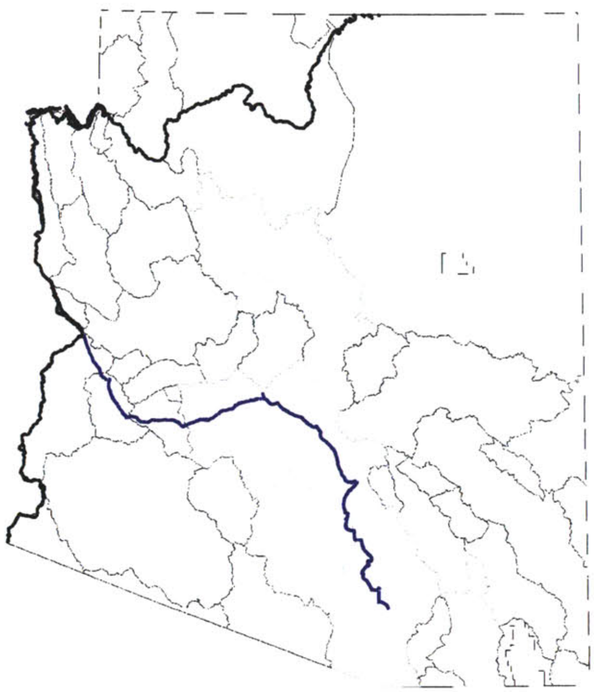
Mona Enachescu, Central Arizona Project, JPEG, http://www.
flickr.com/photos/oceanswell/6607911773/
(accessed, Jan, 17, 2011)

Central Arizona Water Sources

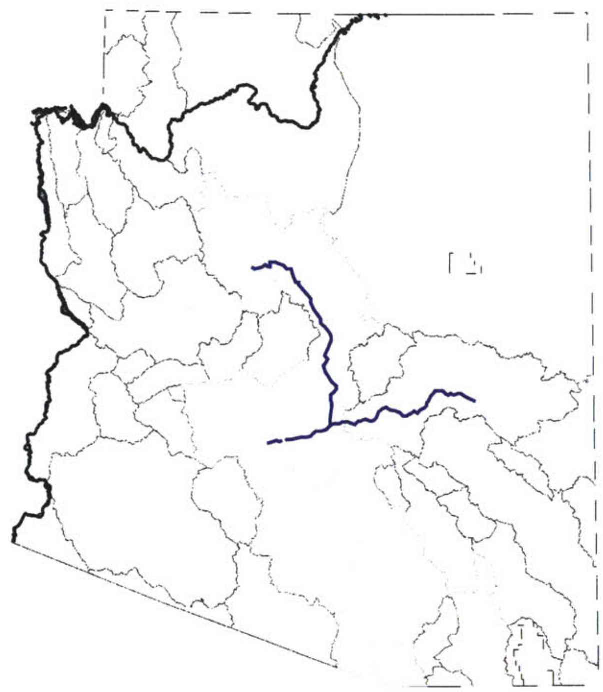
CENTRAL ARIZONA WATER SOURCES

Arizona receives its water from 5 major sources:

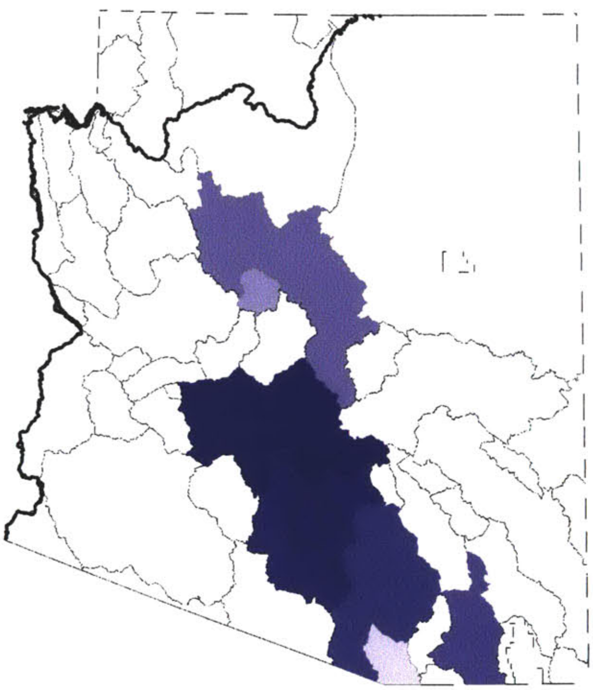
- the Colorado River (via Central Arizona Canal)
- Salte/Verde River watersheds
- Groundwater
- surface water
- Reclaimed/Effluent water.



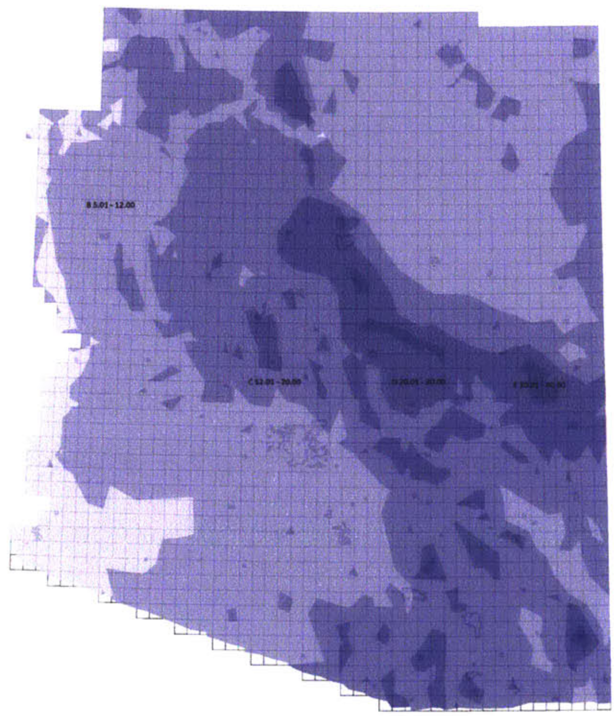
Colorado/CAP delivery



Salte/Verde River



Ground Water



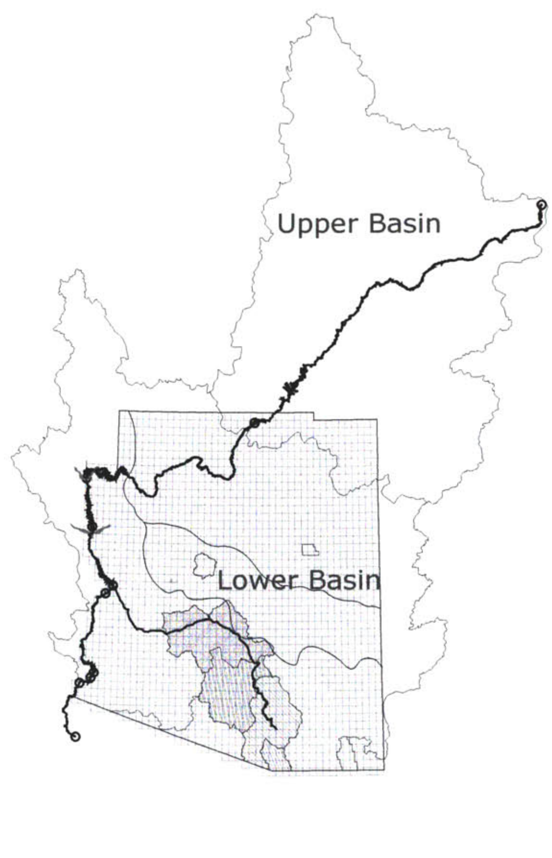
Surface Water

Colorado River Water via Central Arizona Project (CAP):

- Originates in the Rocky Mountains of north-central Colorado and flows southwest for 1,450 miles (2,334 km) to the Gulf of California.
- Total Water Provided: 16.4 million acre feet per year
- Upper River Basin entitled to 7.5 m-acre-ft. of water
- Lower River Basin entitled to 7.5 m-acre-ft. of water
- Mexico is entitled to 1.5 m-acre-ft of water
- Depth of the River varies from 6 feet to 90 feet, with the average depth about 20 feet.

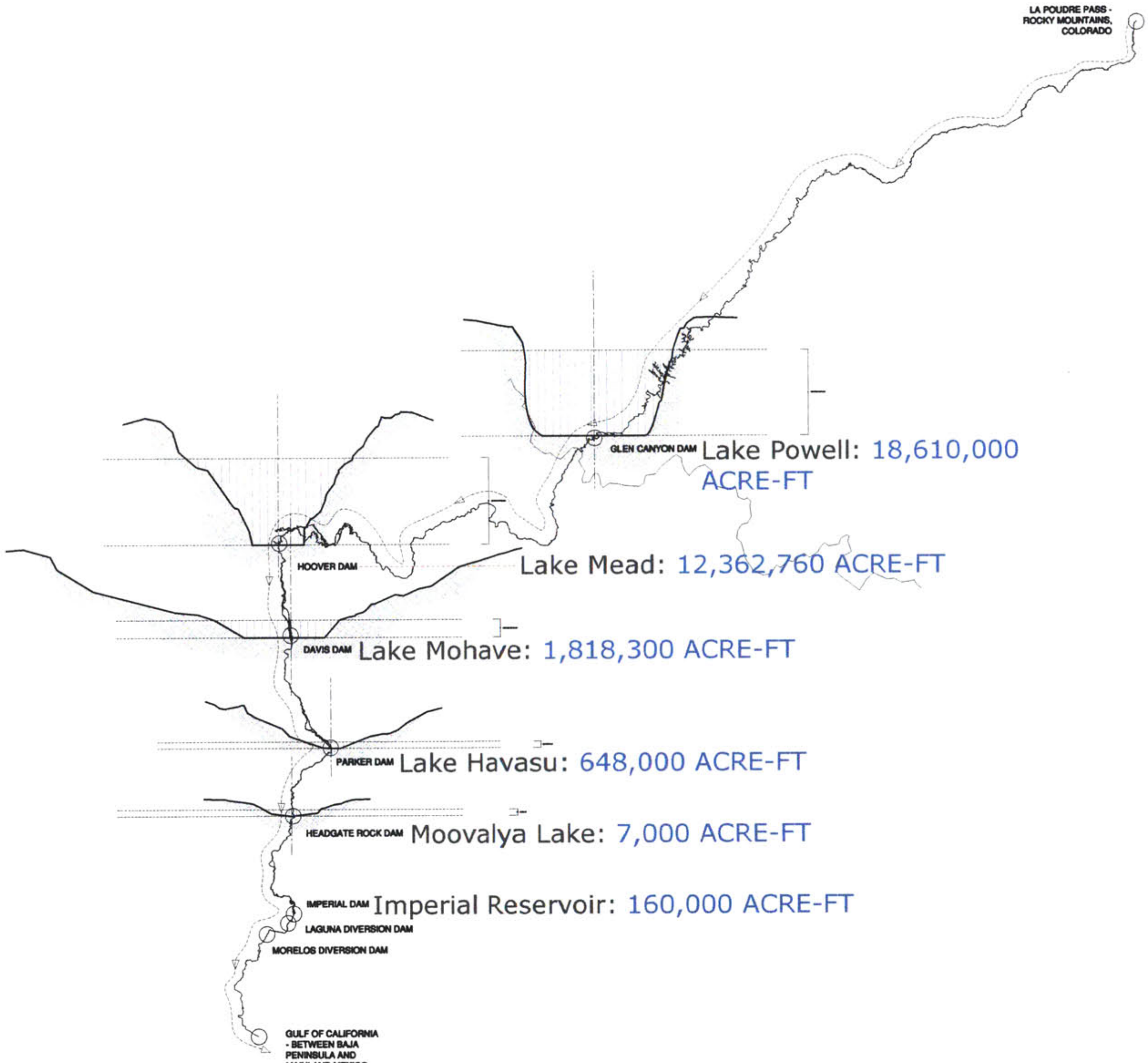
Arizona's current allocation from the Colorado River is 2.8 million acre feet per year. The Colorado River drains 244,000 square miles across the seven states that comprise the Upper and Lower Basin states (Utah, New Mexico, Wyoming and Colorado, Arizona, Nevada and California). (Baker 2009)

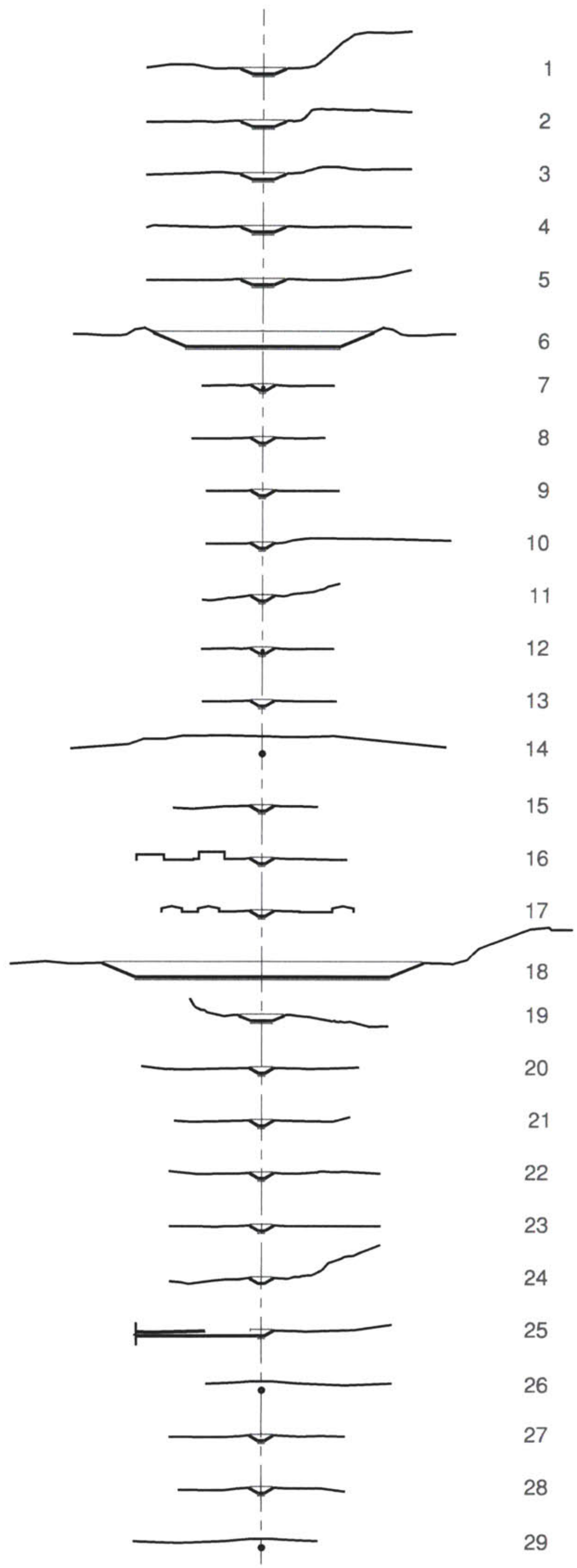
Ethan Miller, Colorado River, JPEG, http://www.kpbs.org/news/2009/apr/21/ucsd-researchers-colorado-river-supplies-wont-keep/
(accessed, Dec, 27, 2011)



Length: 1,450 mi

Upper River Basin: 7.5 MAF of water	Lower River Basin: 7.5 MAF of water	Mexico: 1.5 MAF	Water Provided/Year: 16,500,000 ACRE-FT



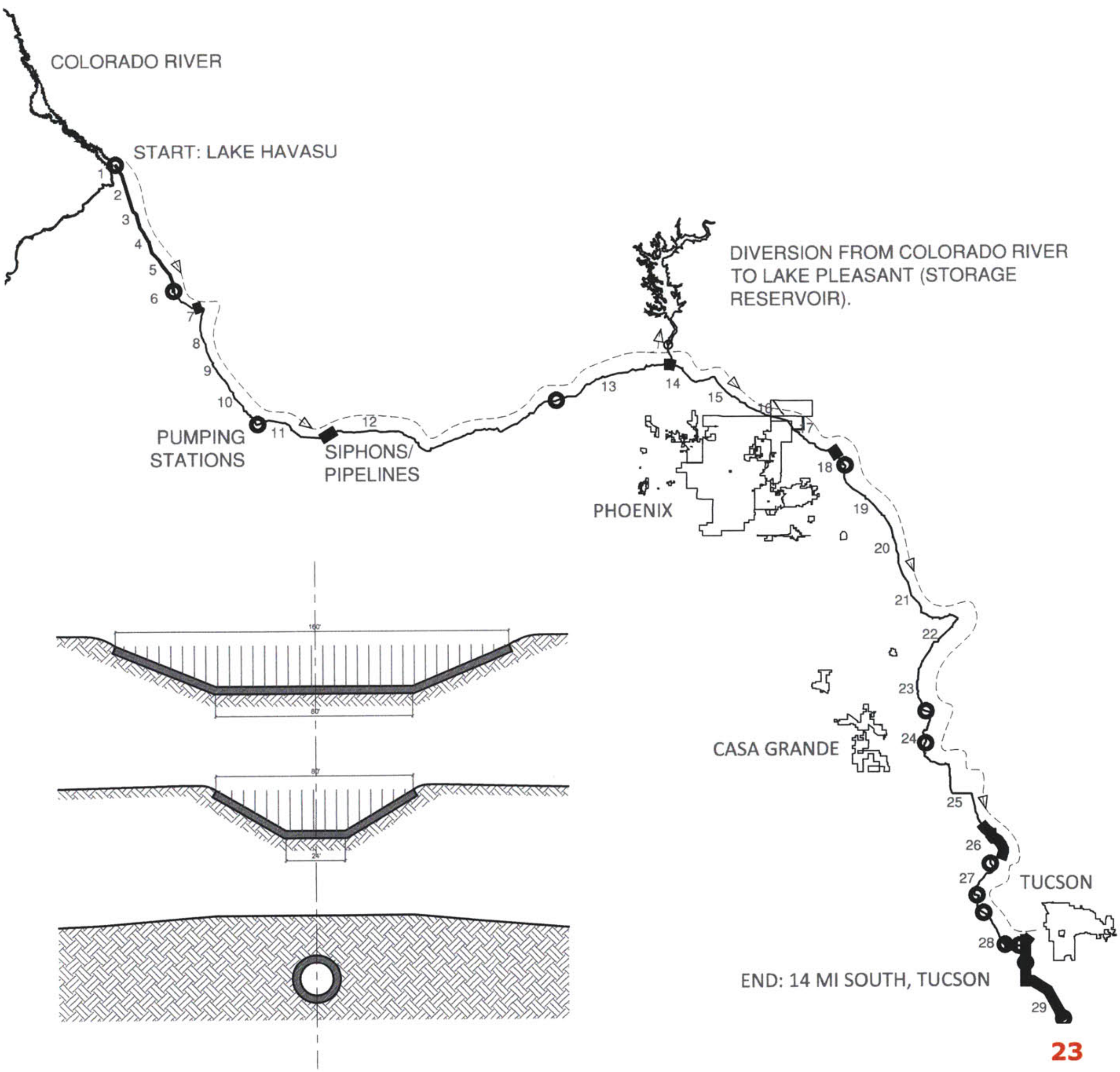


Central Arizona Project (CAP) is designed to bring about 1.5 million acre-feet of Colorado River water per year to Pima, Pinal and Maricopa counties. CAP carries water from Lake Havasu near Parker to the southern boundary of the San Xavier Indian Reservation southwest of Tucson. It is a 336-mile long system of aqueducts, tunnels, pumping plants and pipelines and is the largest single resource of renewable water supplies in the state of Arizona. (CAP 2011)

Water is withdrawn at Lake Havasu at the Mark Wilmer Pumping Plant. It then crosses the Parker, Ranegras Plain and Harquahala basins in the Lower Colorado River Planning Area via the Hayden-Rhodes Aqueduct to the CAP service area in central and southern Arizona. (Resources, Active Management Area Water Supply - Central Arizona Project Water 2011)

Length: 336 mi

Arizona Allocation: 2.8 MAF of Colorado River water			Delivery/Supplies used: 1,500,000 ACRE-FT

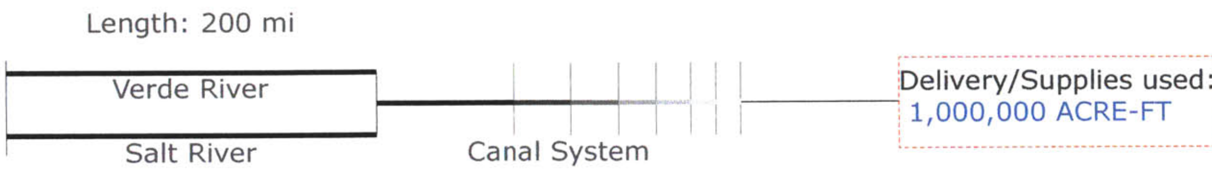


Salt/Verde River (SRP):

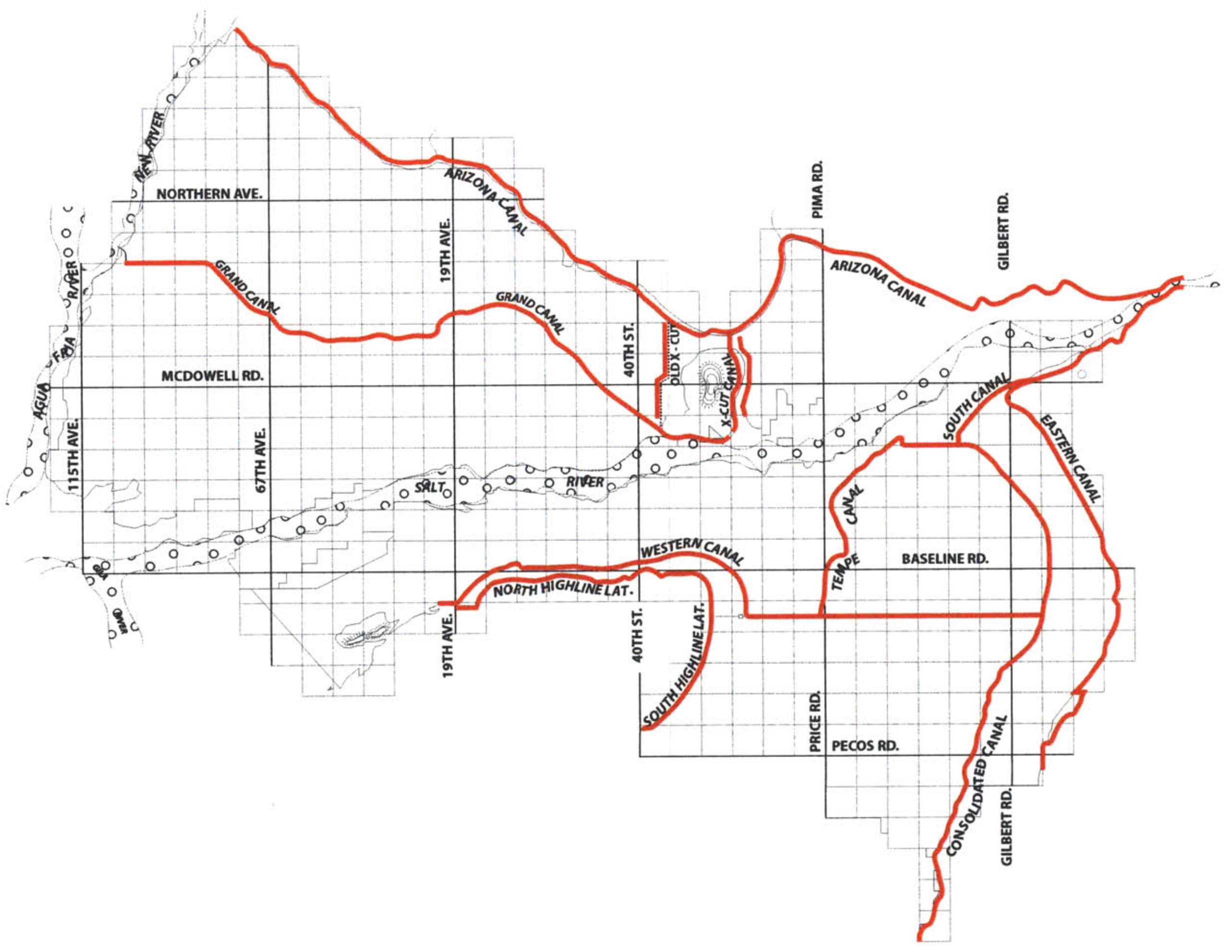
The total SRP service area consists of 248,000 acres and draws from the Salt and Verde river watersheds that cover 13,000 square miles, or approximately 11% of the state of Arizona (114,000 sq.miles). (Baker 2009)

SRP water is stored in 6 reservoirs: four on the Salt River and two on the Verde River. Roosevelt Lake, the largest lake in Arizona, represents 70% of SRP's storage capacity and is located on the Salt River along with Apache Lake, Canyon Lake and Saguaro Lake. SRP currently delivers more than 1 million acre feet of water to the water service area. SRP water is treated in city water treatment plants before being delivered to customers. (Baker 2009)

- Composed of six dams, 1,300 miles of canals and 255 high-capacity wells
- Reservoir Storage Capacity: 2,328,021 acre-feet
- Average water deliveries: 794,235 acre-feet
- Salt River length: 200 miles
- Verde River length: 195 miles



SRP Canal System Map:

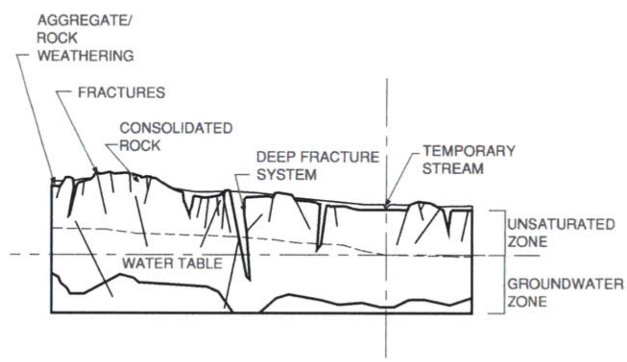


Groundwater:

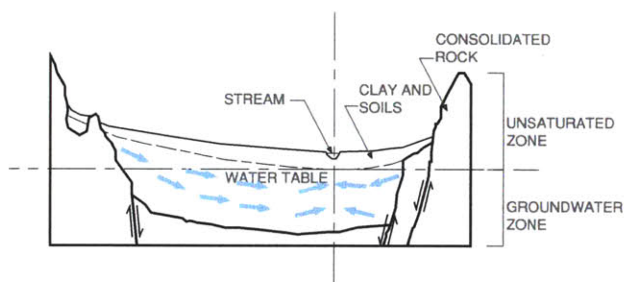
Large amounts of groundwater are in storage within the state's aquifers. About 900 million acre-feet of recoverable water was estimated to be within 1200 feet of the land surface in the Basin and Range Lowlands province aquifers. (Bonnie G. Colby 2007, 53) Groundwater basins contain varying amounts of water in storage (figure 4-7)

Estimates in ground-storage alone are misleading. Overdraft results after ground water has been pumped from underground storage faster than it can be replaced. As groundwater levels fall, it becomes more expensive to pump and the water quality diminishes. This is an on-going issue for the area because many areas rely on groundwater as their primary water supply. (Baker 2009)

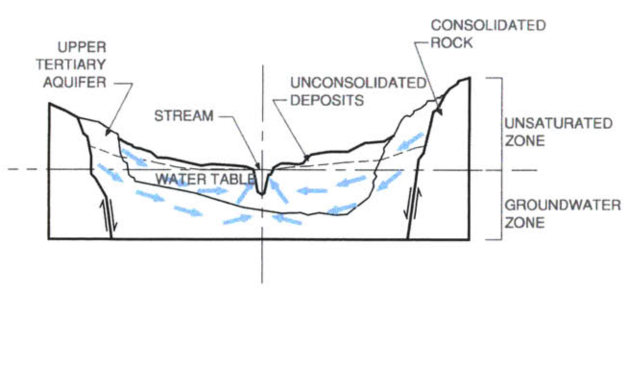
Alluvium Fill Basin:



Alluvium Basin Fill:



Stream Alluvium:



Total Storage:
397,000,000 ACRE-FT
Supplies Used:
1,684,000 ACRE-FT

Groundwater Storage Areas:

Verde River Basin
Storage: 17,000,000 ACRE-FT.
Sup. Used: 24,000 ACRE-FT.

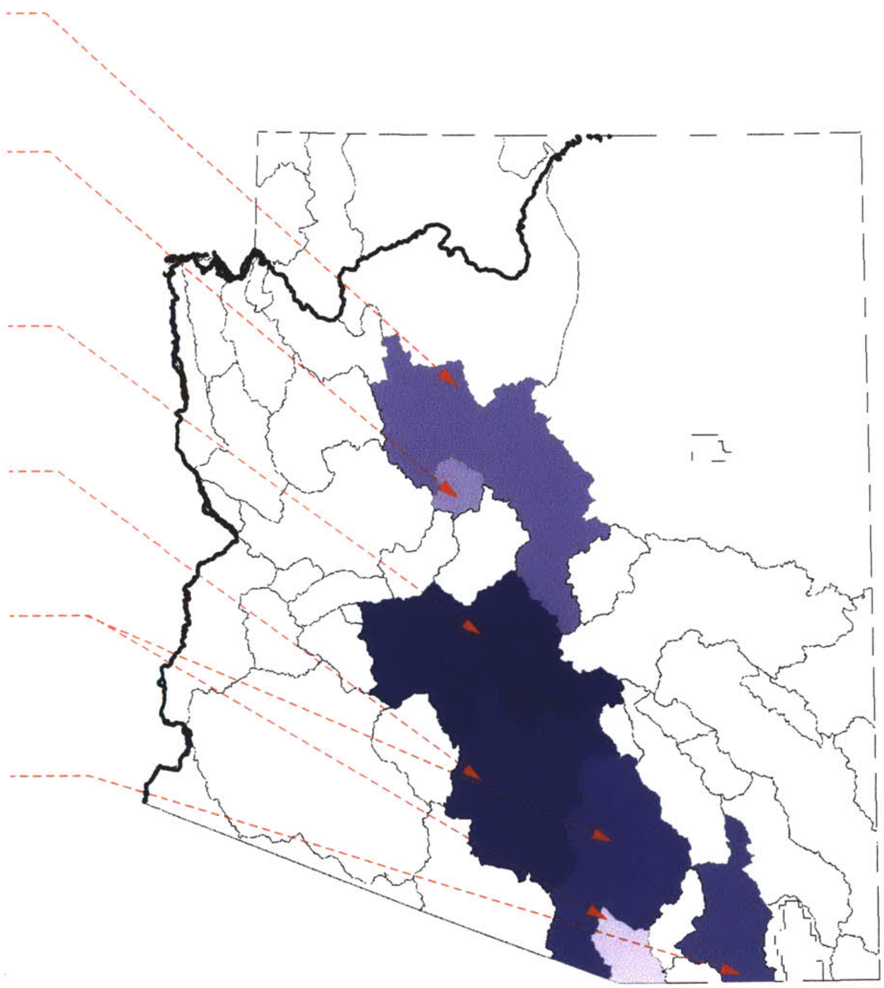
Prescott AMA
Storage: 1,000,000 ACRE-FT.
Sup. Used: 23,000 ACRE-FT.

Phoenix AMA
Storage: 130,000,000 ACRE-FT.
Sup. Used: 900,000 ACRE-FT.

Pinal AMA
Storage: 85,000,000 ACRE-FT.
Sup. Used: 384,000 ACRE-FT.

Tucson/Santa CruzAMA
Storage: 90,000,000 ACRE-FT.
Sup. Used: 320,000 ACRE-FT.

Upper San Pedro Basin
Storage: 74,000,000 ACRE-FT.
Sup. Used: 33,000 ACRE-FT.



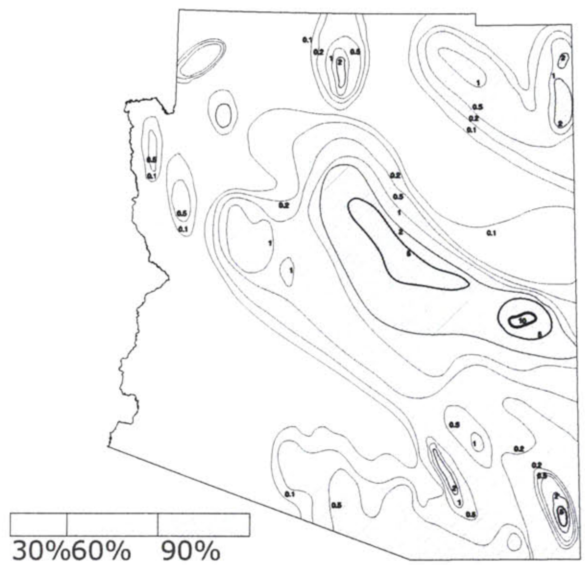
Surface Water:

Surface water, defined by hydrologists, is water that is present on the earth's surface in the form of streams, lakes, and reservoirs. The surface water portion is generally considered to be renewable. However, rates of precipitation and runoff vary greatly from year to year. (Bonnie G. Colby 2007, 45-46) The amount of surface water available can vary dramatically from year to year, season to season, and place to place. In order to make the best use of the surface water when and where it is needed, storage reservoirs and delivery systems have been constructed throughout the state. (Resources, Securing Arizon'a Water Future 2011)

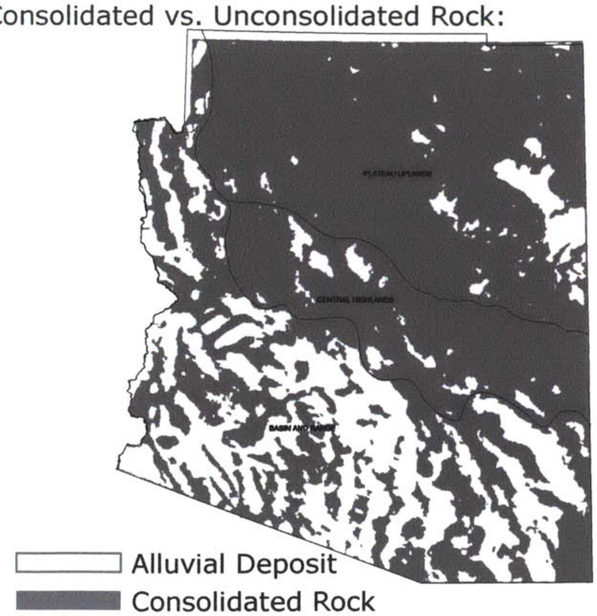
Geographical distribution of surface water is strongly influenced by elevation. Greatest amounts of precipitation and runoff of Arizona come from the mountainous areas of the east-central portions of the state.

About 61,000,000 Acre-feet is delivered annually to Arizona by precipitation. However, only about 4,500,000 Acre-feet result in runoff, and an even smaller fraction result in recharge to groundwater aquifers.

Annual Surface Runoff Diagram:

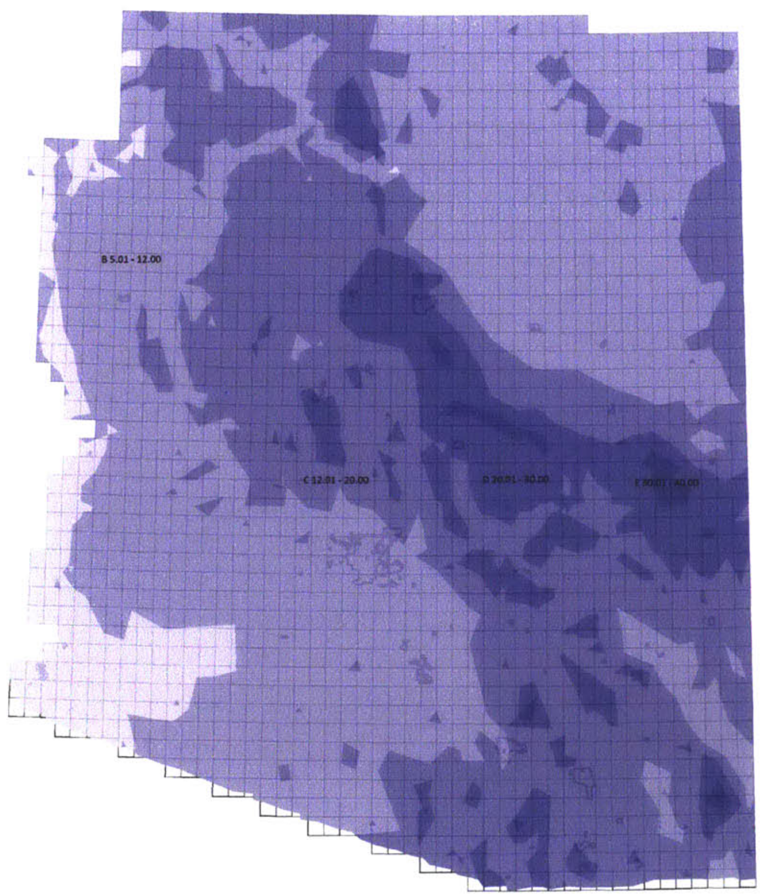


Consolidated vs. Unconsolidated Rock:



Precipitation:
61,000,000 ACRE-FT
Runoff:
4,500,000 ACRE-FT
Supplies Used:
3,500,000 ACRE-FT

Annual Precipitation Map:



A < 5.01
05.01 - 12.0
12.01 - 20.0
20.01 - 30.0
30.01 - 40.0
40.01 - 50.0

Reclaimed/Effluent Water:

Effluent water is collected from sanitary sewers and treated to a level allowing discharge. (Bonnie G. Colby 2007, 27) Effluent is becoming a valuable commodity with some cities predicting more than a 50% recapture and reuse of effluent in the future. (Bonnie G. Colby 2007, 34)

Considerably larger amounts of water have been committed to users in the Southwest than water sources can adequately supply. In 1990, for the first time, the lower Colorado River basin (Arizona, California, Nevada) utilized its full 7.5 million acre-foot legal allotment. Further, long term groundwater pumping exceeds replenishment in many locations. It has been estimated that average annual groundwater over-pumping in the lower Colorado basin (including Mexico) totals 1.24 million acre-feet, with about 80 percent of that occurring in Arizona alone. (Jon Unruh 2003)

The southwest depends on unsustainable use of groundwater and a finite supply of reservoir storage. Regardless of whether humans are causing climate change, it is a certainty that the region will at some point in the future face a severe and prolonged drought similar to what scattered the Anasazi.

Supplies Used:
400,000 ACRE-FT

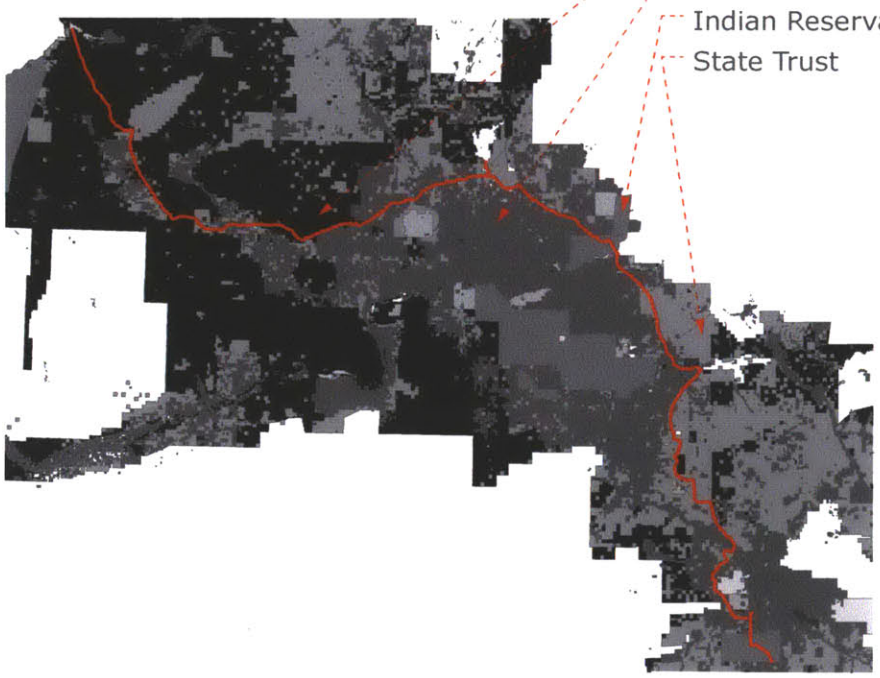
Canal Economics

Ownership

Central Arizona Project is managed and operated by the public organization: "Central Arizona Water Conservation District".

CAP
CENTRAL ARIZONA PROJECT

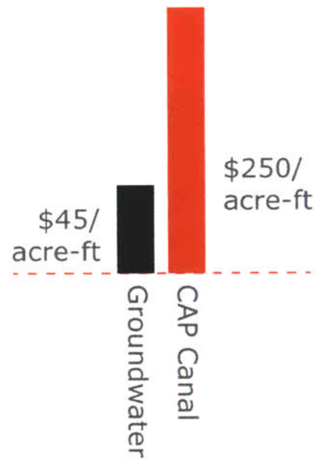
Land Ownership



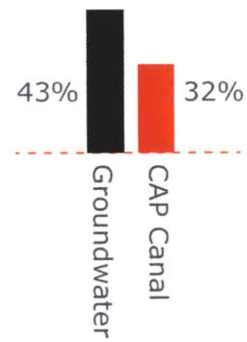
Cost/Benefit analysis

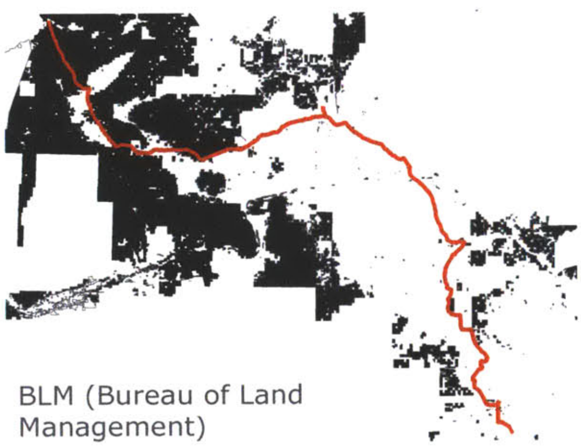
With the project costing over $4 billion towards final phases of construction, covering the canal would have quadrupled the original cost. Currently costs of pulling the water from the CAP far outweigh the costs of groundwater pumping. Although water is provided to agricultural districts at subsidized rates, these districts still aren't able to afford the water at supplied cost, therefore making groundwater pumping more desirable. This results in underutilization of the canal water. Farms/Agricultural districts aren't buying as much water from the CAP as predicted.

Cost:

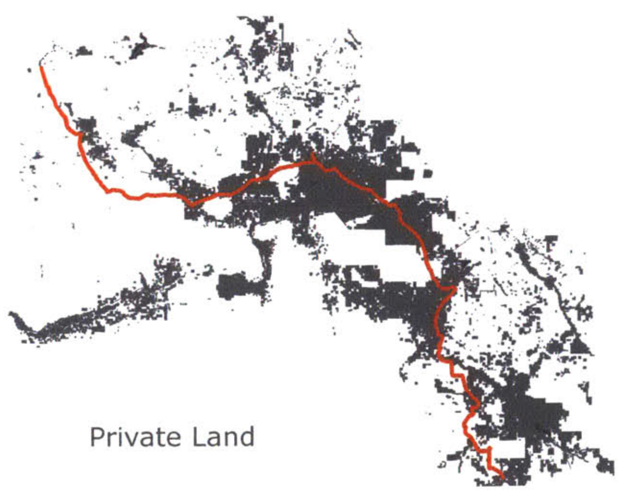


Usage:





BLM (Bureau of Land Management)

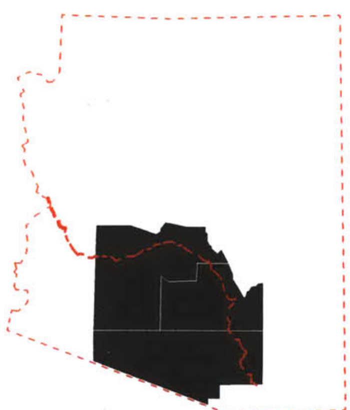


Private Land

CANAL ECONOMICS

Payment/Costs:

- CAP's construction costs = over $4 billion
    - Subsidized by the Bureau of Reclamation at a rate of 52%
- Operating costs = $275/acre-foot
    - Subsidized at a rate of 61%
- Property Taxes from municipalities, property owners, three counties: Pima, Pinal and Maricopa



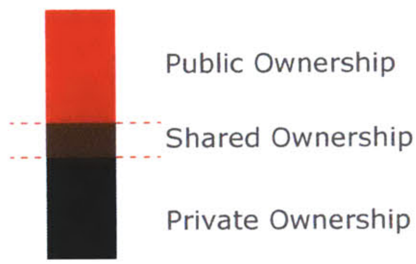
Property taxes from Pima, Pinal, Maricopa counties

Municipal Users and Taxpayers

Agriculture Districts

Public/Private Partnerships

A possible way to reduce costs may be to combine the advantages of the public and private sectors in public-private partnerships. The skills and assets of each sector are shared. A service or facility for the use of the general public is delivered. In addition to sharing resources, each party also shares the risks and potential rewards.



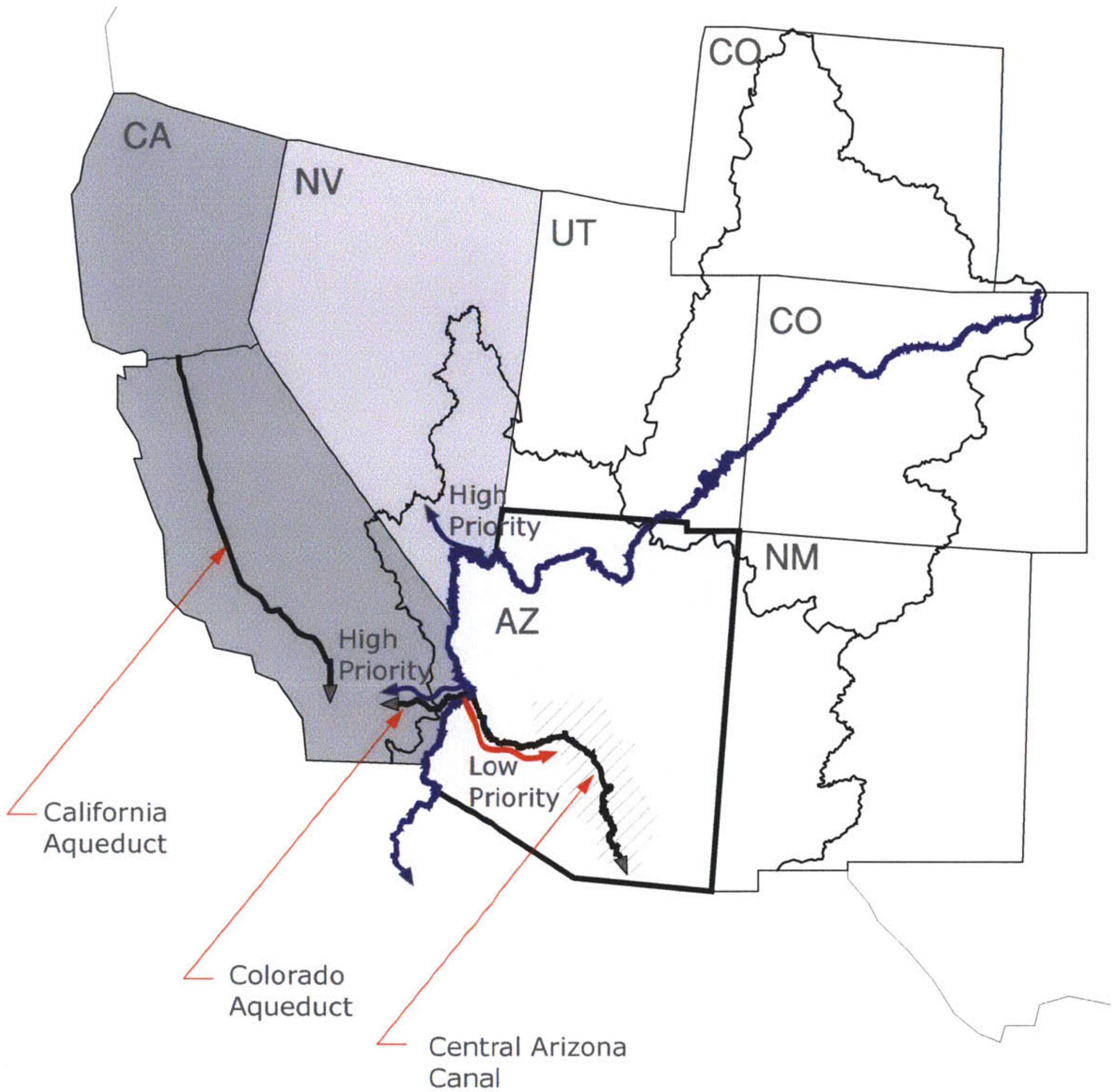
Sponsorships:

- Customers wishing to store at a CAP recharge facility
- Arizona Department of Parks and Recreation
- State Trust

Urgency and crisis of the Canal Infrastructure

Southwest Water
Allocation of Colorado
River Supply:

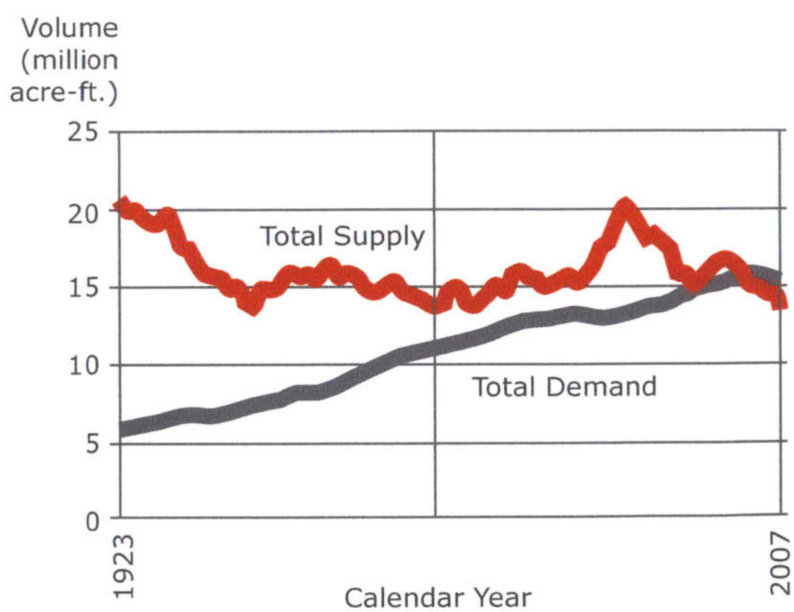
NV = 2ND Priority
CA = 1ST Priority
AZ/CAP = 3RD Priority



Derived from source:
Timo Matti Wirth, "Water, Agriculture + Settlement in the Arid Lower Colorado River Basin" (SMarchs Thesis, Massachusetts Institute of Technology, 2011).

Canal Cut from Colorado River Supply

Due to legal issues and regulations, the canal has low priority on the Colorado River supply. The canal is vulnerable to drought as it competes against California and Nevada for water. The canal is able to sustain for three to five years (depending on usage) in time of drought. If there's a shortage on the Colorado River, the canal's 1.5 million acre-foot allocation would be cut before any of the other Southwest states lose a drop. Arizona has made huge investments in importing and storing water supplies for the major metropolitan areas, and those investments have significantly buffered the state from impacts during the current drought. However, there is a need for further preparedness in case conditions worsen." Arizona Drought Preparedness Plan

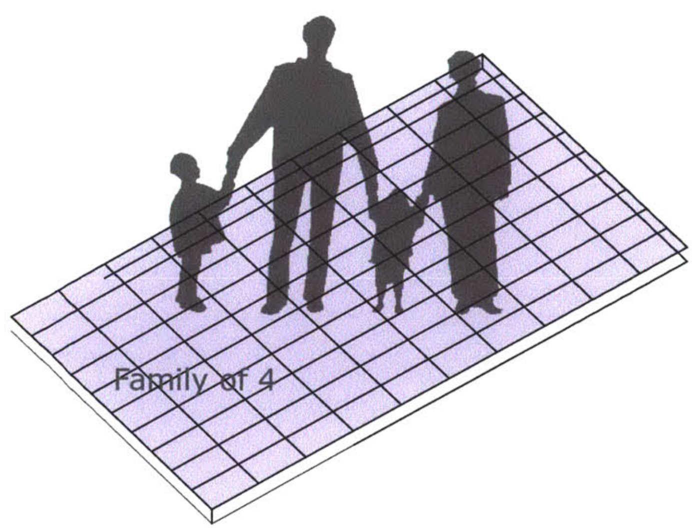


Projections of Water Demand exceeding supply

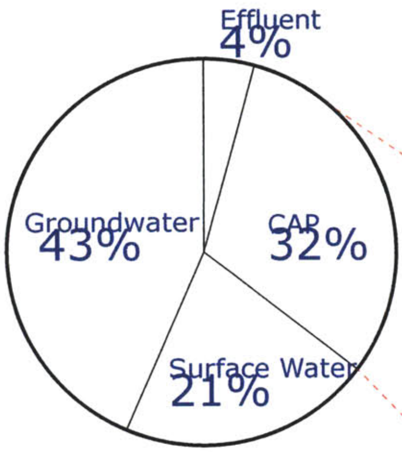
Derived from source: Bureau of Reclamation WWW.USBR.Gov

Amount of Water loss due to evaporation

Due to design of the canal, 4.4% of the water is lost to evaporation per year. Further a 0.6% loss, per year, occurs due to water seepage from the canal. This is approximately a 5% (75,000 million acre-ft) water loss per year. Equivalent to the amount of water required to supply 75,000 households annually (One acre foot of water = 325,851 gallons = amount used by a family of four in one year).

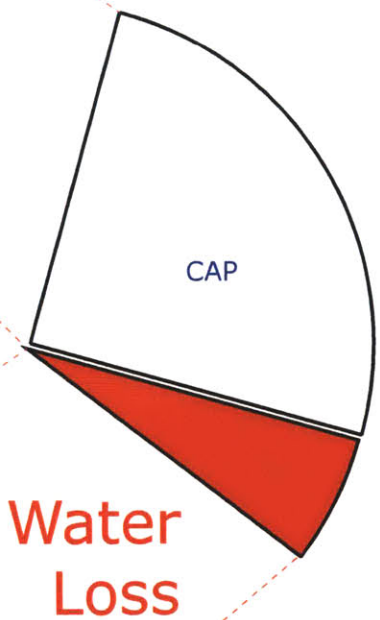


Average Water Use in Arizona:
1 ACRE-FT (325,851 Gal)/Year
for a family of four



Derived from source: Arizona Water Policy: Management Innovations in an urbanizing, Arid Region

Water Supply Utilized in the AMA Planning Area



- 55,000 acre-ft (Lake Pleasant)
- 16,000 acre-ft (Aqueduct)
- 9,000 acre-ft (seepage)

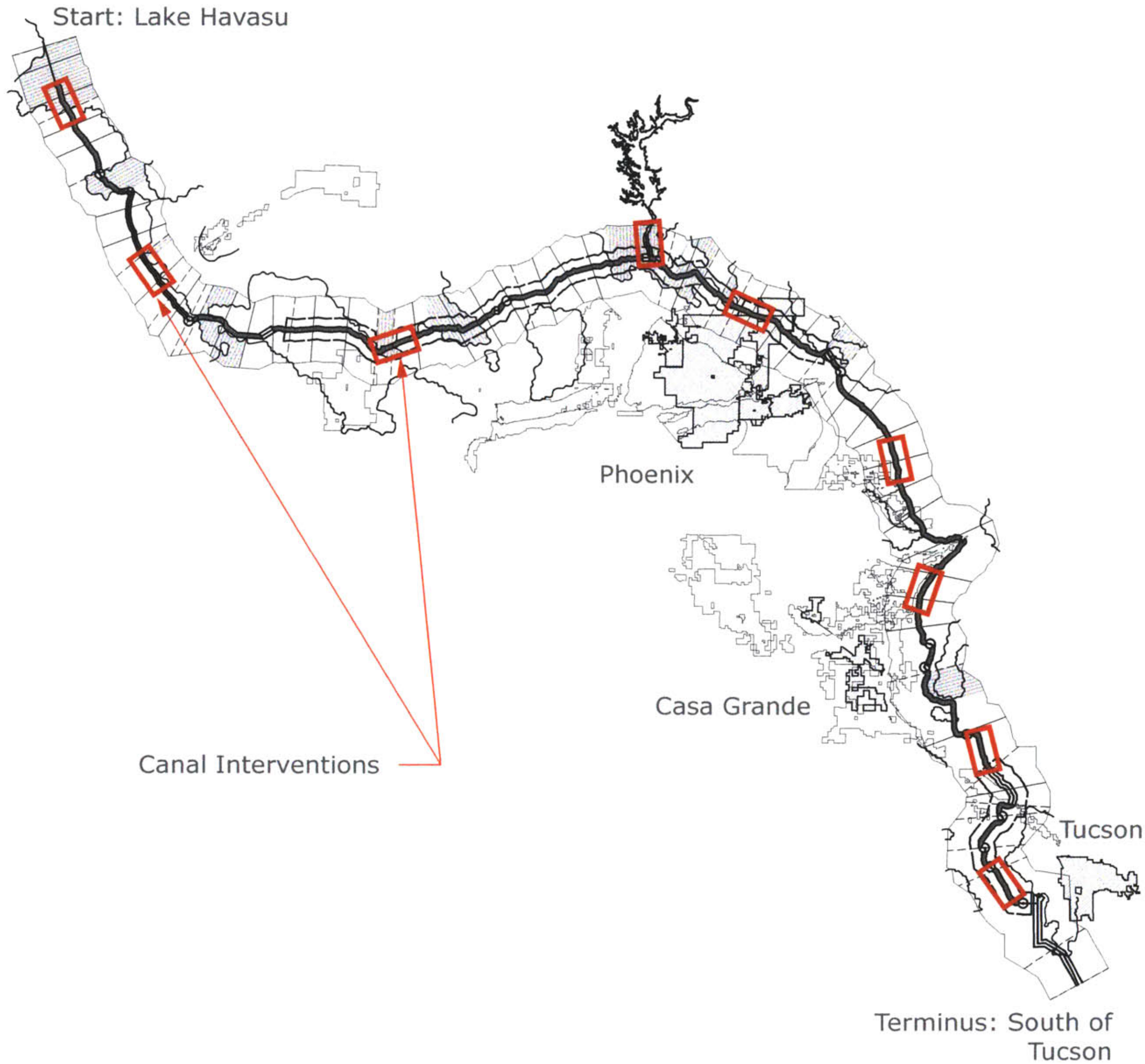
=75,000 acre-ft (Total water Loss)
Scale of water loss ~75,000 households affected

Uncle Kick-Kick, Central Arizona Project, JPEG, http://www.flickr.com/photos/28016468@N06/5636069439/ (accessed, Jan, 17, 2011)

Masterplan and Design Proposal

With increasing pressures on the canal, we should re-strategize and reinvest in this infrastructure. This thesis re-thinks the relationship between water infrastructure and architecture in order to transform the canal into a water-efficient repository and recreational venue.

I'm proposing to cover this canal through a phased construction in order to shield the water from the brutal desert environment.

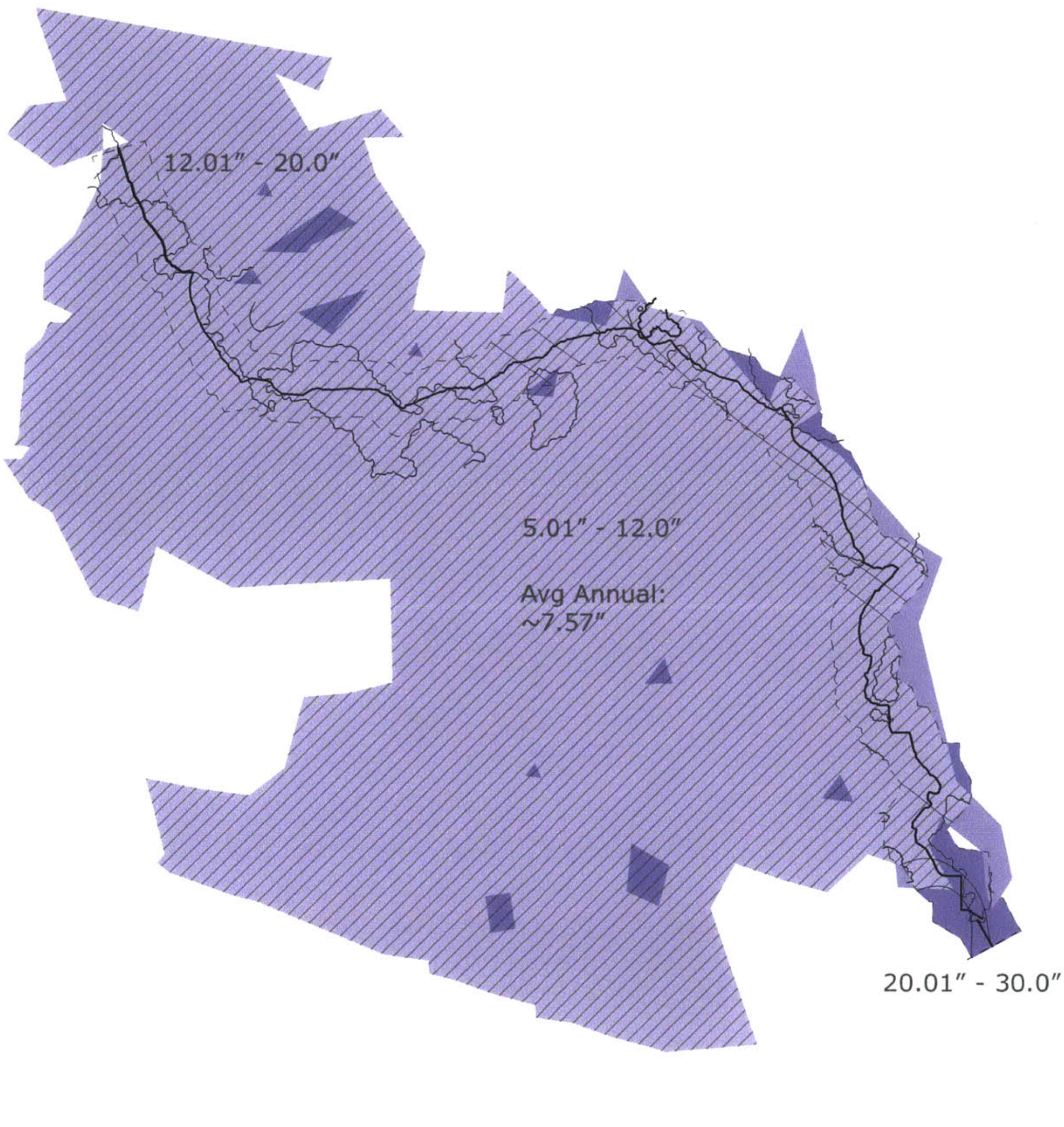


The canal is divided into three administrative divisions: Hayden Rhodes, Fannin-McFarland, and Tucson.

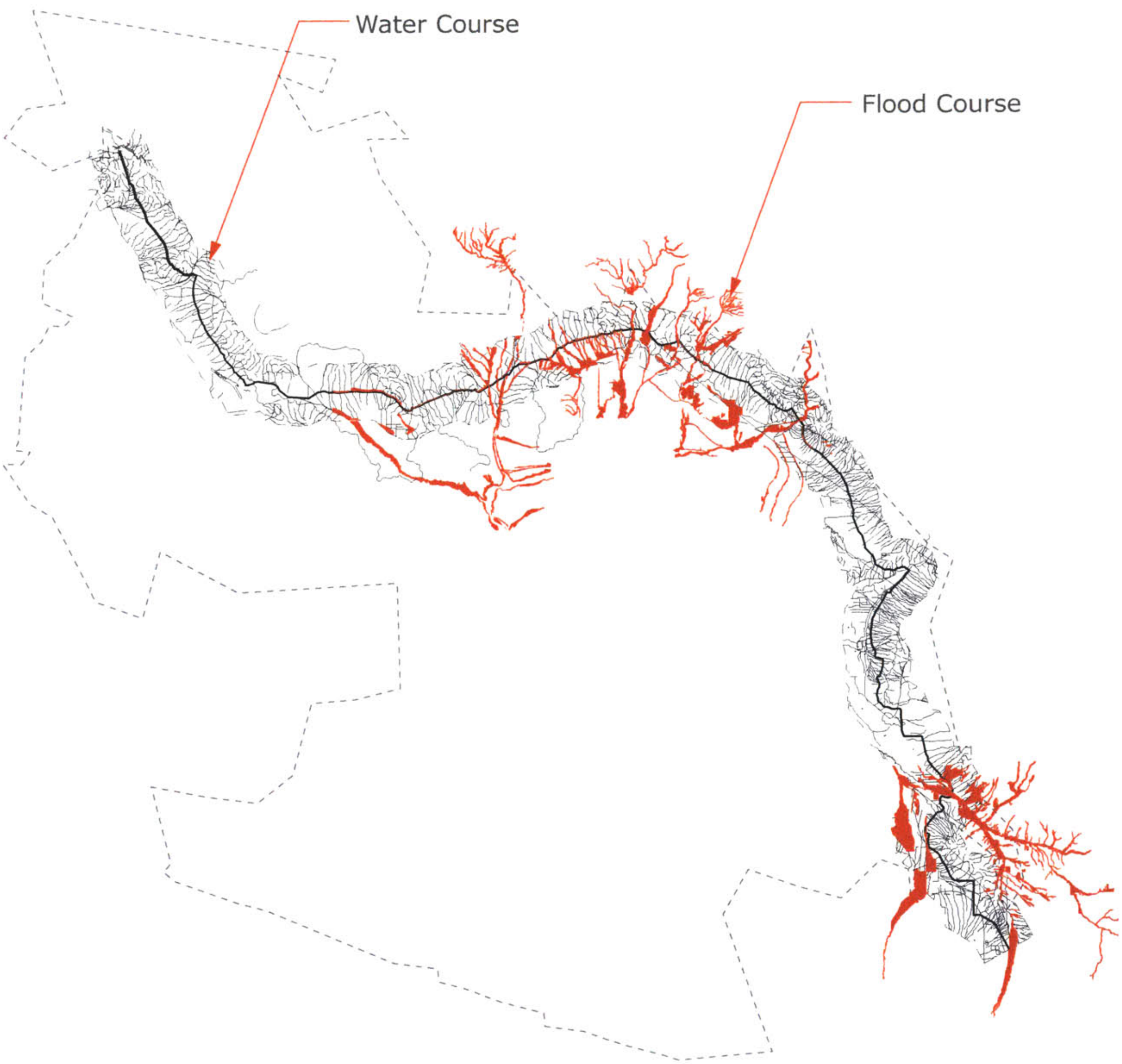
Highlighted in grey are the construction phases for the covering of the canal

Highlighted in red are the exposed portions of the canal that are vulnerable to water evaporation.

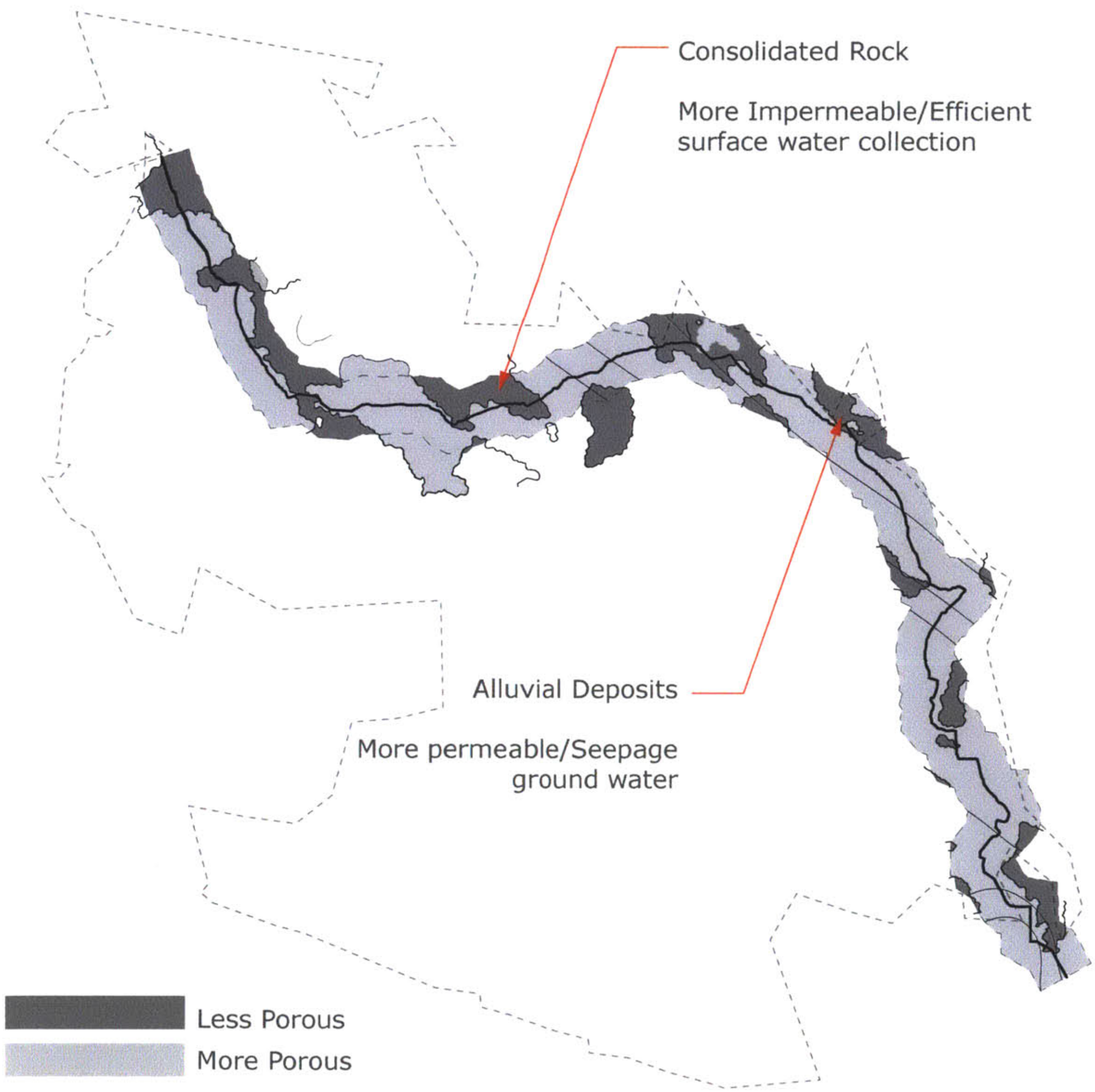
Mean Annual Precipitation



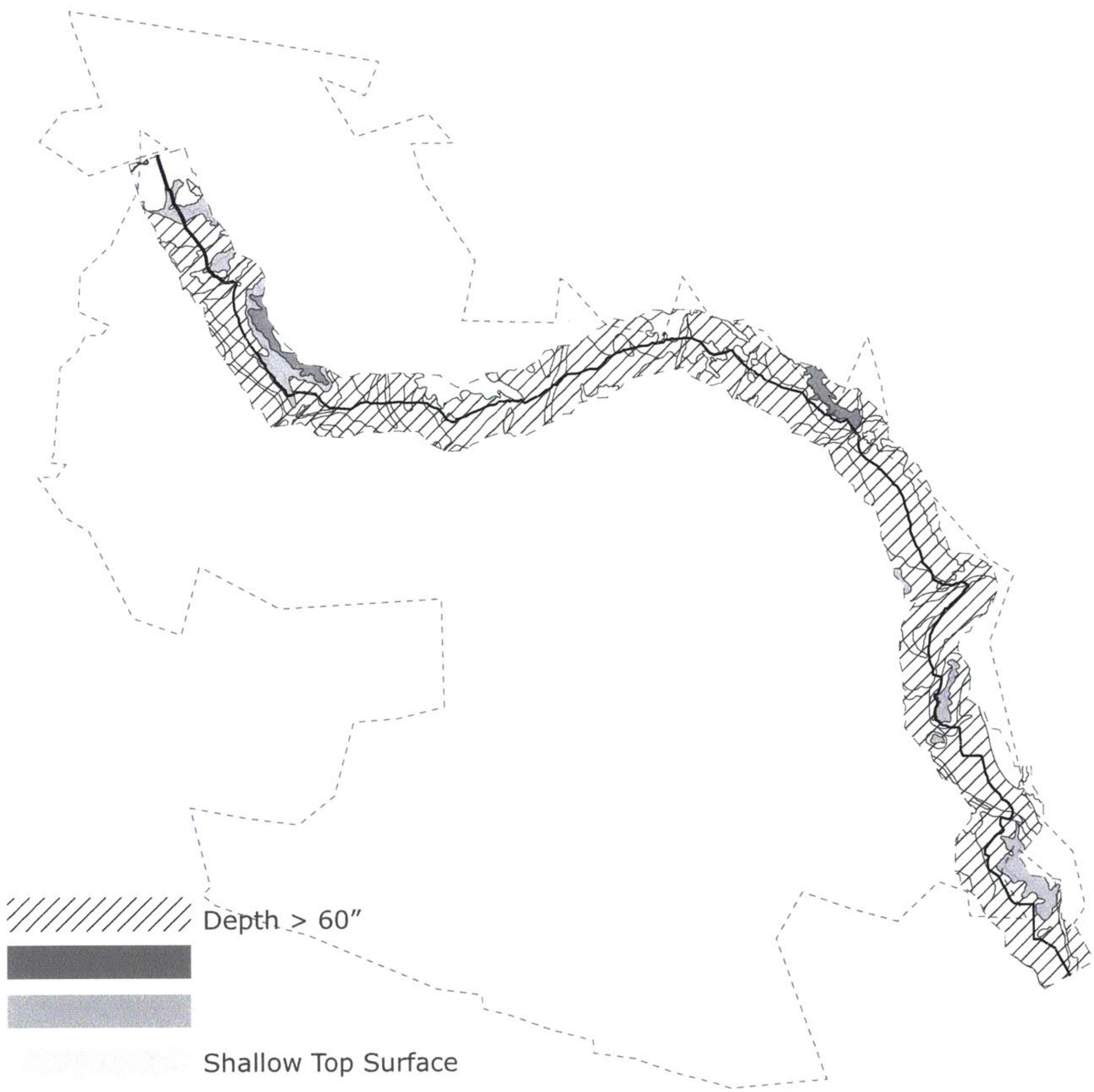
Water course/Flood
Scenario



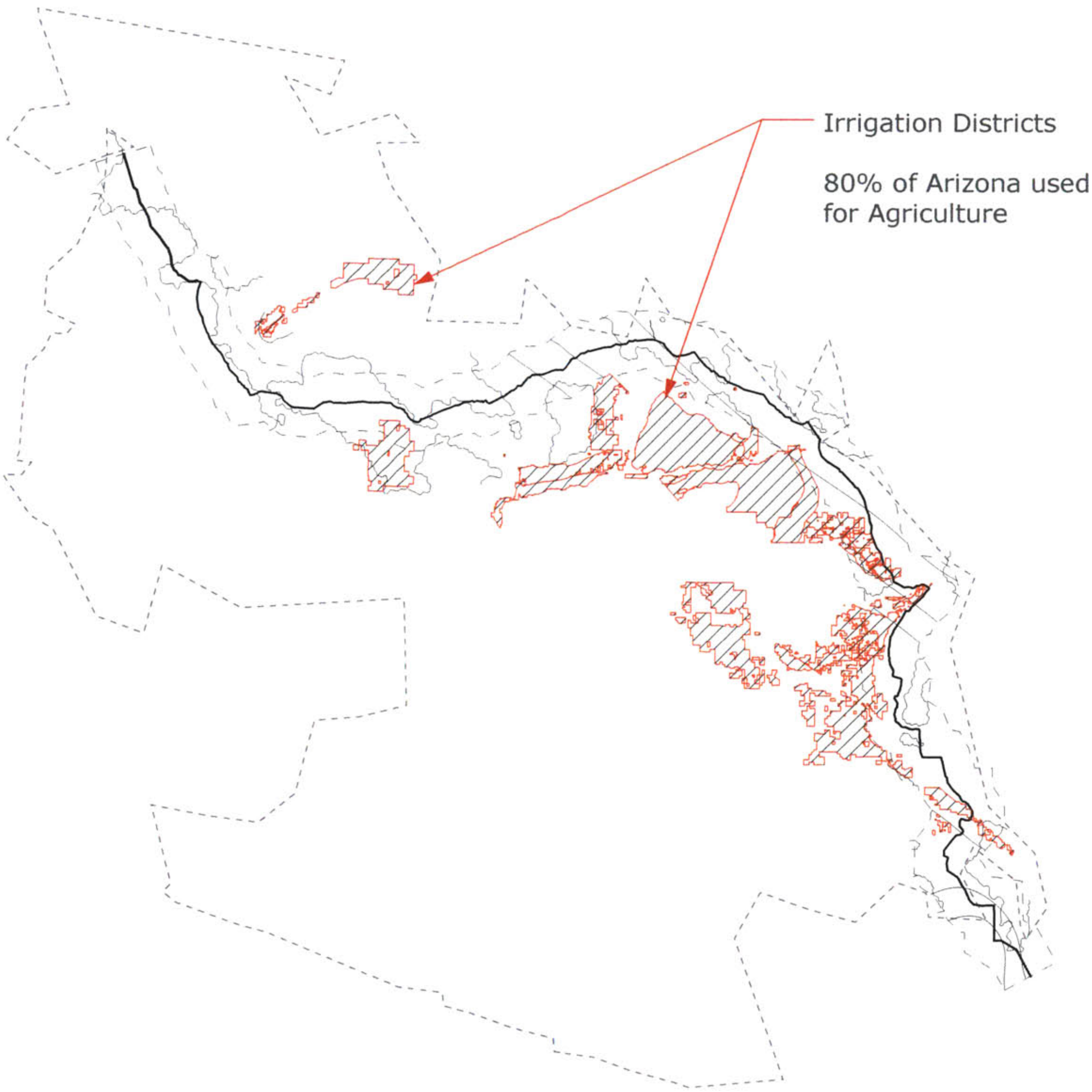
Consolidated/
Unconsolidated Rock:



Top Soil Composition/Soil Depths:

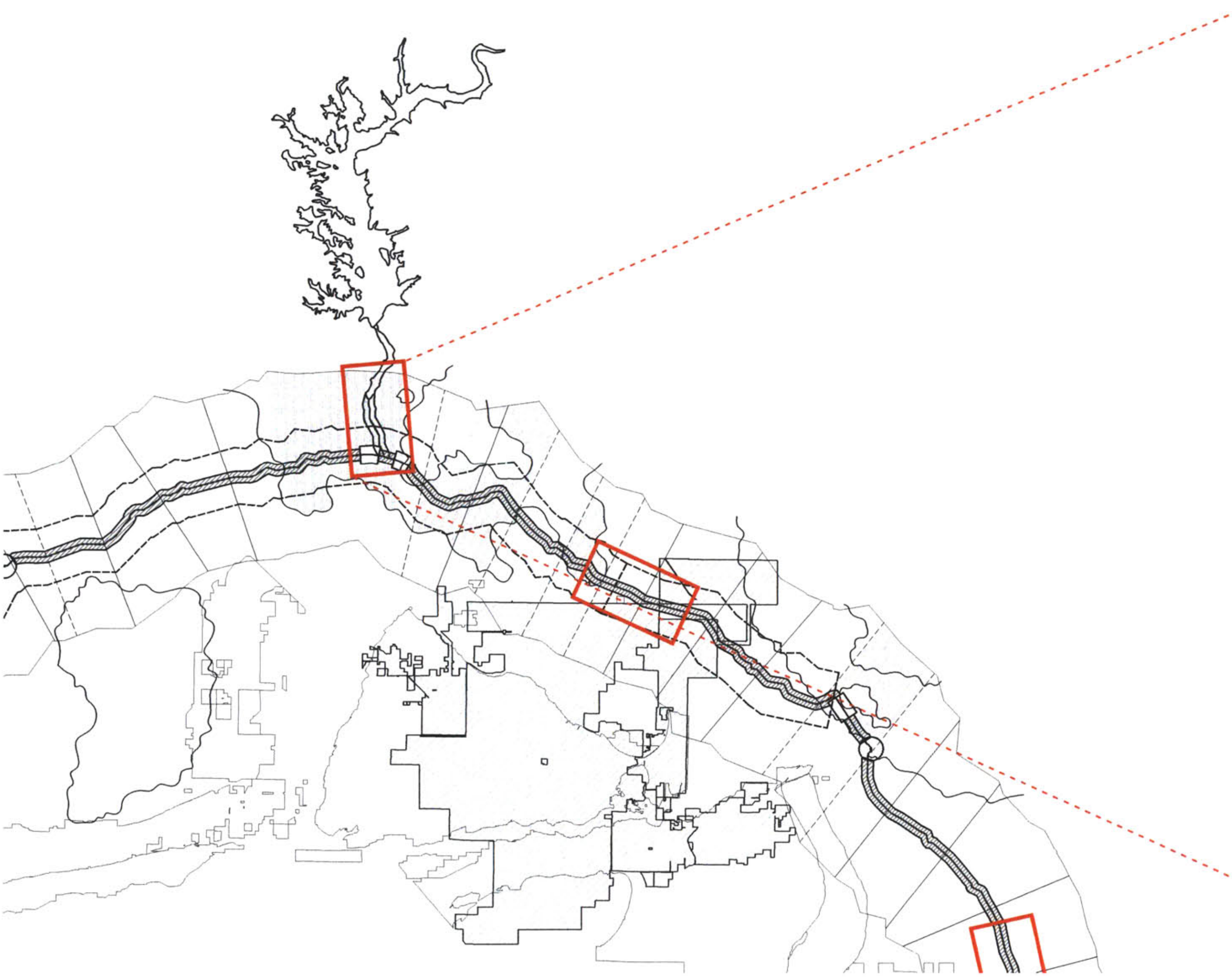


Central Arizona Irrigation Districts

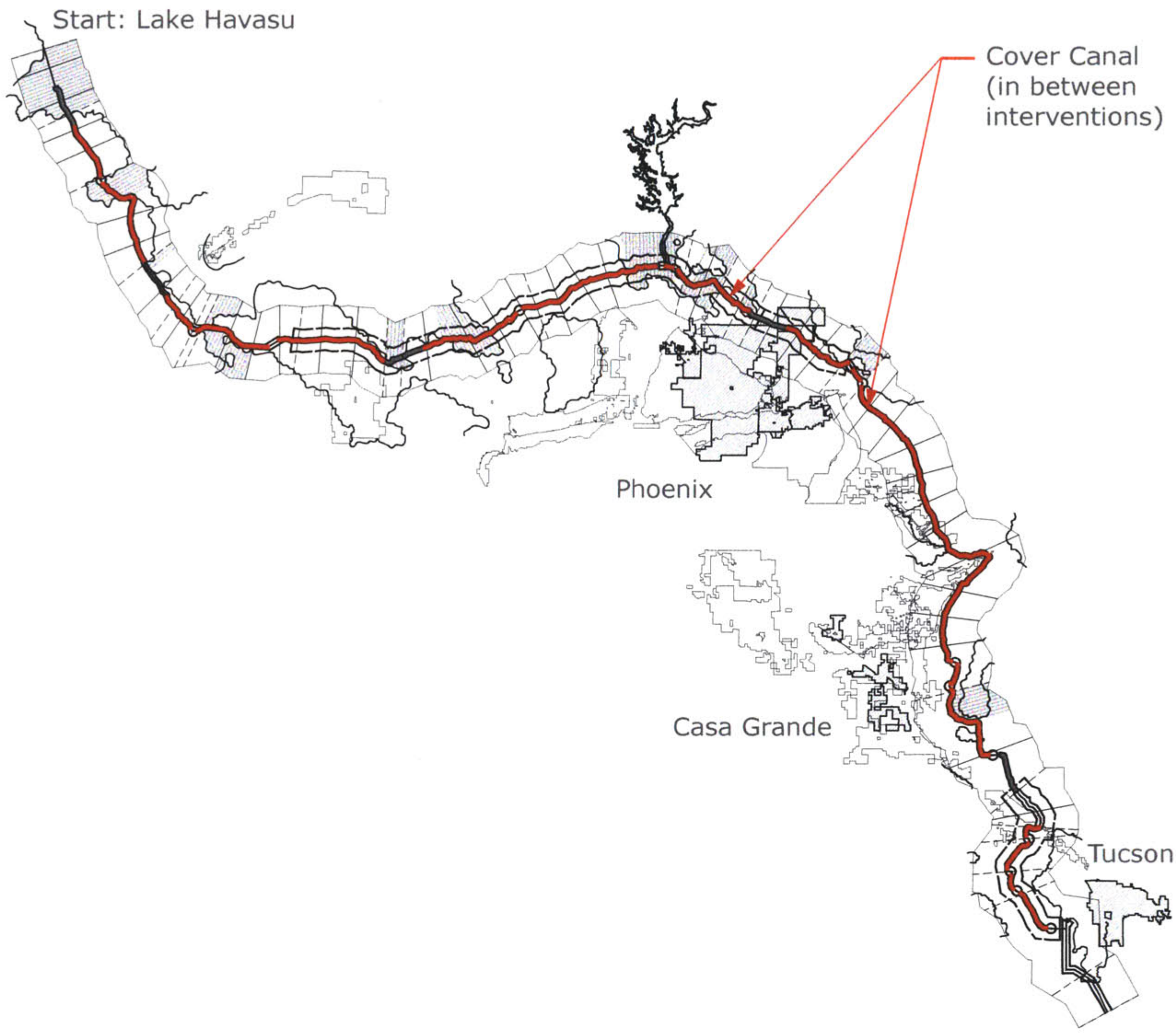


Distance/Time Analysis:

In addition to the covering, a series of three types of nodes are inserted along the canal in order to function as rainwater harvesters to collect and store water for public and recreational use. Further, the objective of these interventions aims to recuperate the amount of water lost, each year, from this canal.



In order to blend water collection with public recreation, I'm inserting three types of program into the architectural interventions: farmers' market/exchange of goods, oasis/rest area, and a bio-pool spa.



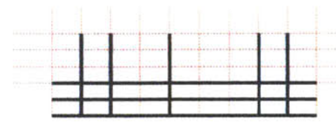
Start: Lake Havasu
Cover Canal
(in between
interventions)
Phoenix
Casa Grande
Tucson
Terminus: South of
Tucson

By intervening on the canal, a set of variables are created in order to help set the stage and guide the architectural design.

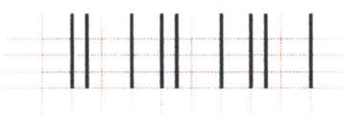
Regular Horizontal

Angled-Horizontal

Crossgrain



Irregular Horizontal



Crossgrain

The mapping of rhythmic patterns serves as guidelines for volumetric spatial rhythms of water. These simple patterns allow for flexibility for further expansion space for water storage, if needed.

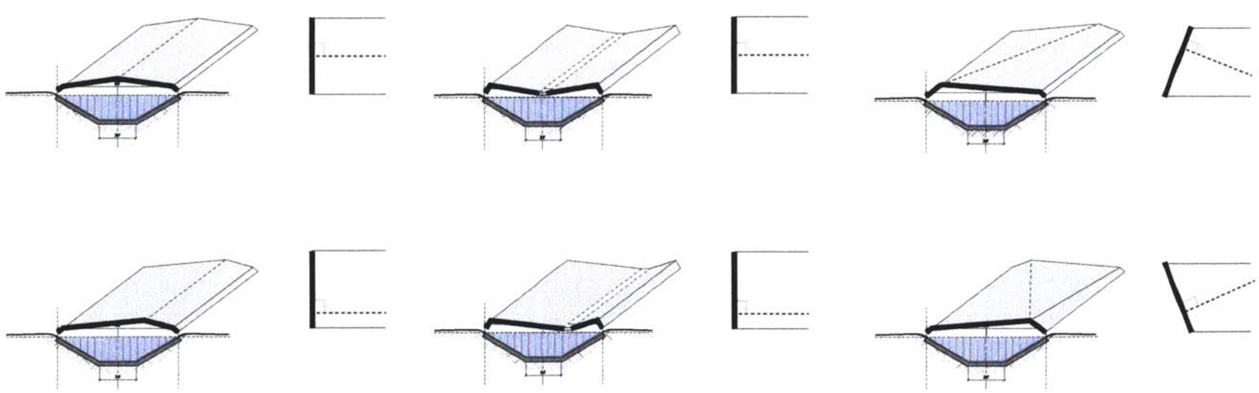
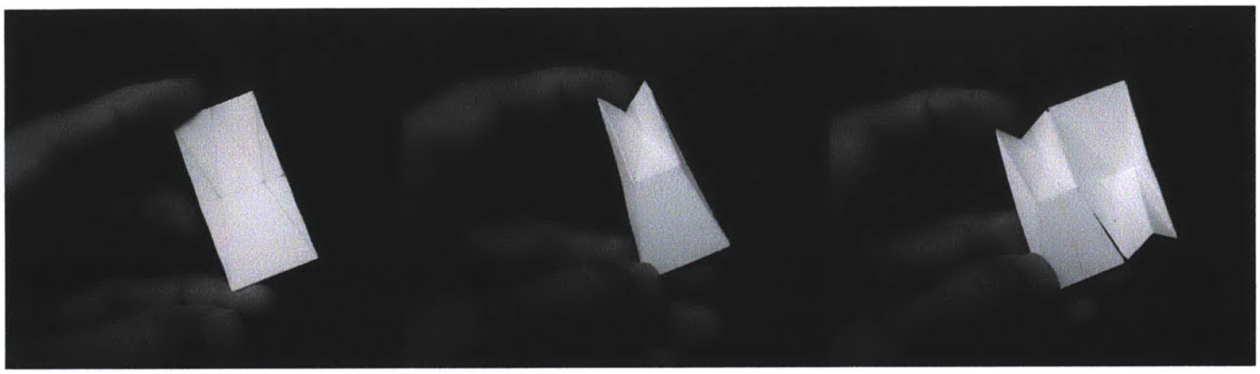
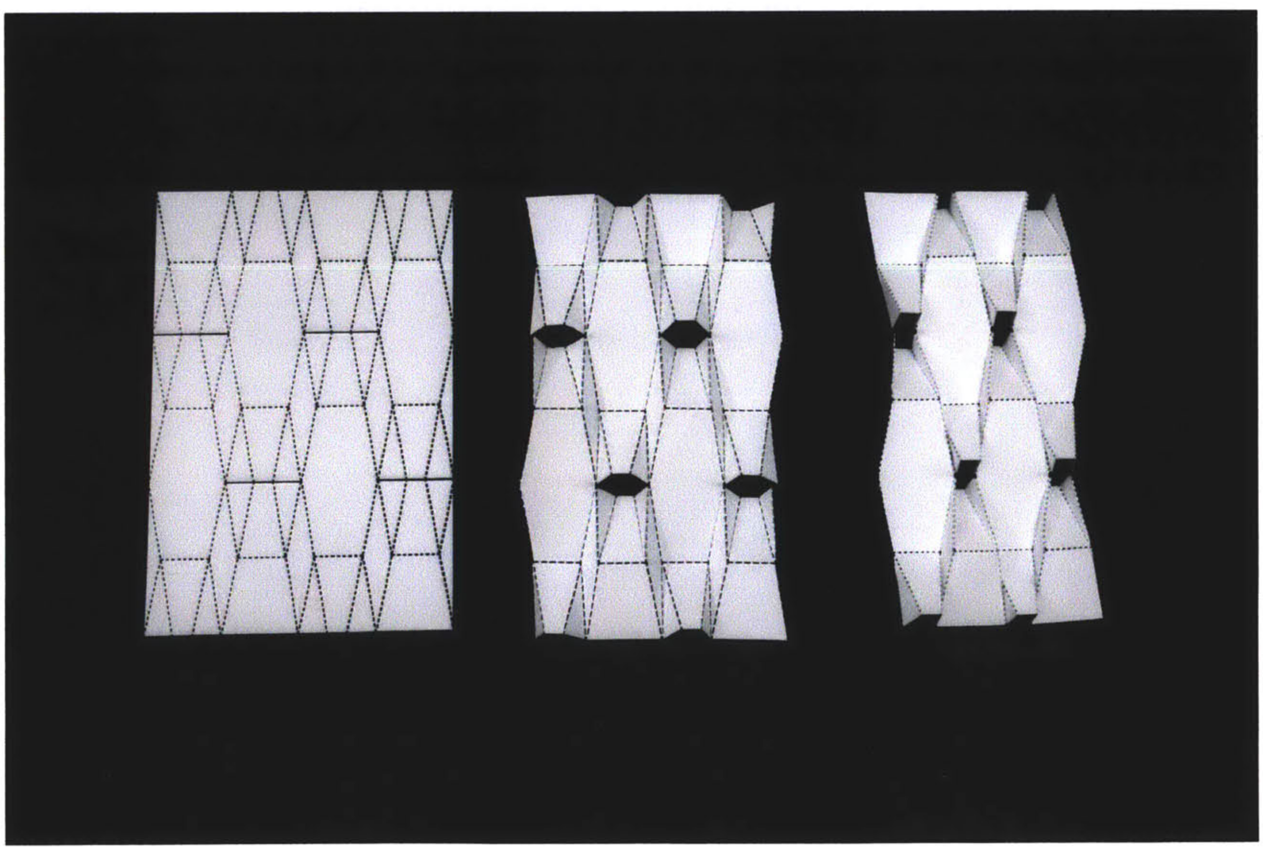


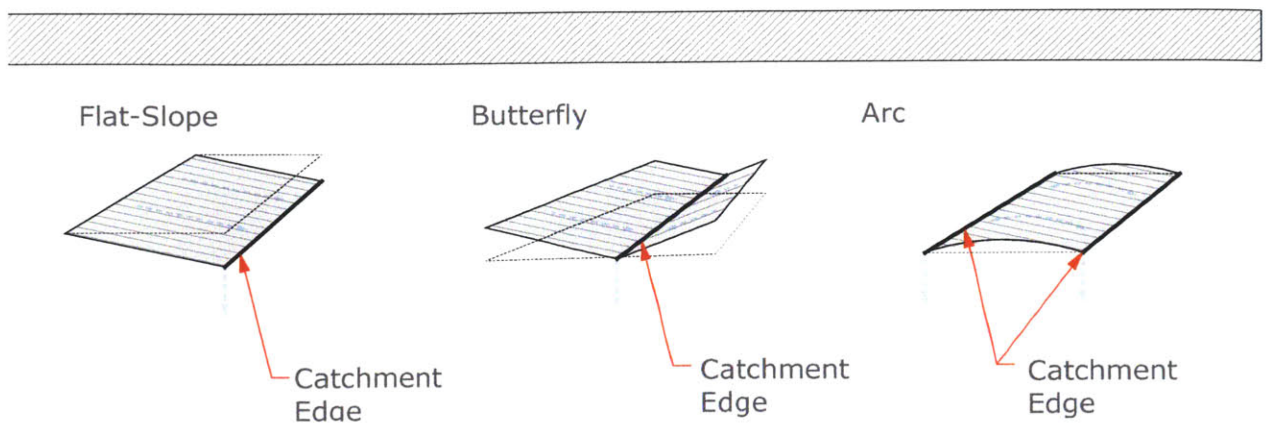
Diagram of multiple options for canal cover types.

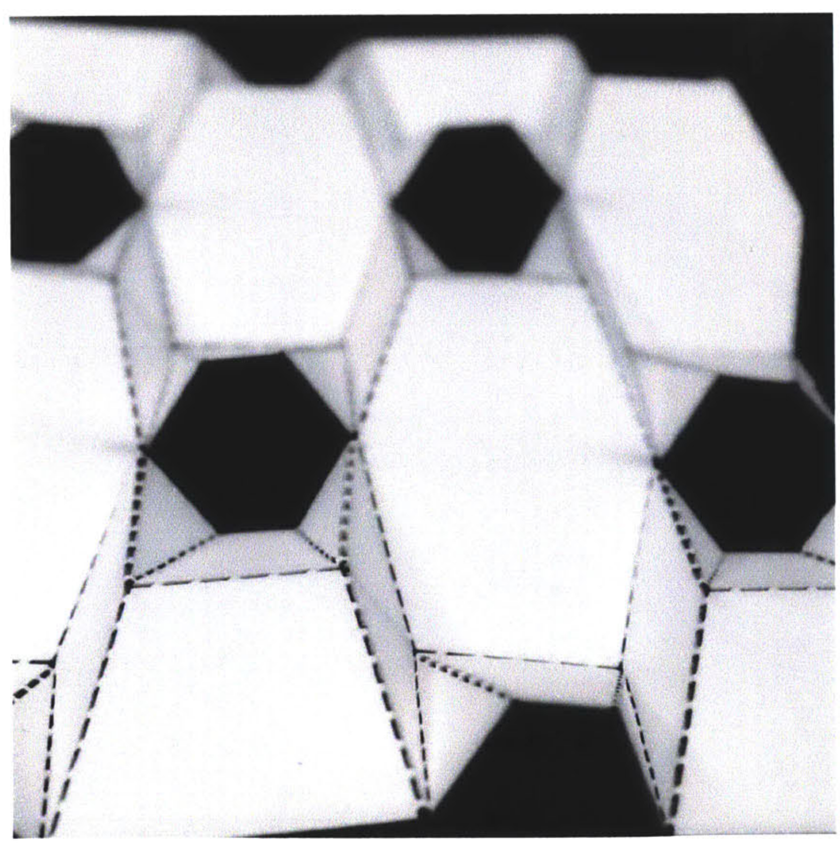
This set of design variables identifies the main types of overhead conditions of rainwater collection: Flat slope, Butterfly, and Arced roof.

As an alternative to the basic rainwater catchment types, a series of surface studies are designed to become performative architectural conditions for the process of catching, directing, and storing water.

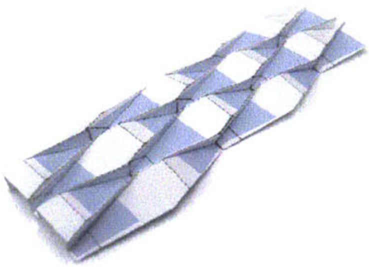


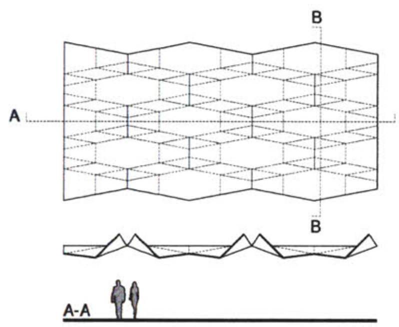



Flat-Slope
Catchment
Edge
Butterfly
Catchment
Edge
Arc
Catchment
Edge

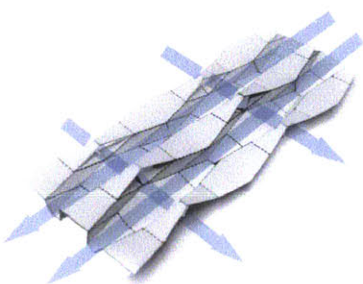


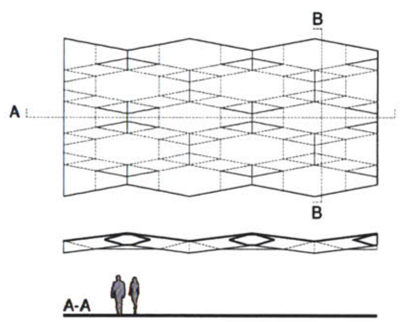
Surface Type 1: Container

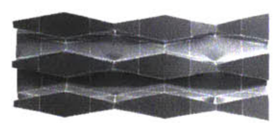




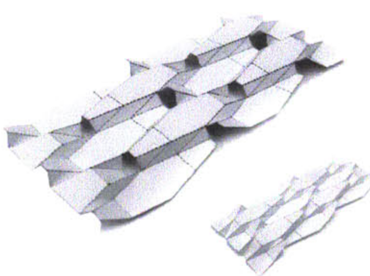
Surface Type 2: Channel

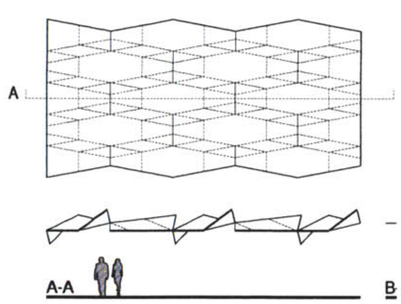


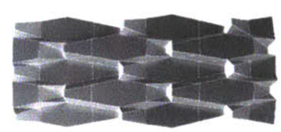


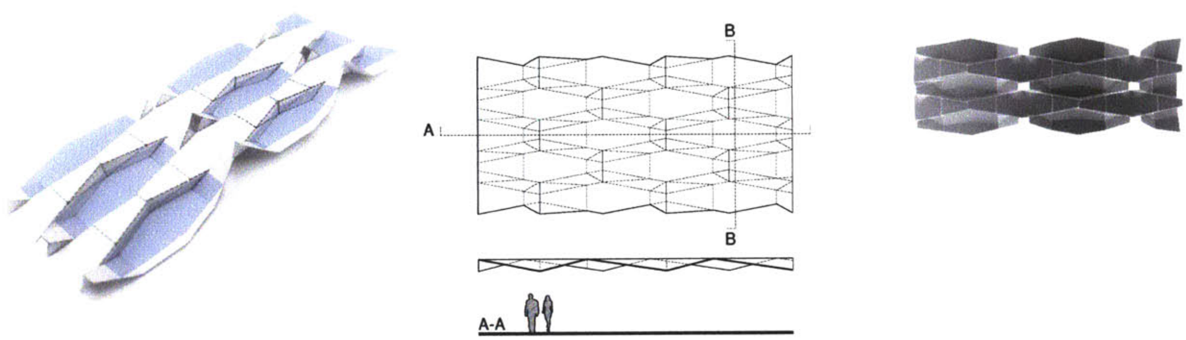


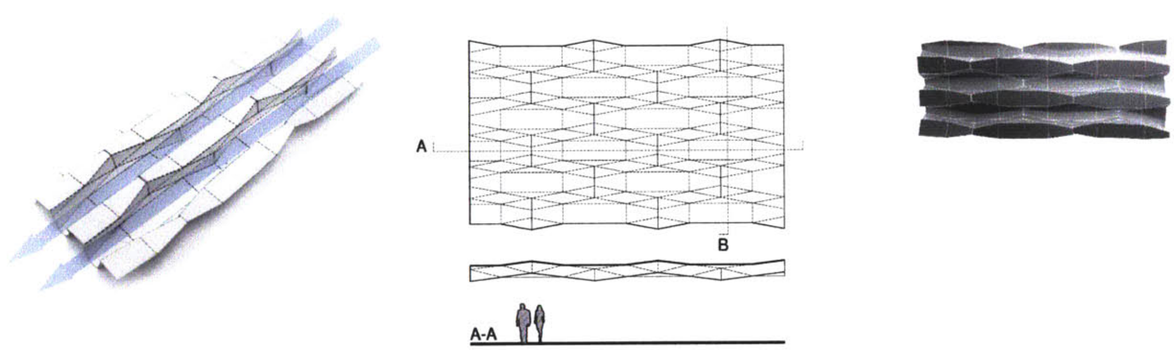
Surface Type 3: Rainscreen/Tile

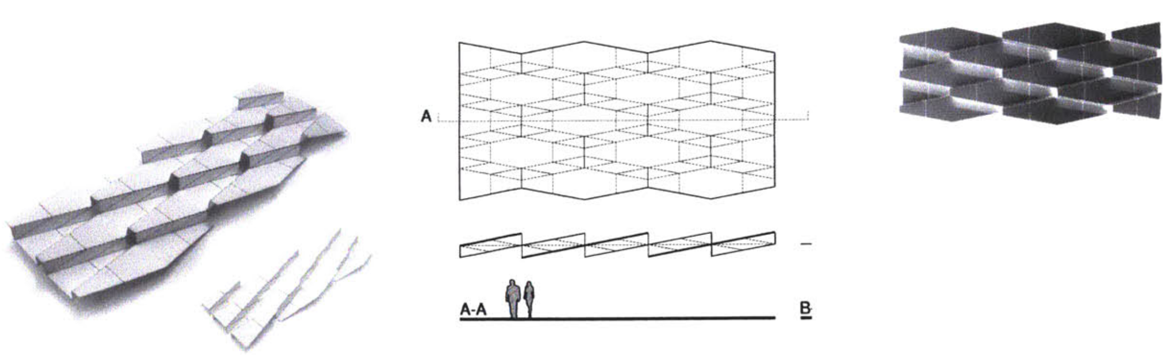







B
A
B
A-A


A
B
A-A


A
A-A
B

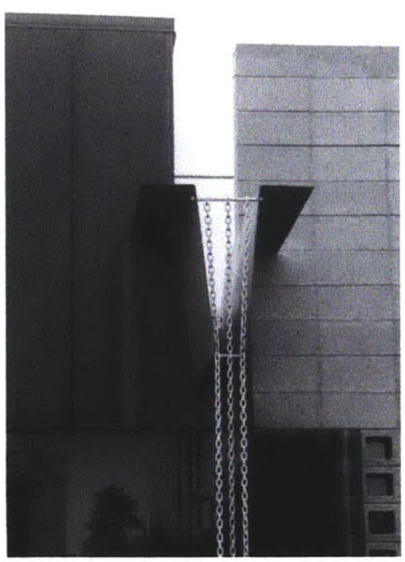
Alternative water sources: Rainwater Harvesting

In order to guarantee adequate future water supplies in Arizona, viable alternative water supplies in addition to reclaimed water need to be evaluated. Greywater reuse and rainwater harvesting are two alternatives that can be effective ways for consumers to lower use of municipal water. (Kinkade-Levario 2004, 6)

Greywater (wastewater generated from domestic activities such as baths, showers, washing machines, etc.) undergoes numerous operating conditions in order to meet greywater systems requirements. The Greywater must only come from private residential resources and can be used only for associated residence landscape irrigation. When greywater is applied to a landscape it must be done in such a manner that it minimizes standing water on the surface. Further, a greywater system can't be connected to potable or municipal water supply. Greywater irrigation must be applied by drip systems or flood irrigation in areas of good percolation rates. No spray applications are allowed in order to prevent greywater contamination from becoming airborne. Overall, the application of greywater to the landscape is a complex task because of the restrictions placed on irrigation techniques and locations. In addition, no commercial and industrial applications are allowed. (Kinkade-Levario 2004, 6-7)

Rainwater harvesting is another comparable option that provides supply of water that isn't regulated. This method also has the potential to augment municipal water supplies with little or no treatment. There are fewer restrictions placed rainwater harvesting as opposed to the greywater system. Rainwater can be surface applied for residential, commercial, or industrial landscape irrigation. (Kinkade-Levario 2004, 7)

A 100% on-site retention rate of rainwater that falls within the project boundaries is required in Arizona. (Kinkade-Levario 2004, 7) In order to accommodate the quantities of rainfall runoff, large landscape basins or underground storage systems must be provided by these developments. Harvesting and retaining the rainwater runoff in storage tanks for future potable and non-potable use during dry periods is the goal, rather than just permitting infiltration into the ground.



(Left) Heather Kinkade-Levario, *Gutter from metal roof transporting rainwater over walkway to an open-air cistern*, 31, JPEG

(Right) Heather Kinkade-Levario, *Commercial Rainchain*, 84, JPEG

Rainwater harvesting is a promising method that can be used in both residential and commercial building design. This method can help meet the need of a new development paradigm that is focused on environmental sensitivity and resource sustainability. (Kinkade-Levario 2004, 7) There are four levels of commitment to rainwater harvesting: Occasional, Intermittent, Partial, and Full. (Hartung 2002) Full commitment is typically for large storage capacity that provides all of the water needed by the user for the whole year. (Kinkade-Levario 2004, 30) This system requires strict monitoring and regulated use of water supply. This option is best for areas with no alternative water source.

Heather Kinkade-Levario, *Raincatching, shade-roviding, upside-down ubrellas in a central courtyard of multiple commercial office buildings*, 82, JPEG

In order to determine the appropriate water catchment surface area, programmatic constraints are applied to each canal intervention type. I've identified and researched the amount of water necessary to supply the demand created by the people who occupy and use the spaces of each intervention.

From these calculations I'm able to determine the roof catchment area required to catch and supply the water as well as the amount of water storage space.

Estimated Surface Runoff Efficiencies:

90% (0.90)	Smooth, impervious roof surfaces
80% (0.80)	Gravel Roof/Paved Surfaces
60% (0.60)	Treated Soil
30% (0.30)	Natural Soil

Estimated Catchment Area Required:

(Total Water Required/per day) / ((Annual Rainfall) x (0.623) x (Efficiency))
= Total Catchment Area (ft2)

Estimated Net Runoff from a Catchment Surface:

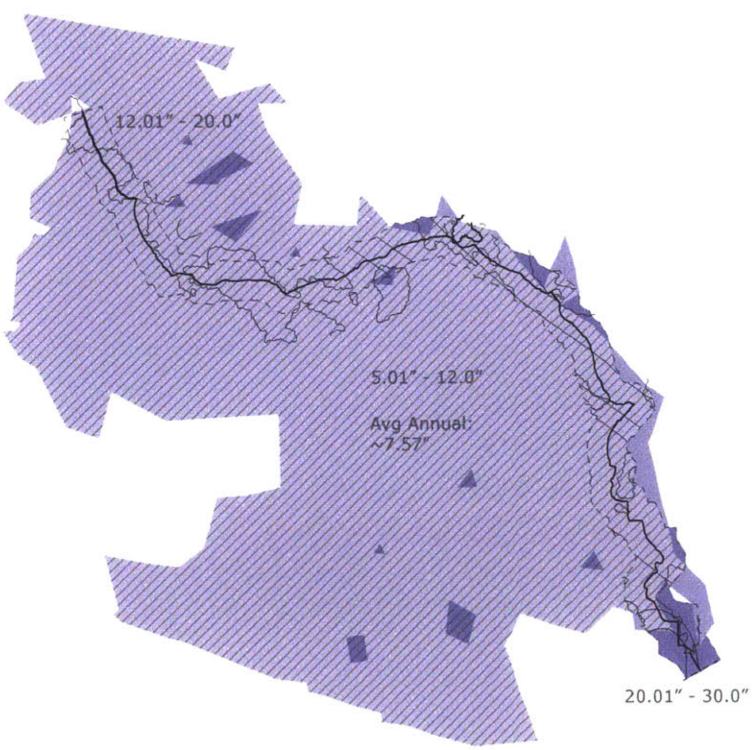
(Catchment Area) x (Rainfall) x (Surface Effiency) x (7.48)
= Catchment Runoff in Gallons

Estimated Water Storage (in Cubic Feet):

(Accumulative Storage (gal)) / (7.48 (gal/ft.3) = Storage (ft.3)

Avg. End-Use of Water (U.S.A.)			
Waste Disposal	70 - 95 l/p/d	18.50 - 25.10 gal/p/d	
Bathing	75 l/p/d	19.81 gal/p/d	
Drinking	5 l/p/d	1.32 gal/p/d	
Total	135 - 175 l/p/d	35.66 - 46.23 gal/p/d	≈ 13016 - 16874 gal/p/year

Basic Water Requirements			
Waste Disposal	20 l/p/d	5.28 gal/p/d	
Bathing	70 l/p/d	18.50 gal/p/d	
Drinking	5 l/p/d	1.32 gal/p/d	
Total	95 l/p/d	25.1 gal/p/d	≈ 9162 gal/p/year



Intervention Type 1: Farmers' Market Structure

Platform for exchange of farmed goods

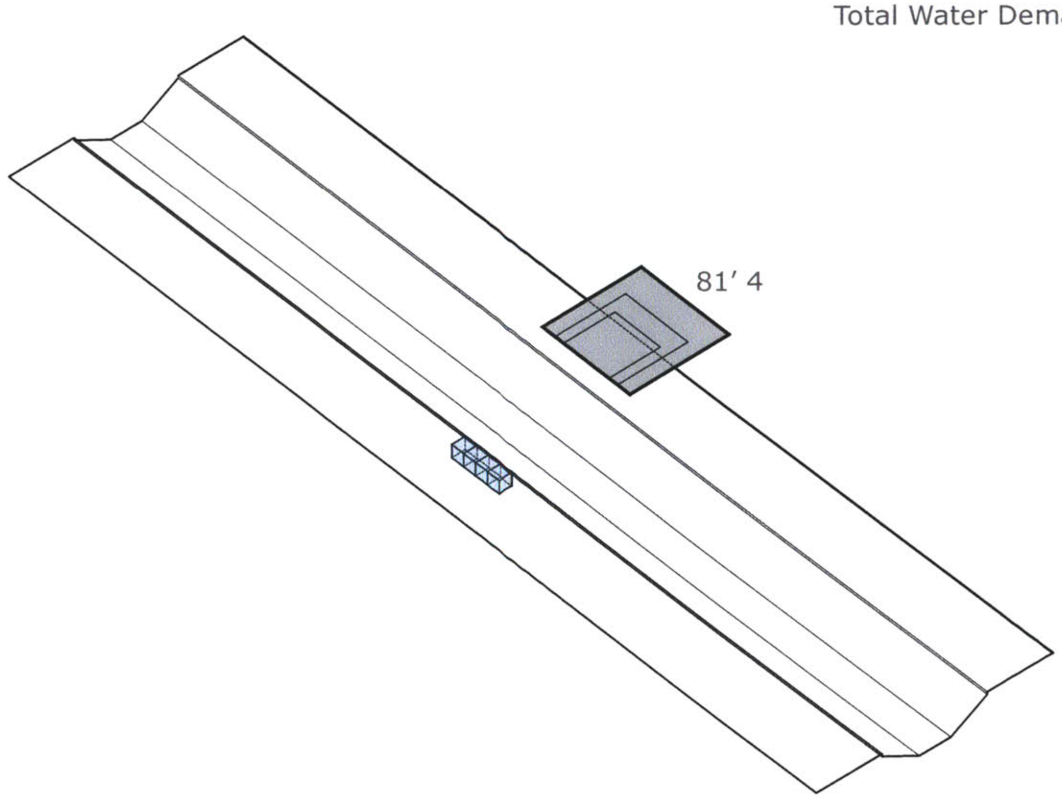
INTERVENTION TYPE 1: FARMERS' MARKET STRUCTURE

Programmatic Constraints and Water Calculations:

Basic Water Requirements (Restroom/Changing)			
Function	Quantity (liters/person/day)	Quantity (gallons/person/day)	Annual Quantity
Waste Disposal	20 l/p/d	5.28 gal/p/d	-
Bathing	70 l/p/d	18.50 gal/p/d	-
Total	90 l/p/d	23.78 gal/p/d	≈ 8680 gal/p/year

Basic Water Requirements (Drinking Water)			
Function	Quantity (liters/person/day)	Quantity (gallons/person/day)	Annual Quantity
Drinking	5 l/p/d	1.32 gal/p/d	-
Total	5 l/p/d	1.32 gal/p/d	≈ 482 gal/p/year

Total Water Demand



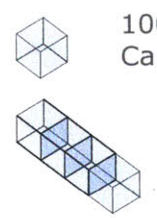
Annual Quantity Frequency @ 10 ppl/day	Annual Quantity Frequency @ 20 ppl/day	Annual Quantity Frequency @ 40 ppl/day
-	-	-
-	-	-
≈ 86800 gal/year	≈ 173600 gal/year	≈ 347200 gal/year

Annual Quantity Frequency @ 10 ppl/day	Annual Quantity Frequency @ 20 ppl/day	Annual Quantity Frequency @ 40 ppl/day
-	-	-
≈ 4820 gal/year	≈ 9640 gal/year	≈ 19280 gal/year

≈ 91620 gal/year	≈ 183240 gal/year	≈ 366480 gal/year

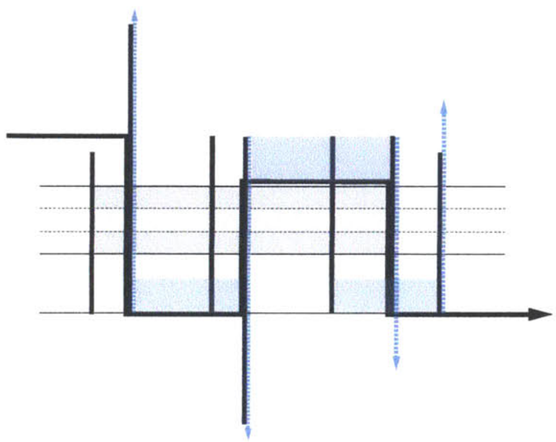
Total Estimated
Catchment Area:
≈ 6613 ft2

Total Estimated
Water Storage:
3749 (ft3)

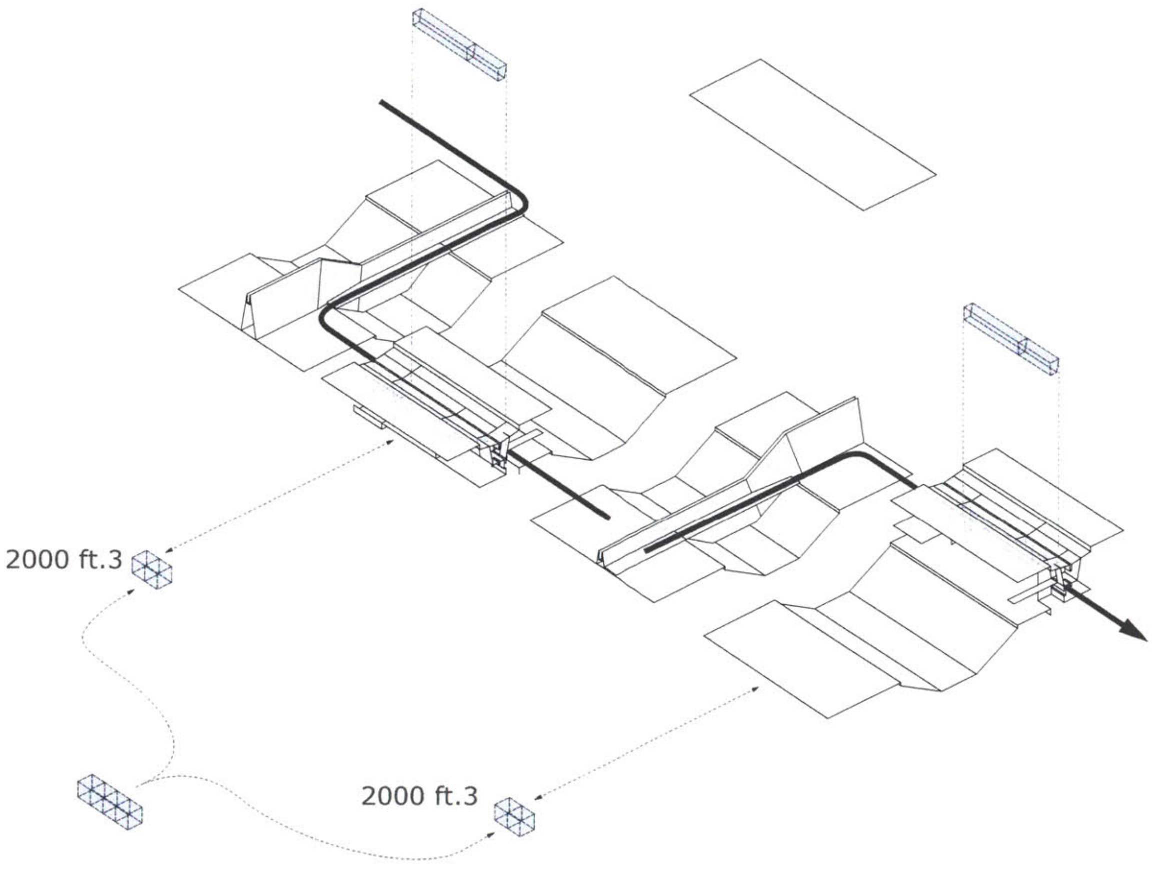


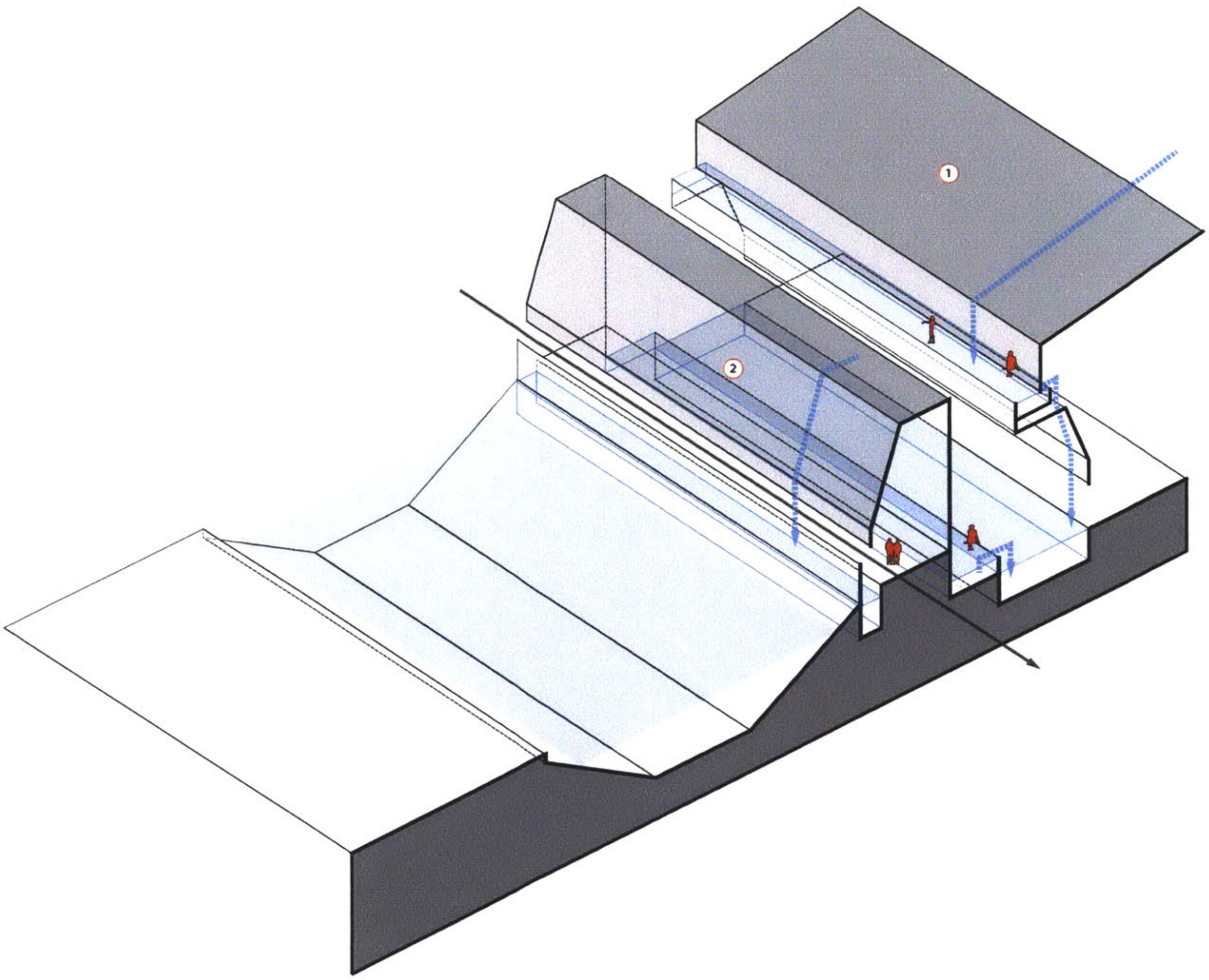
1000 ft.3
Capacity

INTERVENTION TYPE 1: FARMERS' MARKET STRUCTURE



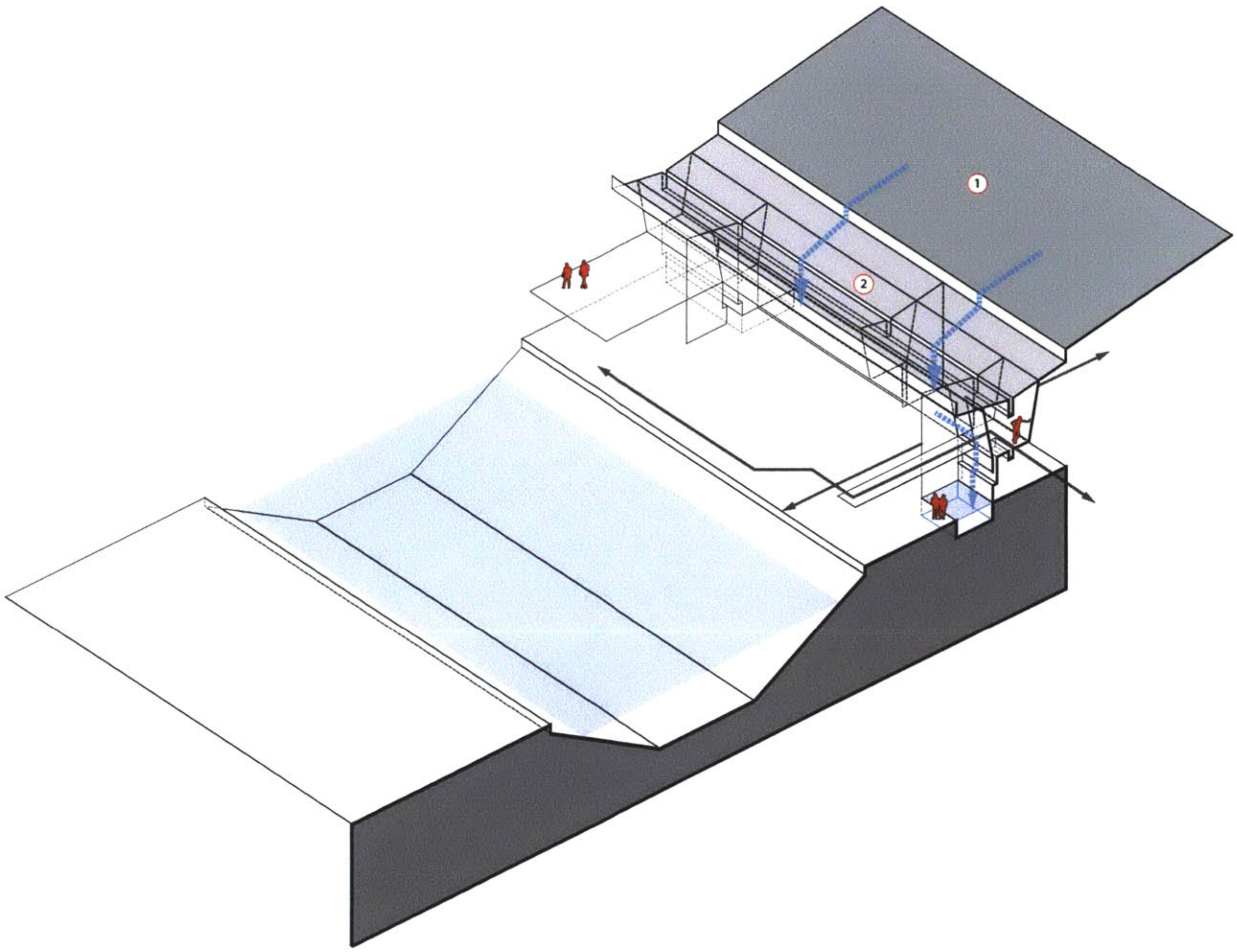
After calculating approximate water catchment surface are and water storage space, I'm taking volumes of water adjusting and stretching them to become architectural forms.

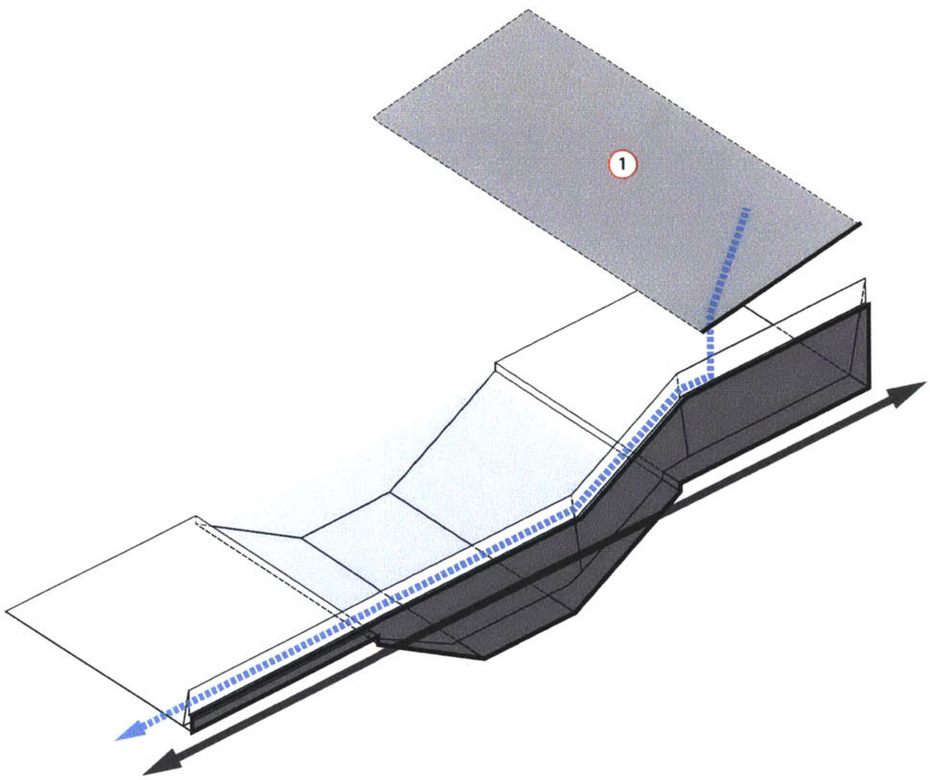



1
2

INTERVENTION TYPE 1: FARMERS' MARKET STRUCTURE

Through sectional investigation, I'm designing ways of combining spatial moments around water catchment, and storage, as well as the interaction of people and space.

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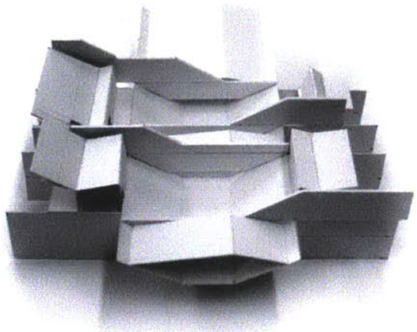
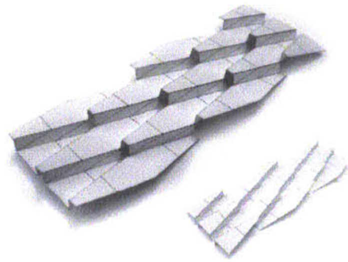
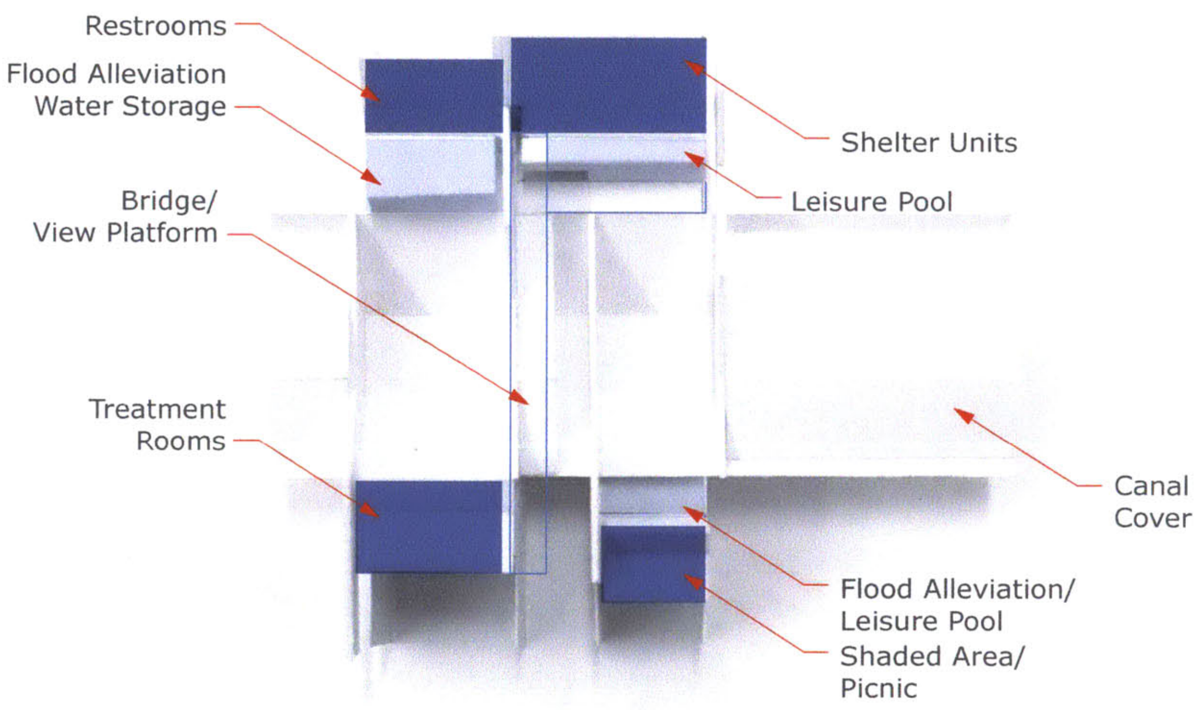
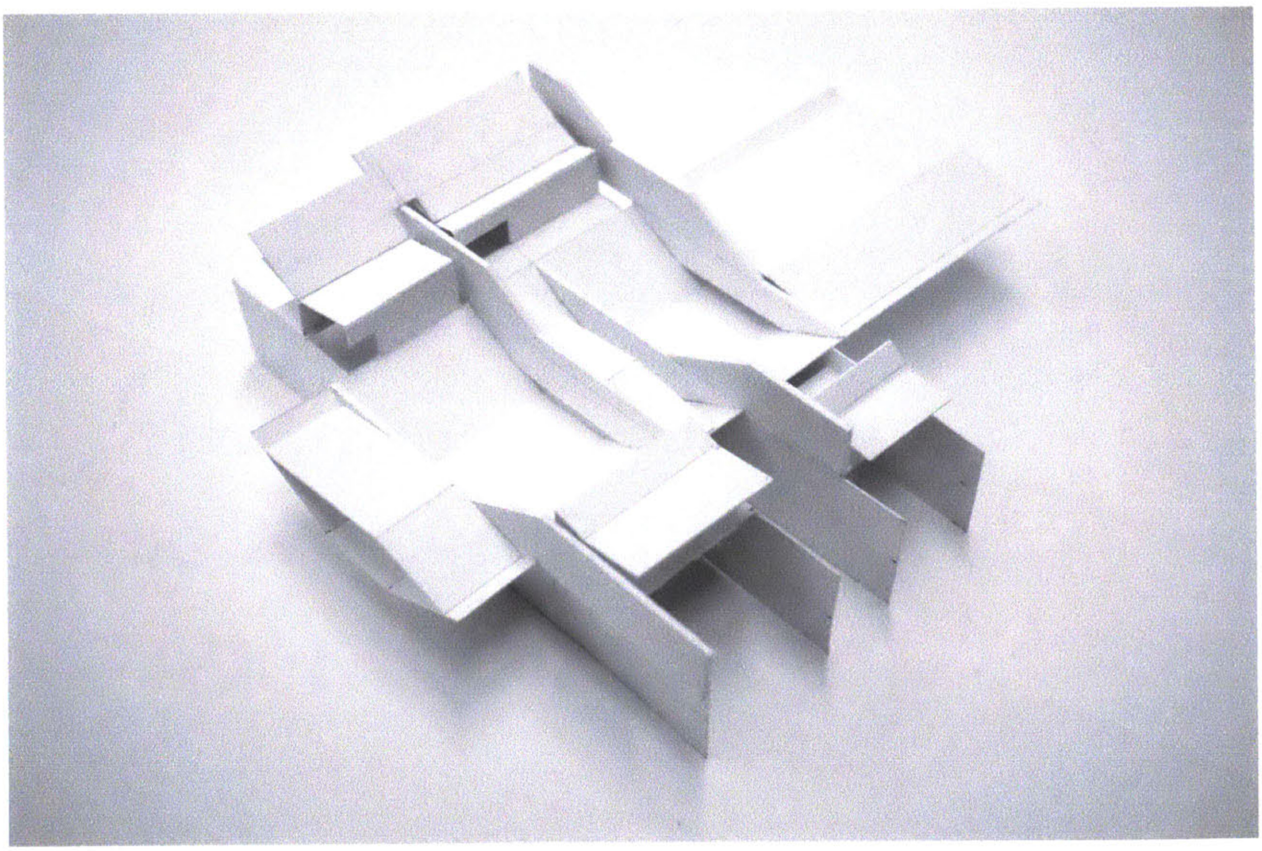
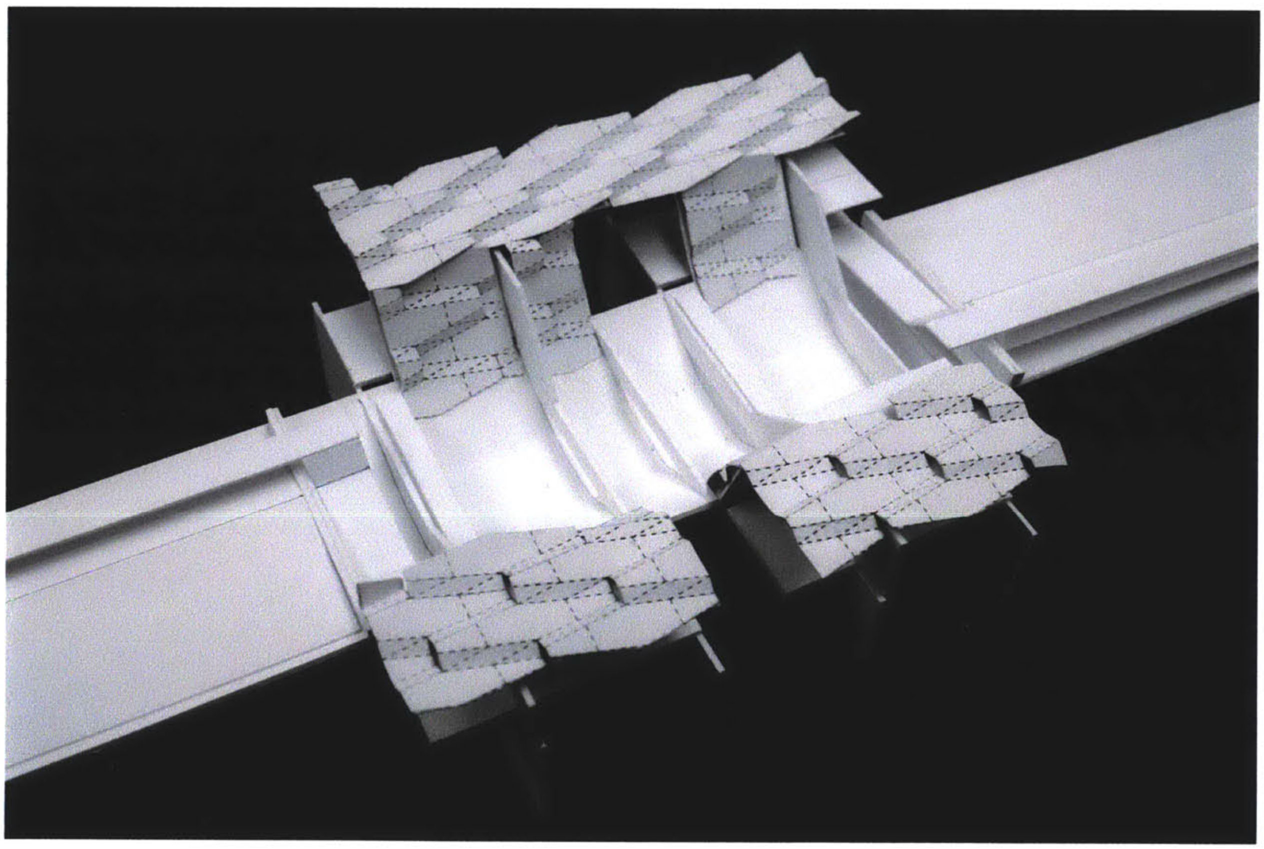
INTERVENTION TYPE 1: FARMERS' MARKET STRUCTURE



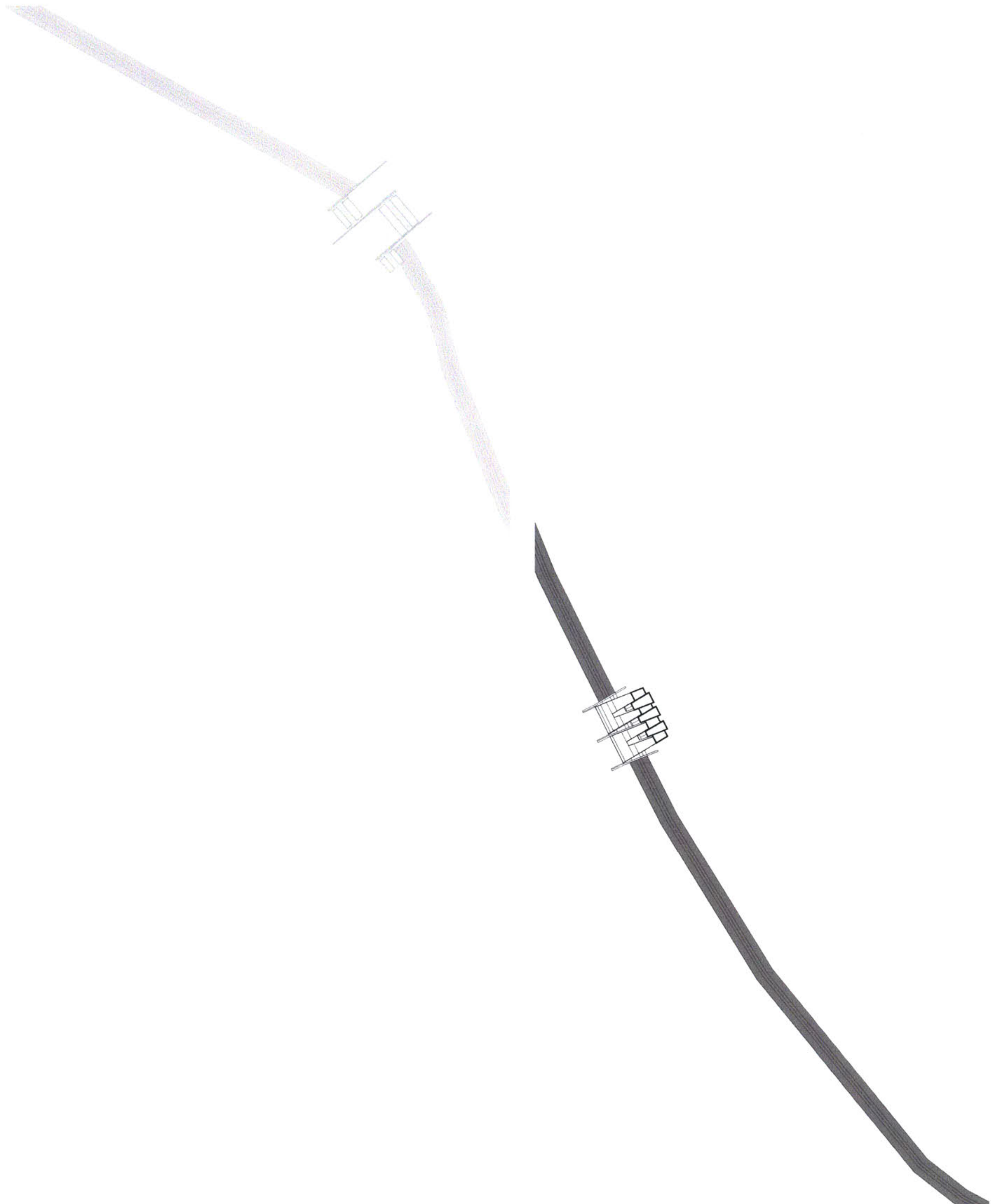








Iteration 2:
Physical model with surface articulation applied



Intervention Type 2: Oasis/Rest Pavilion

Shelter and rejuvenation point for hikers, bicyclists, and pedestrians

INTERVENTION TYPE 2: OASIS/REST PAVILION

Programmatic Constraints and Water Calculations:

Basic Water Requirements (Restroom)			
Function	Quantity (liters/person/day)	Quantity (gallons/person/day)	Annual Quantity
Waste Disposal	20 l/p/d	5.28 gal/p/d	-
Total	20 l/p/d	5.28 gal/p/d	≈ 275 gal/p/year

Basic Water Requirements (Drinking Water)			
Function	Quantity (liters/person/day)	Quantity (gallons/person/day)	Annual Quantity
Drinking	5 l/p/d	1.32 gal/p/d	-
Total	5 l/p/d	1.32 gal/p/d	≈ 69 gal/p/year

Basic Water Requirements (Floor Flushing)			
Function	Quantity (liters/day)	Quantity (gallons/person/day)	Annual Quantity (once/week)
Flush	38 l/day	10 gal/d	-
Total	38 l/day	10 gal/d	≈ 520 gal/year

Total Water Demand

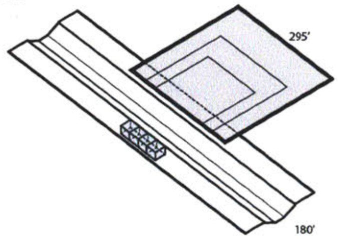
Annual Quantity Frequency @ 20 ppl/week	Annual Quantity Frequency @ 40 ppl/week	Annual Quantity Frequency @ 80 ppl/week
-	-	-
≈ 5500 gal/year	≈ 11000 gal/year	≈ 22000 gal/year

Annual Quantity Frequency @ 20 ppl/week	Annual Quantity Frequency @ 40 ppl/week	Annual Quantity Frequency @ 80 ppl/week
-	-	-
≈ 1380 gal/year	≈ 2760 gal/year	≈ 5520 gal/year

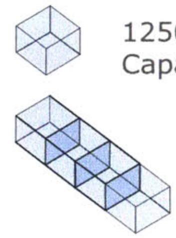
≈ 7400 gal/year	≈ 14280 gal/year	≈ 28040 gal/year

INTERVENTION TYPE 2: OASIS/REST PAVILION

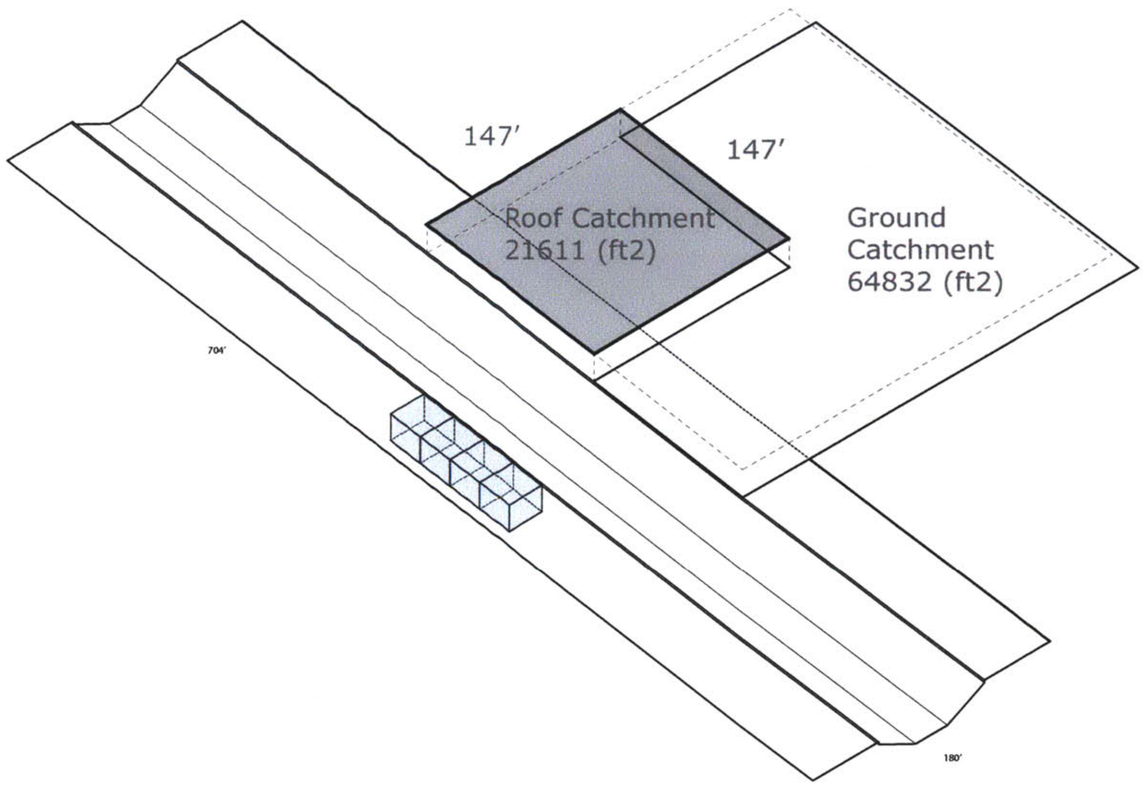
Total Estimated
Catchment Area:
≈ 86444 ft2



Total Estimated
Water Storage:
50000 (ft3)



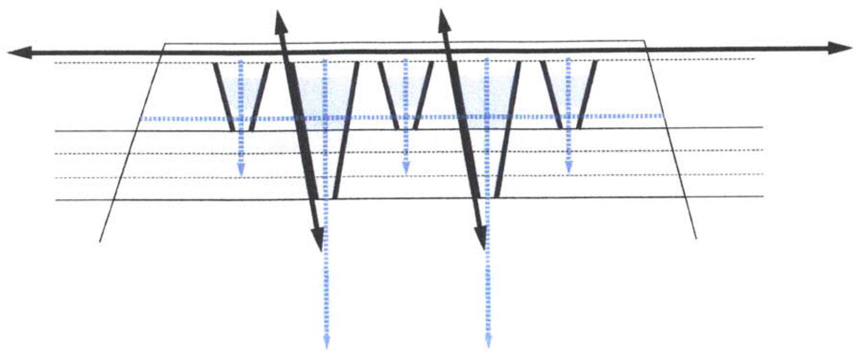
12500 ft.3
Capacity

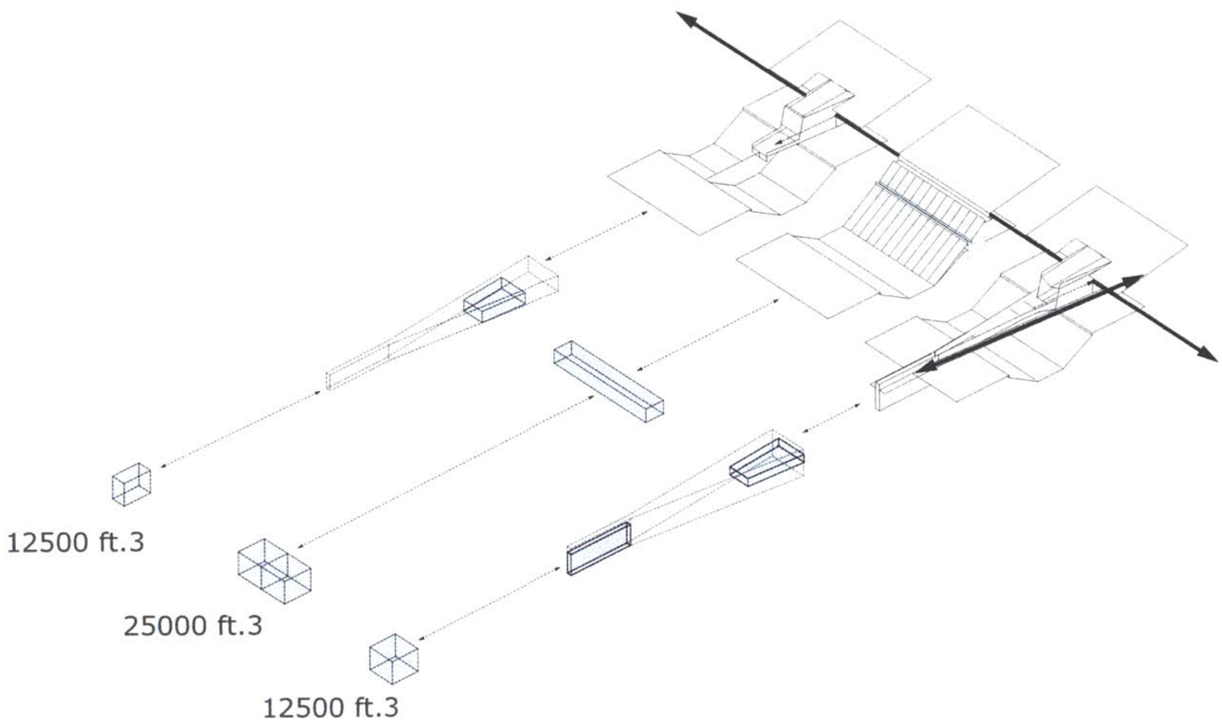


Estimated Catchment Area Required:

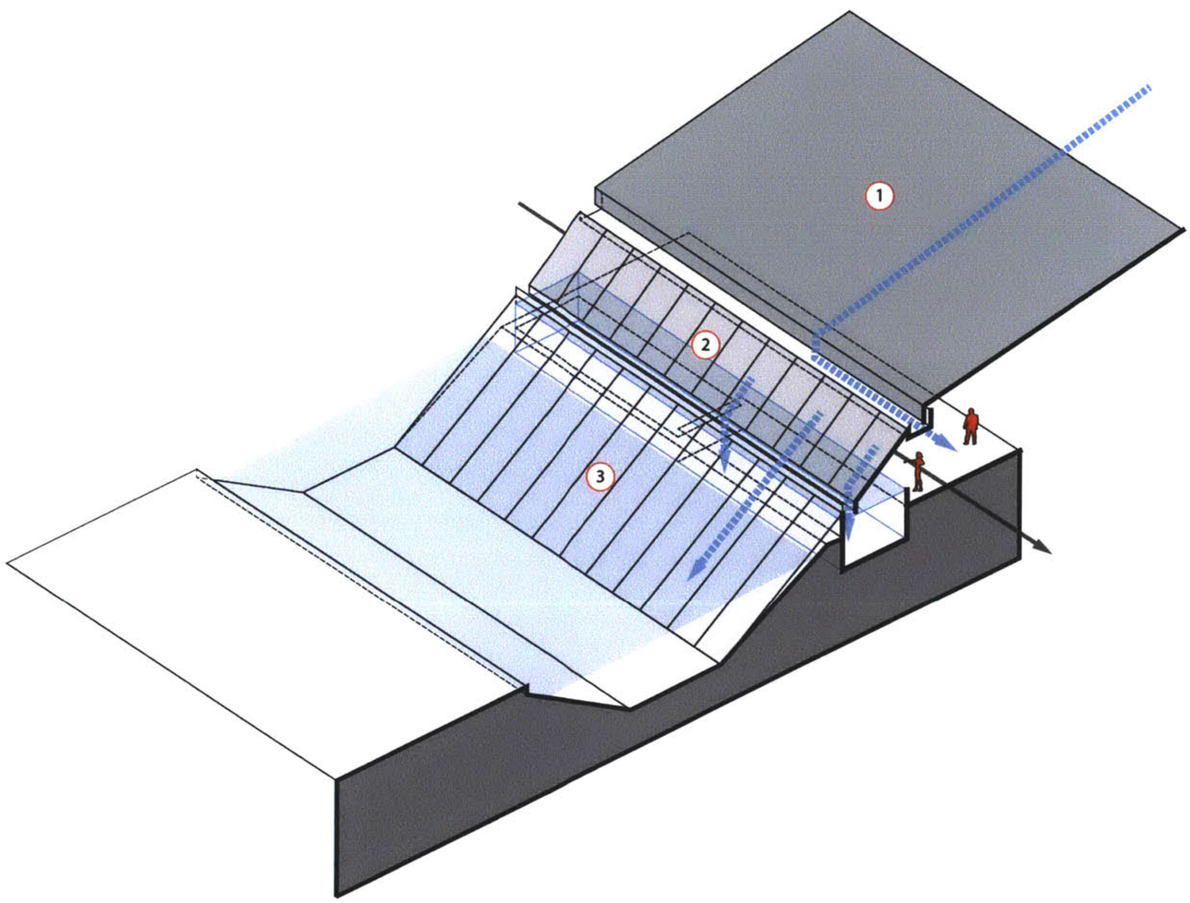
For Roof Catchment at 90% efficiency:
366480 gal / (7.57 x 0.623 x 0.90) = 77644 (ft2)
366480 gal / 4.24 = 86444 (ft2)
86444 (ft2) / 4 = 21611 (ft2)

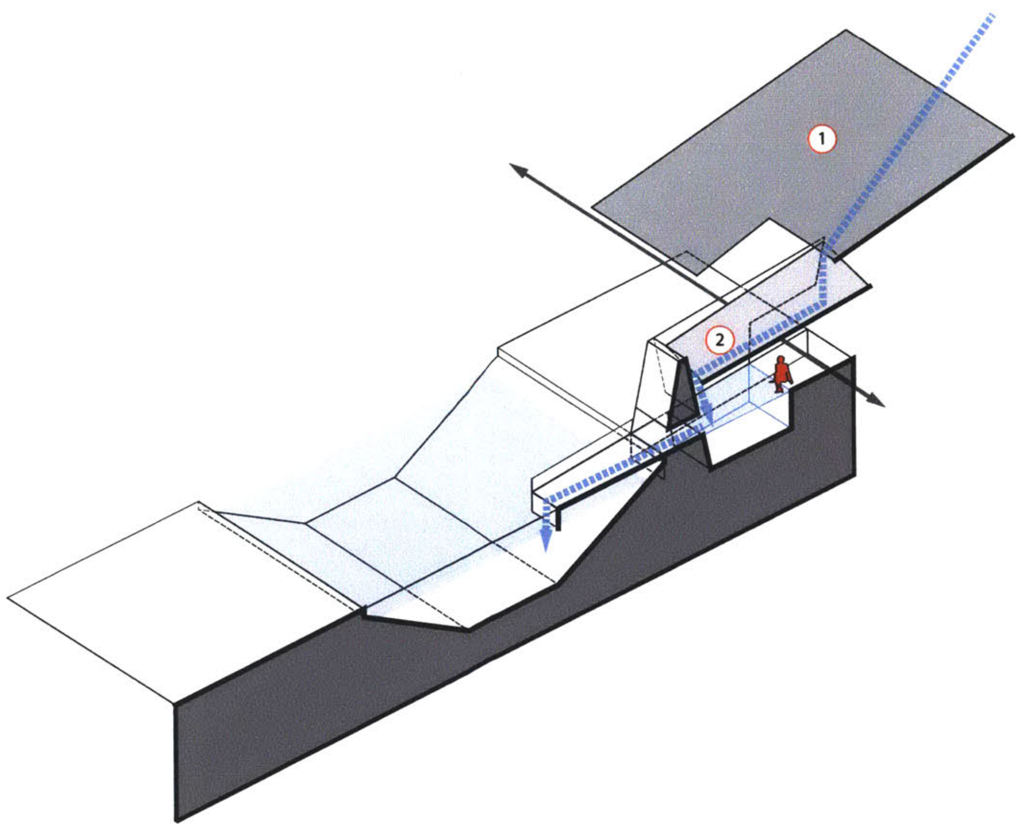
For Ground Catchment at 80% efficiency:
244415 gal / (7.57 x 0.623 x 0.80) = 77644 (ft2)
244415 gal / 3.77 = 64832 (ft2)



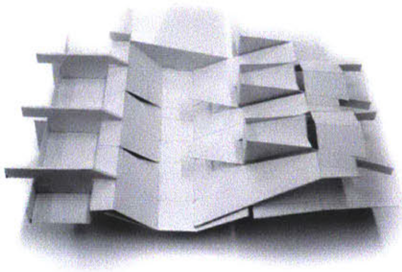

12500 ft.3
25000 ft.3
12500 ft.3

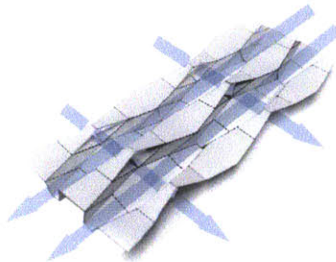
INTERVENTION TYPE 2: OASIS/REST PAVILION

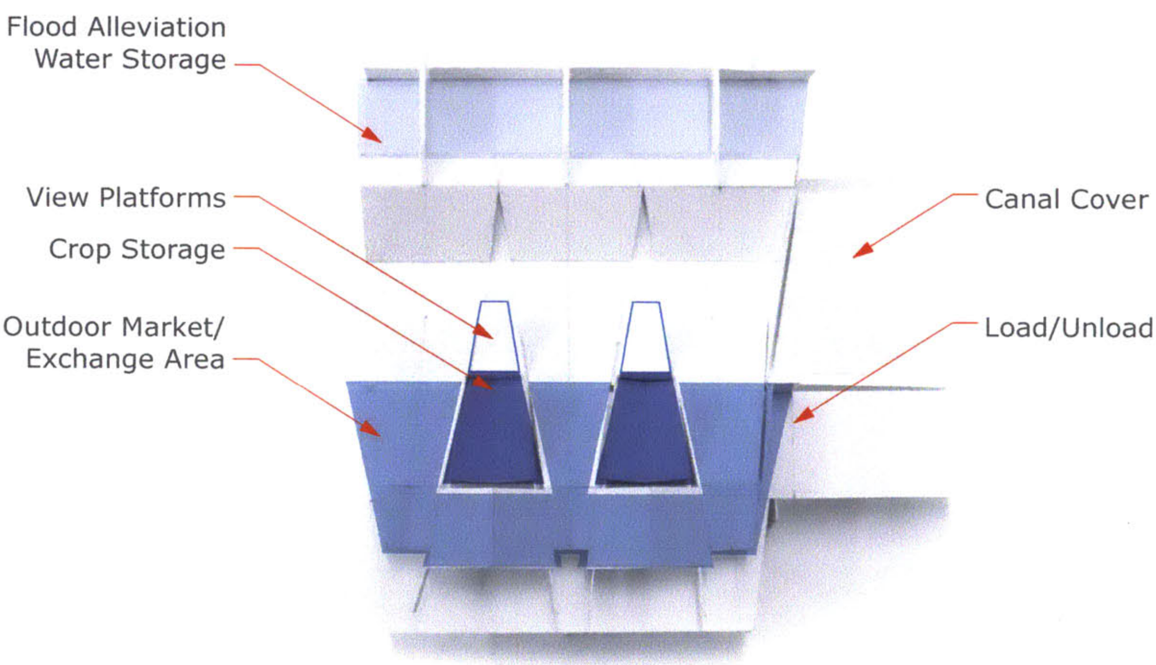


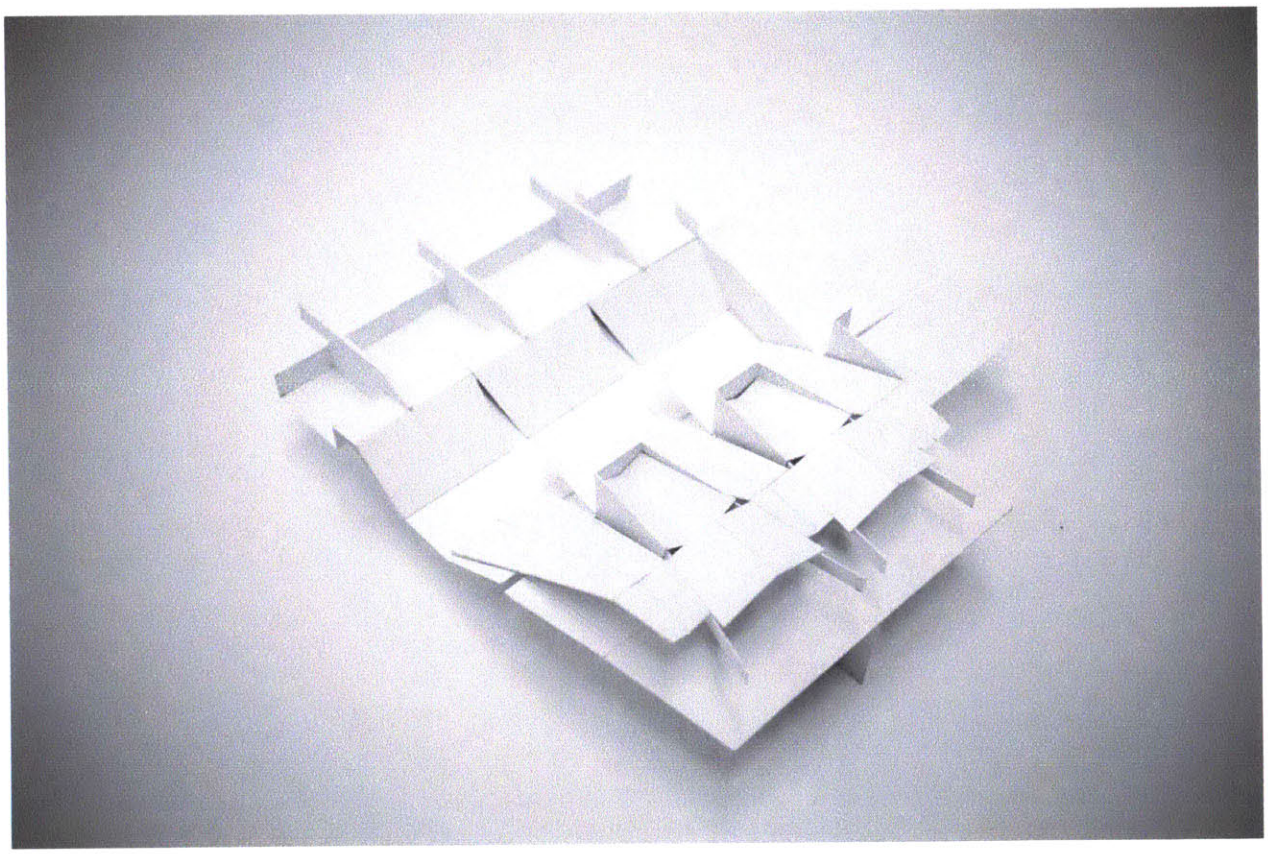

1
2

INTERVENTION TYPE 2: OASIS/REST PAVILION

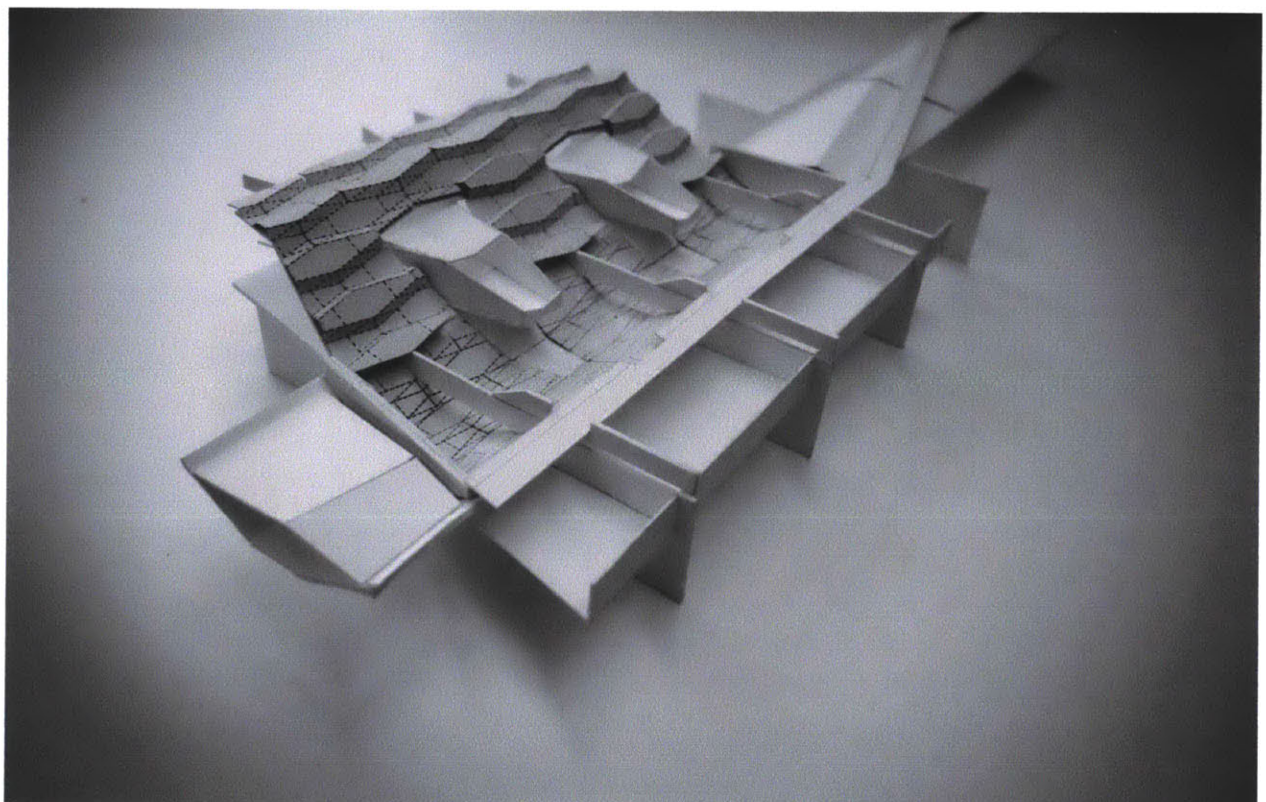




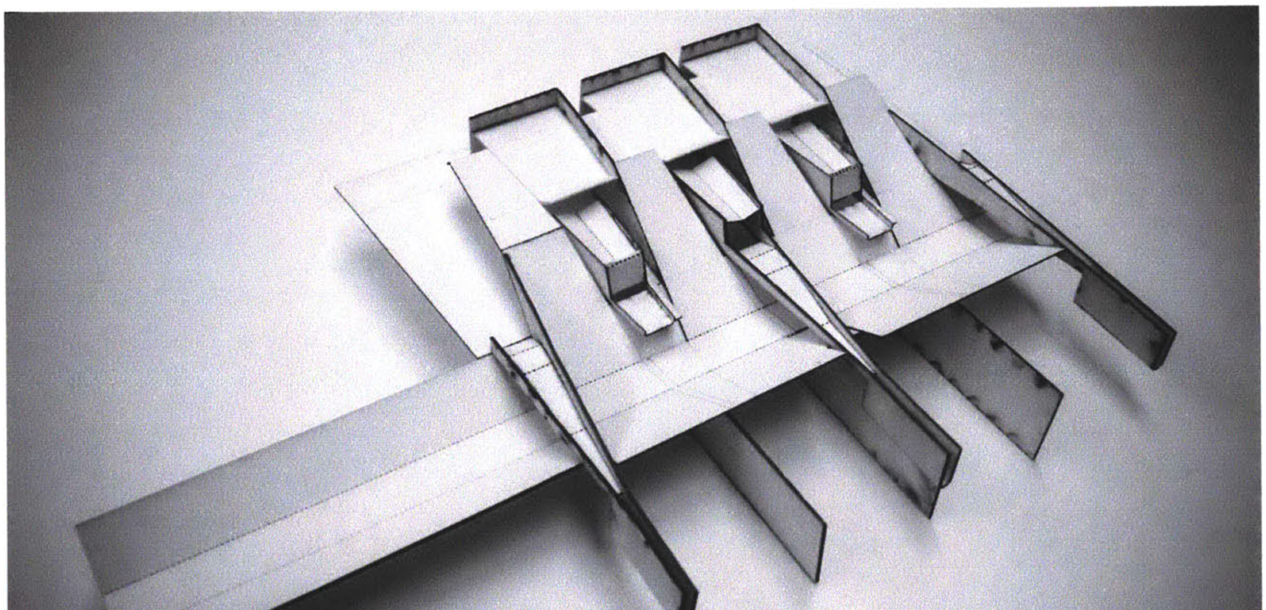




Iteration 1:
Physical Model

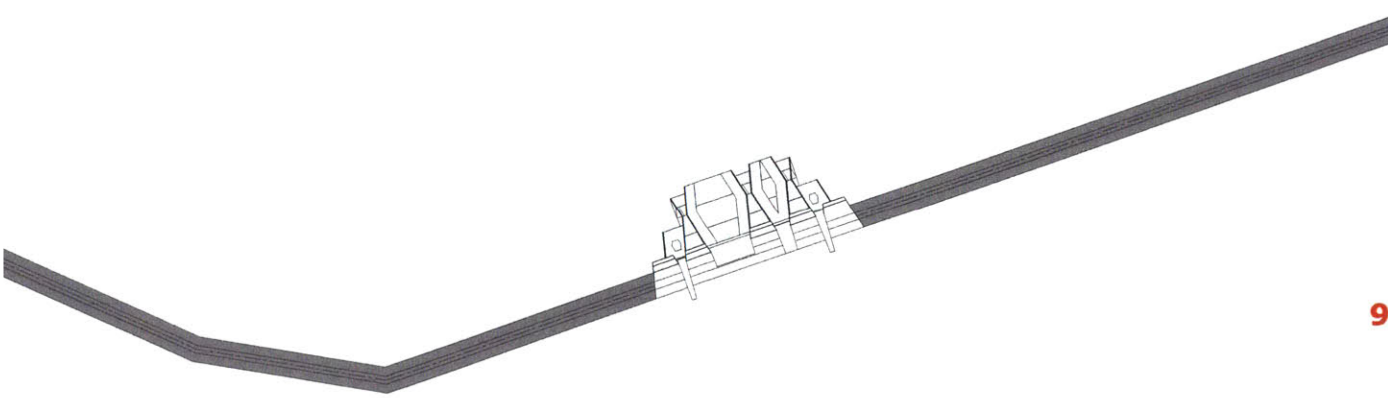


Iteration 2:
Physical model with surface articulation applied


Iteration 3:
Physical model with adjusted catchment surface areas

Intervention Type 3: Bio-Pool Spa

Building form that combines the act of swimming with the act of collecting and cleansing water.



INTERVENTION TYPE 3: BIO-POOL SPA

Pools and Community: The Bio-pool spa

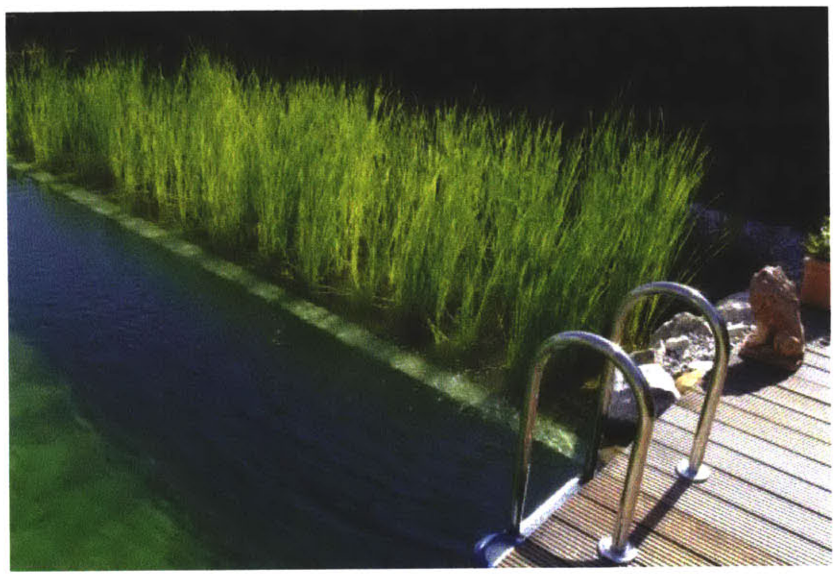
A series of pools are beneficial to the society as mini reservoirs that are able to collect and store rainwater. The pool can serve as a reservoir and emergency container of water in time of severe drought.

The source of water for pools typically comes from municipal water supply. However, rainwater collected can be filtered and placed in the pool instead of using the municipal supply. When using water from a rainwater tank, the pool should be disinfected to 1mg/L of free residual chlorine respectively for at least half an hour and the pH should be about 7.5. The pumps and filters should be operating during the disinfection period prior to swimming or bathing.

Economy of Pool:

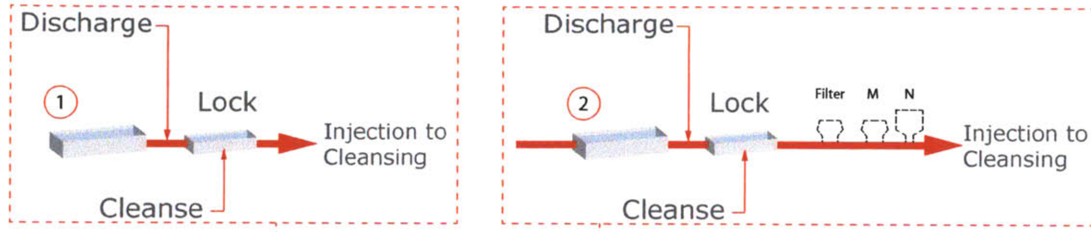
Pools play a big role in contributing billions of dollars to the economy. In the current economy, the community can benefit from this facility. Once the economy recovers, the price of this type of facility for the community will skyrocket. Property value will increase; as a result there will be higher demand in the area.

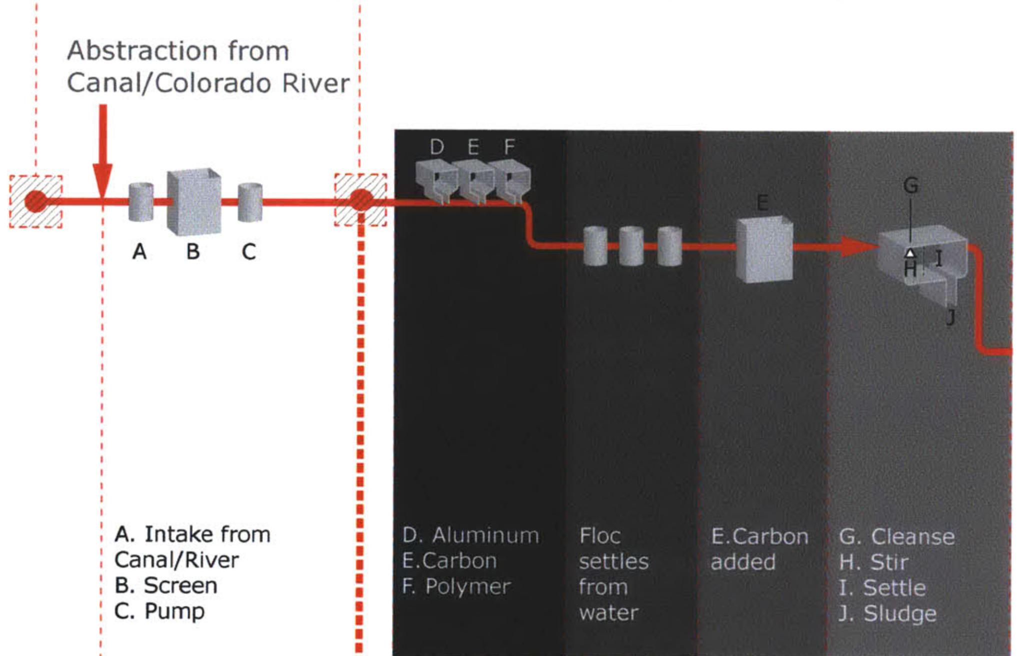
This diagram illustrates the cleansing process and stages that water goes through in order to be prepared

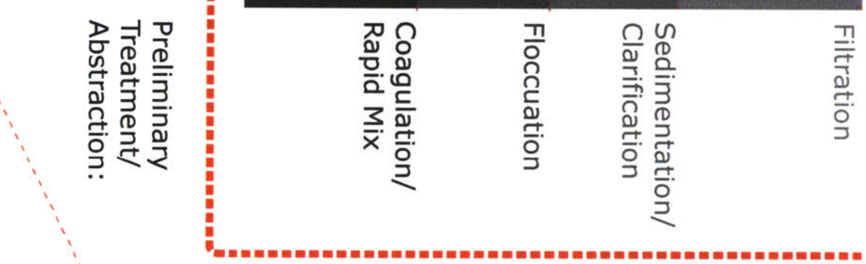


Tauchner, Bio-pool, JPEG, http://www.tauchner.at/biopool-pflanzenwachstum (accessed October, 11, 2011)

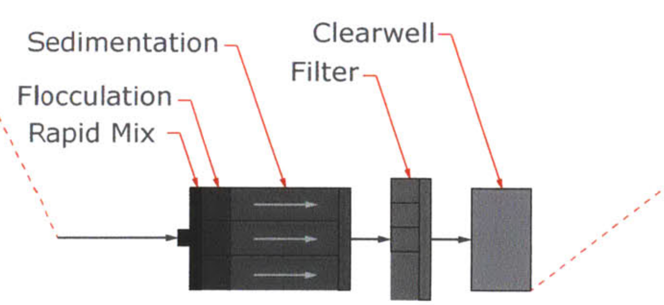
INTERVENTION TYPE 3: BIO-POOL SPA







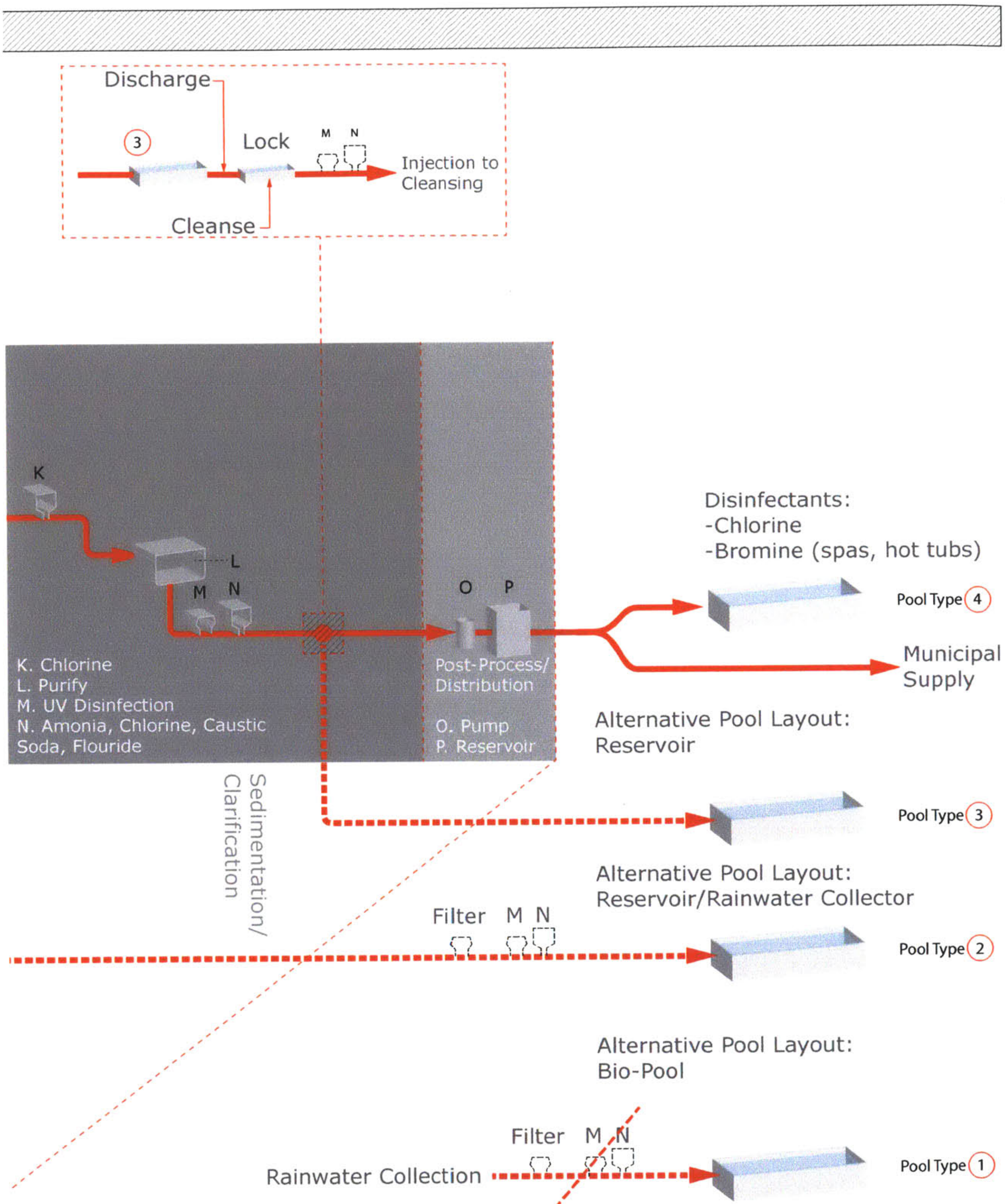
for public and municipal use. Pools, to be used for recreation, are inserted along the linear cleansing process. Water from the treatment can be taken, temporarily out of the process, and injected into pools.
Afterwards, the water is discharged and fed back into the treatment process.



Linear Plant Layout

Design:

The form of the final itera-


Discharge
3
Lock
M N
Injection to Cleansing
Cleanse
K
L
M N
O P
K. Chlorine
L. Purify
M. UV Disinfection
N. Amonia, Chlorine, Caustic Soda, Flouride
Post-Process/ Distribution
O. Pump
P. Reservoir
Sedimentation/ Clarification
Disinfectants:
-Chlorine
-Bromine (spas, hot tubs)
Pool Type 4
Municipal Supply
Alternative Pool Layout: Reservoir
Pool Type 3
Alternative Pool Layout: Reservoir/Rainwater Collector
Filter M N
Pool Type 2
Alternative Pool Layout: Bio-Pool
Filter M N
Rainwater Collection
Pool Type 1

Programmatic Constraints and Water Calculations:

Basic Water Requirements (Restroom/Changing)			
Function	Quantity (liters/person/day)	Quantity (gallons/person/day)	Annual Quantity
Waste Disposal	20 l/p/d	5.28 gal/p/d	-
Bathing	70 l/p/d	18.50 gal/p/d	-
Total	90 l/p/d	23.78 gal/p/d	≈ 8680 gal/p/year

Basic Water Requirements (Drinking Water)			
Function	Quantity (liters/person/day)	Quantity (gallons/person/day)	Annual Quantity
Drinking	5 l/p/d	1.32 gal/p/d	-
Total	5 l/p/d	1.32 gal/p/d	≈ 482 gal/p/year

Basic Water Requirements (Cafe)			
Function	Quantity (liters/person/day)	Quantity (gallons/person/day)	Annual Quantity
Cafe	11 l/p/d	3 gal/p/d	-
Total	11 l/p/d	3 gal/p/d	≈ 1056 gal/p/year

Basic Water Requirements (Pool Types)			
Function	Quantity (liters)	Quantity (gallons)	Annual Quantity
Pool Type 1	250774 l	66000 gal	-
Pool Type 2	57087 l	15080 gal	
Pool Type 3	174432 l	46080 gal	
Pool Type 4	250774 l	66000 gal	
Total	7330674 l	193160 gal	≈ 193160 gal/year

Total Water Demand

Annual Quantity Frequency @ 10 ppl/day	Annual Quantity Frequency @ 20 ppl/day	Annual Quantity Frequency @ 40 ppl/day
-	-	-
-	-	-
≈ 86800 gal/year	≈ 173600 gal/year	≈ 347200 gal/year

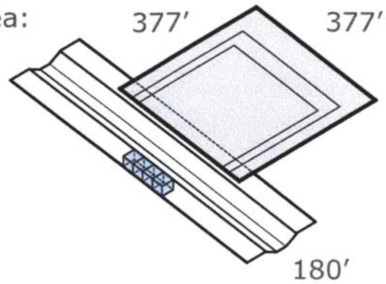
Annual Quantity Frequency @ 10 ppl/day	Annual Quantity Frequency @ 20 ppl/day	Annual Quantity Frequency @ 40 ppl/day
-	-	-
≈ 4820 gal/year	≈ 9640 gal/year	≈ 19280 gal/year

Annual Quantity Frequency @ 10 ppl/day	Annual Quantity Frequency @ 20 ppl/day	Annual Quantity Frequency @ 40 ppl/day
-	-	-
≈ 10560 gal/year	≈ 21120 gal/year	≈ 42240 gal/year

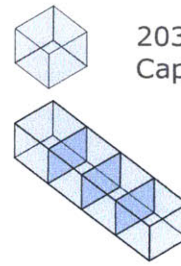
+ 193160 gal/year	+ 193160 gal/year	+ 193160 gal/year
≈ 295340 gal/year	≈ 397520 gal/year	≈ 601880 gal/year

INTERVENTION TYPE 3: BIO-POOL SPA

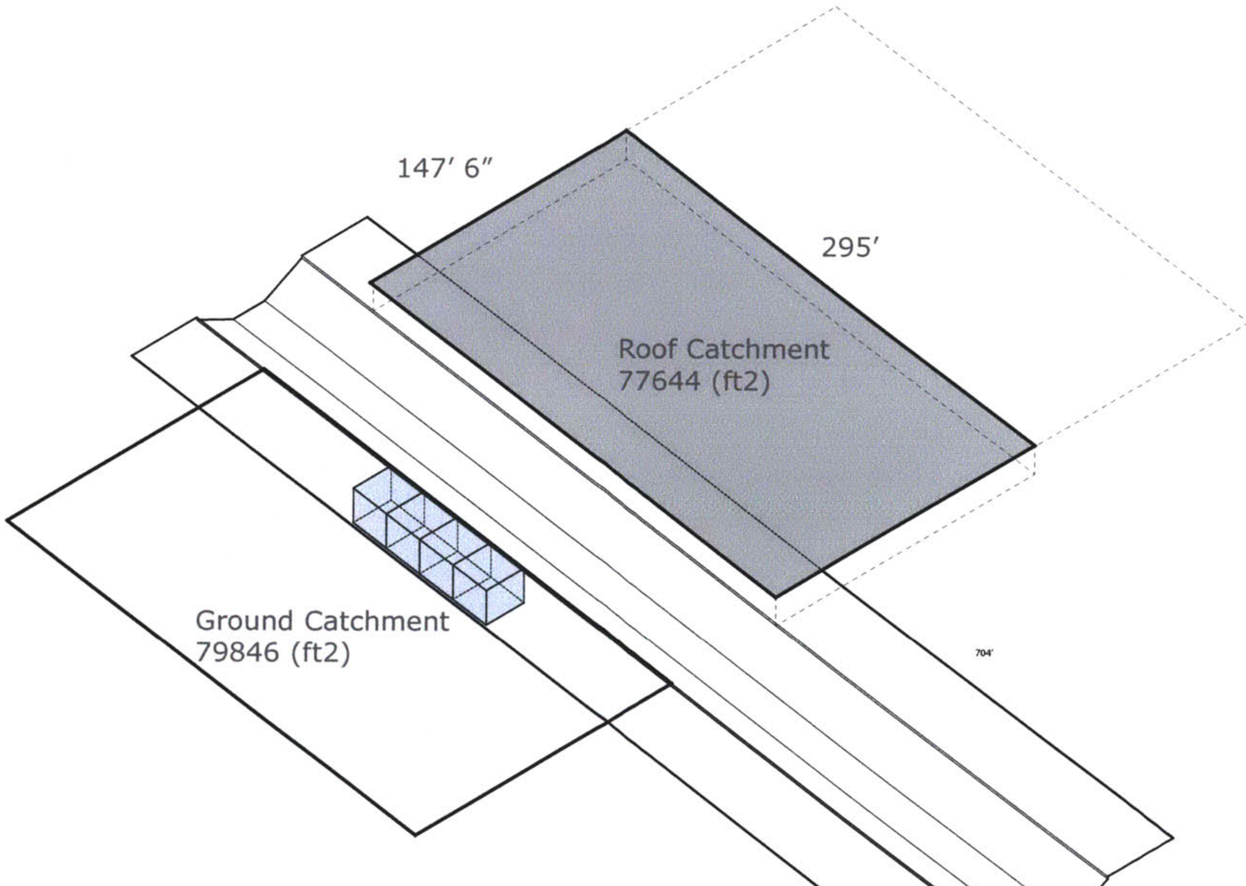
Total Estimated
Catchment Area:
≈ 141953 ft2



Total Estimated
Water Storage:
80465 (ft3)



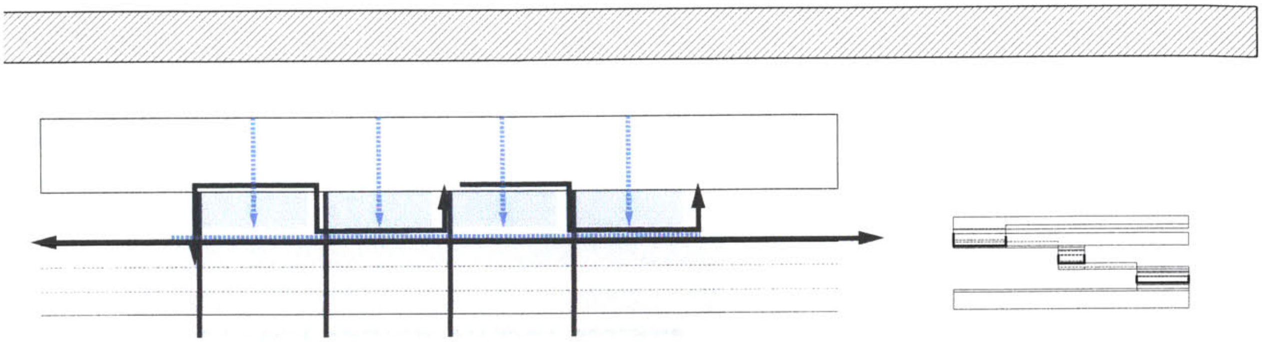
20384 ft.3
Capacity

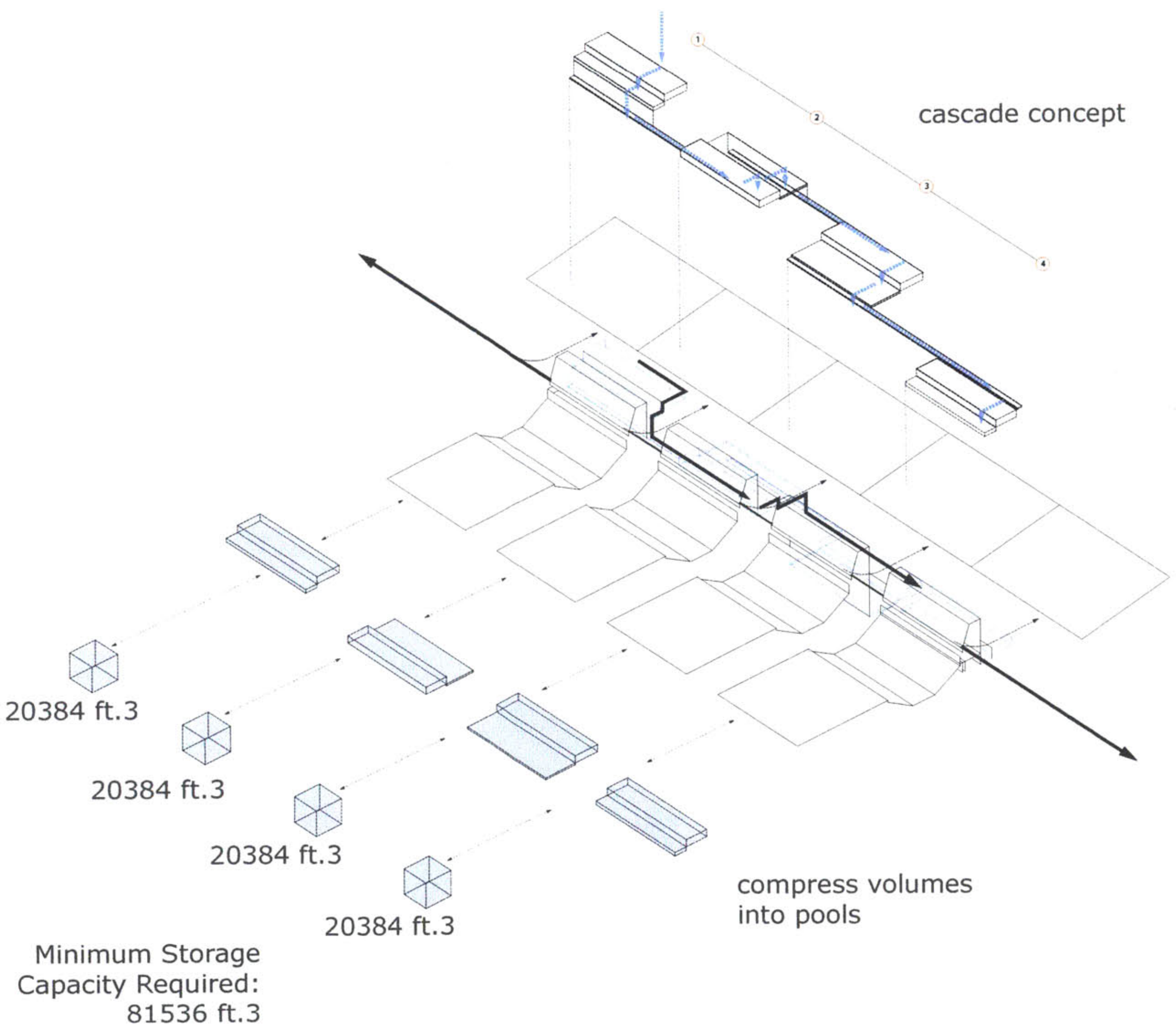


Estimated Roof Catchment and Ground Catchment:

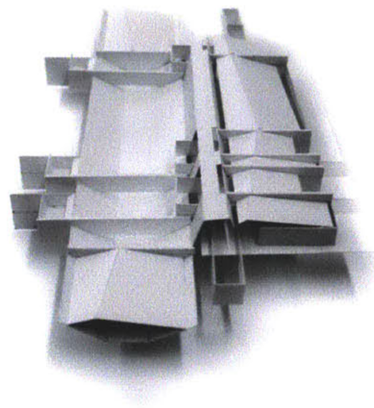
For Roof Catchment at 90% efficiency:
601880 gal / (7.57 x 0.623 x 0.90) = 77644 (ft2)
601880 gal / 4.24 = 141953(ft2)
86444 (ft2) / 2 = 70976 (ft2)

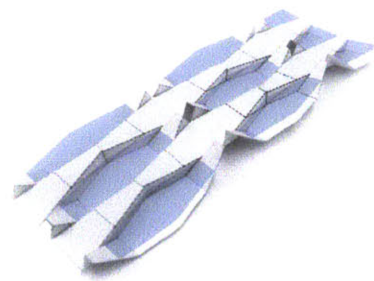
For Ground Catchment at 80% efficiency:
301021 gal / (7.57 x 0.623 x 0.80) =
301021 gal / 3.77 = 48624(ft2) = 79846 (ft2)

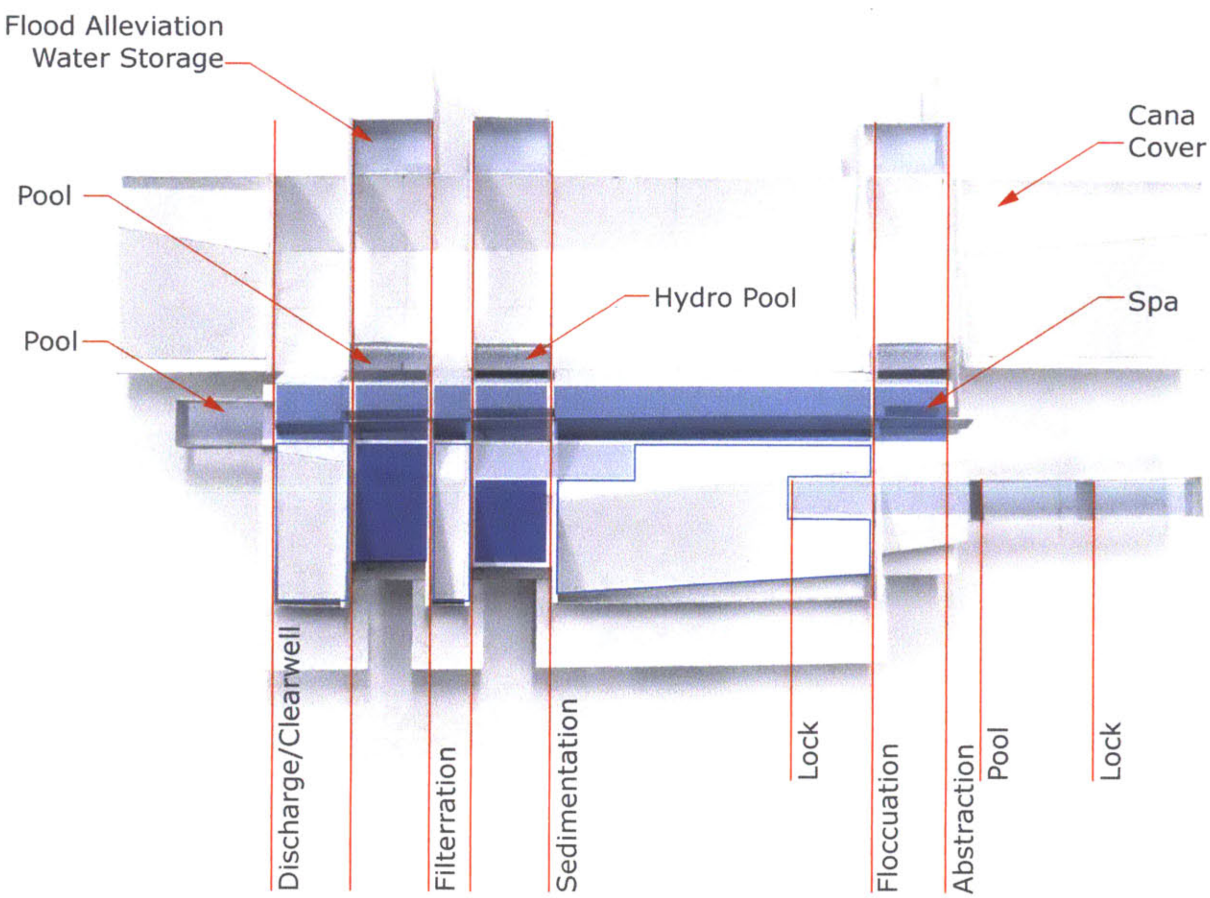



cascade concept
20384 ft.3
20384 ft.3
20384 ft.3
20384 ft.3
compress volumes
into pools
Minimum Storage
Capacity Required:
81536 ft.3

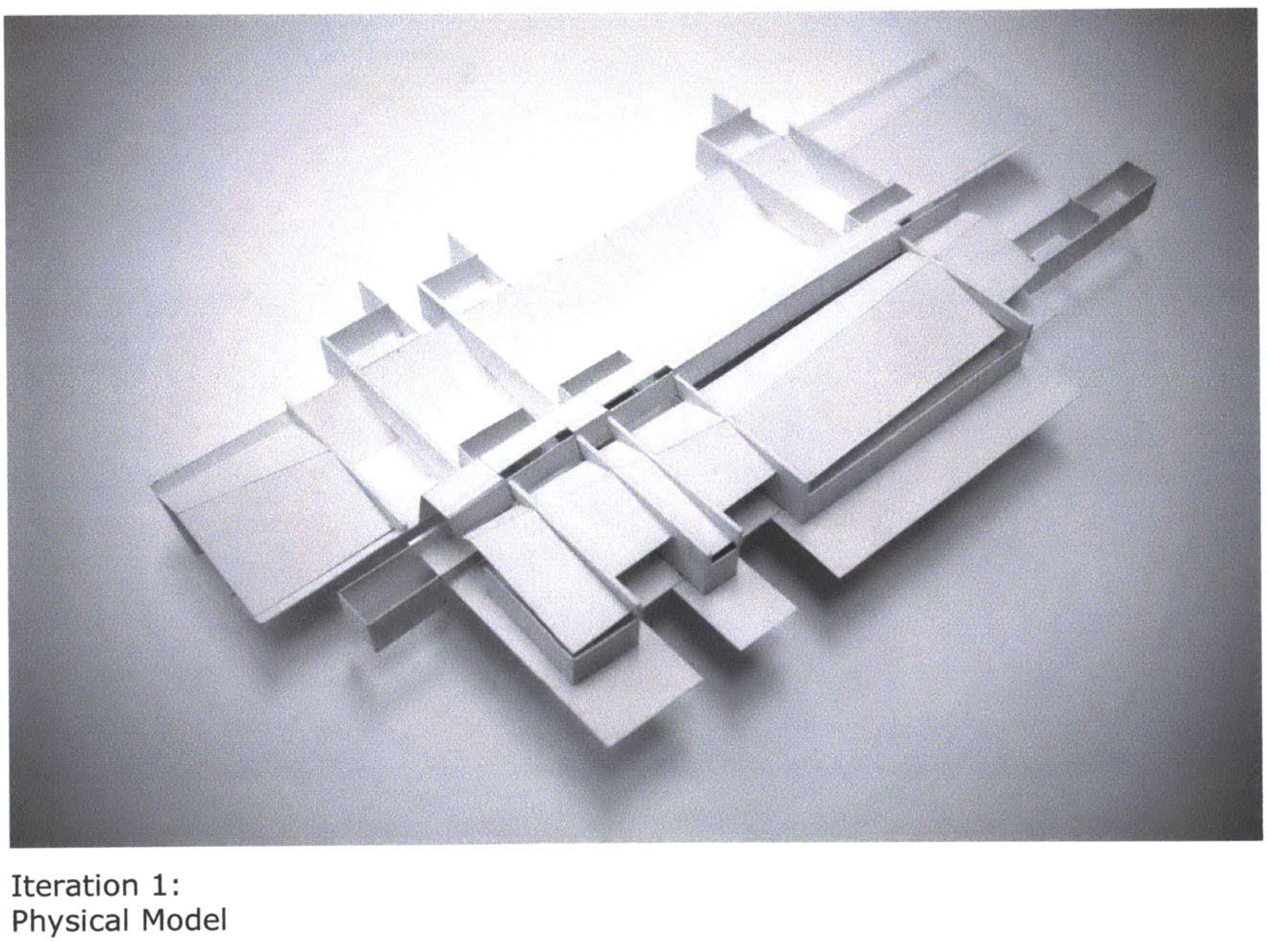
INTERVENTION TYPE 3: BIO-POOL SPA



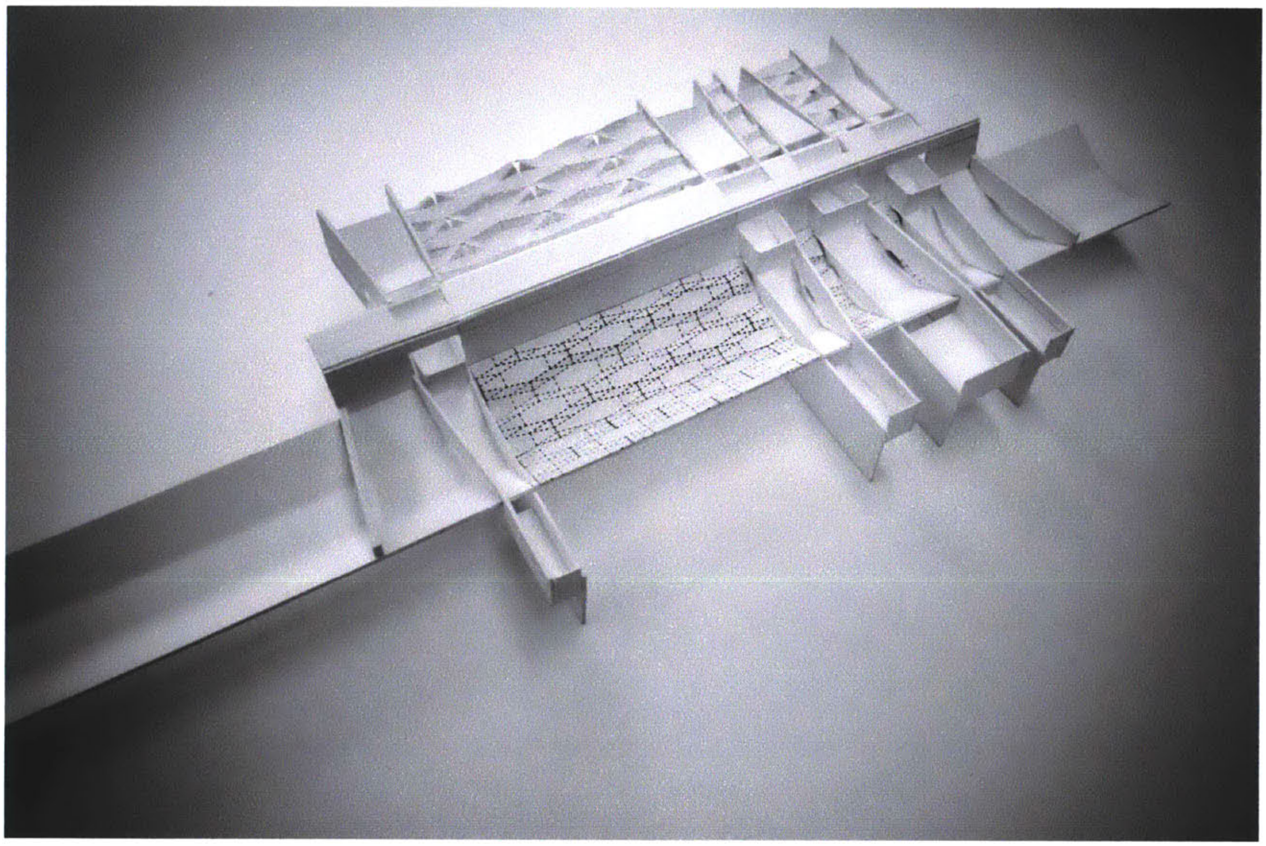




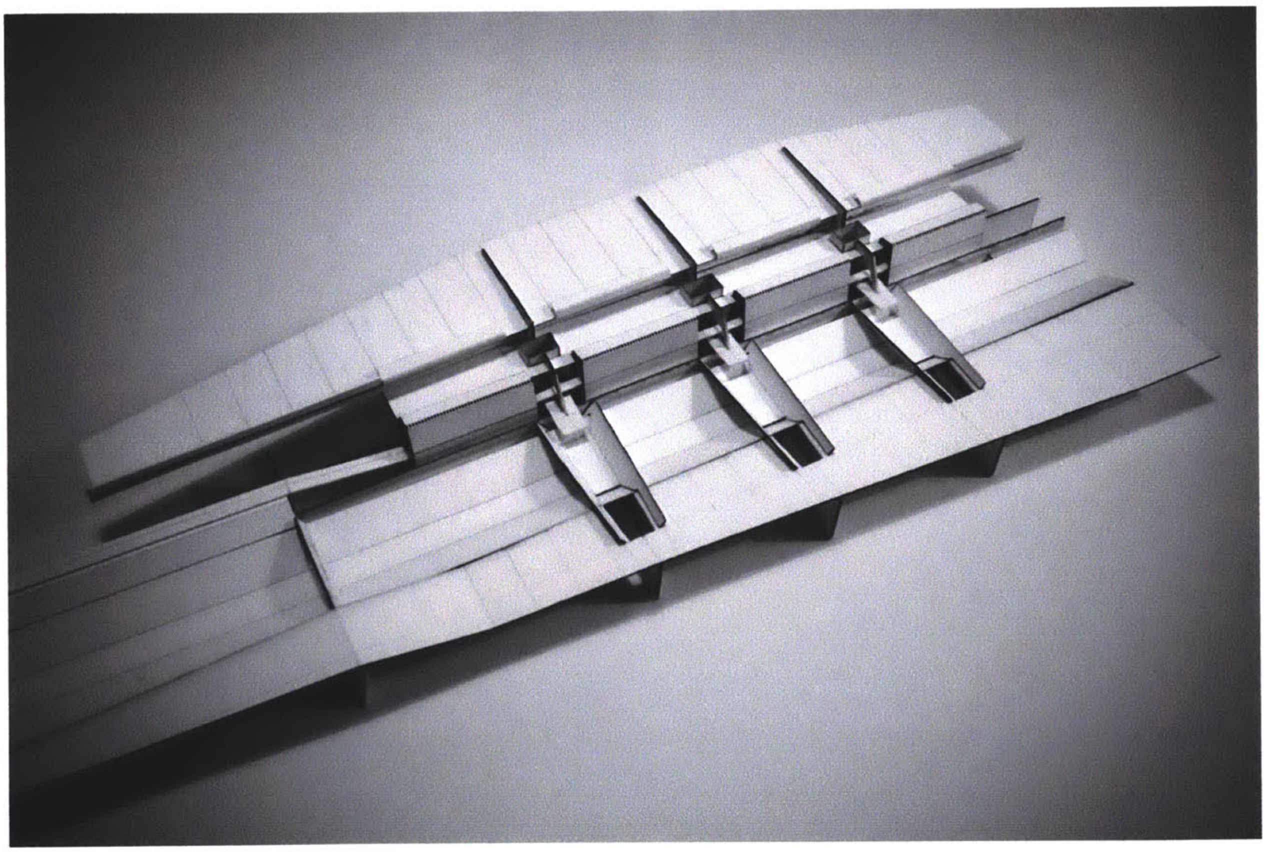
Bio-pool spa design iteration one



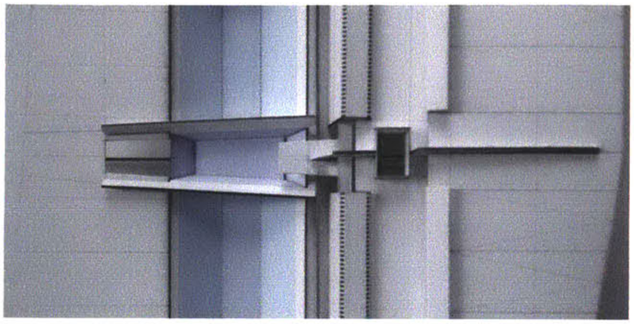
Iteration 1:
Physical Model



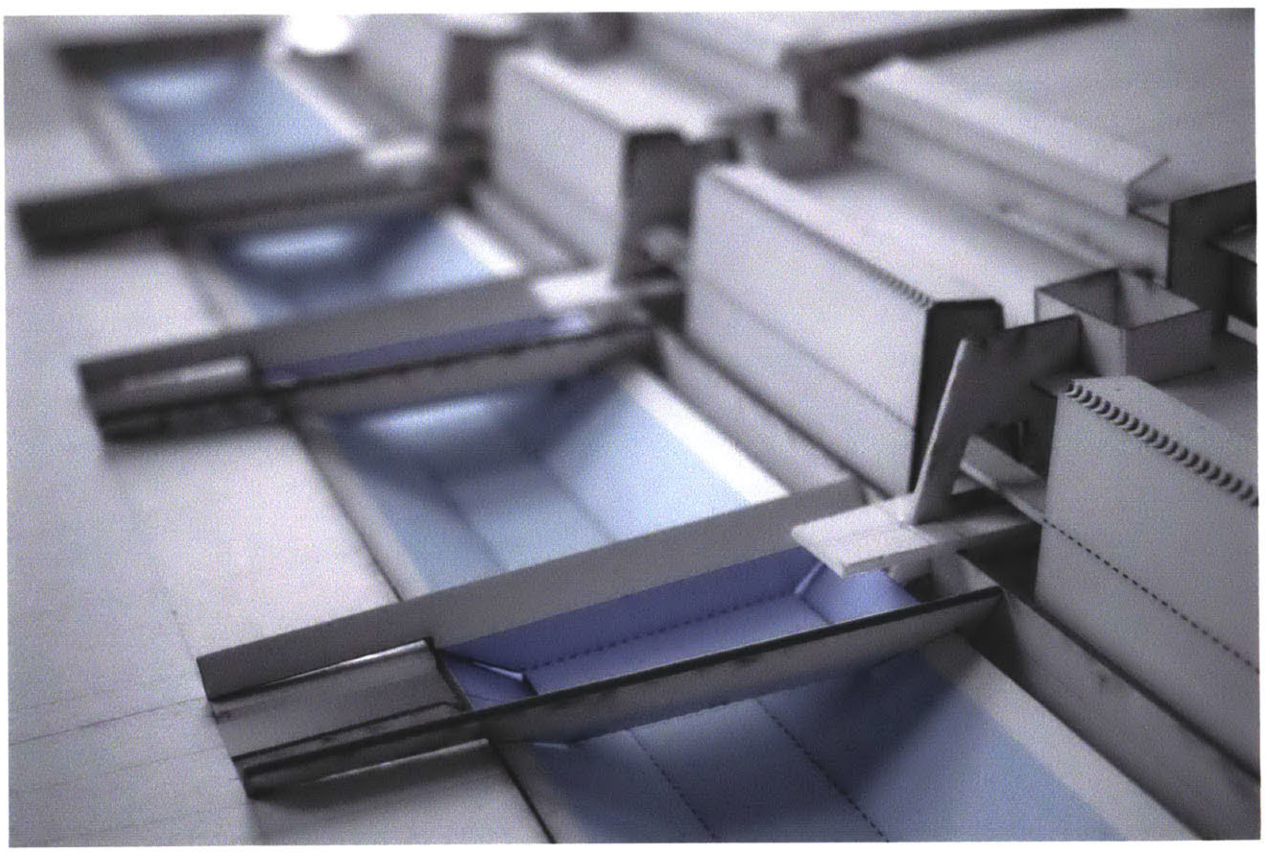
Iteration 2:
Physical model with surface articulation applied



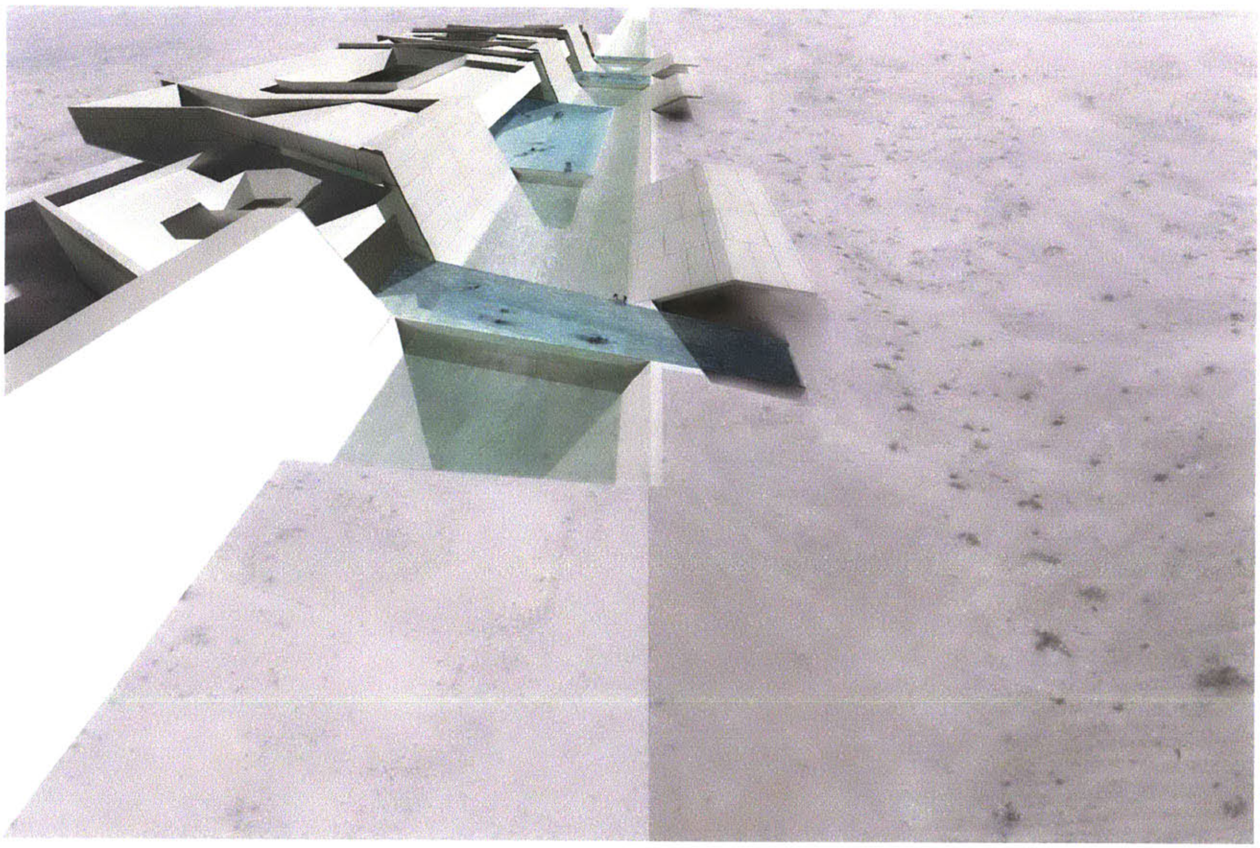
Iteration 3:
Physical model with adjusted catchment surface areas



Iteration 3:
Plan view of bridge detail

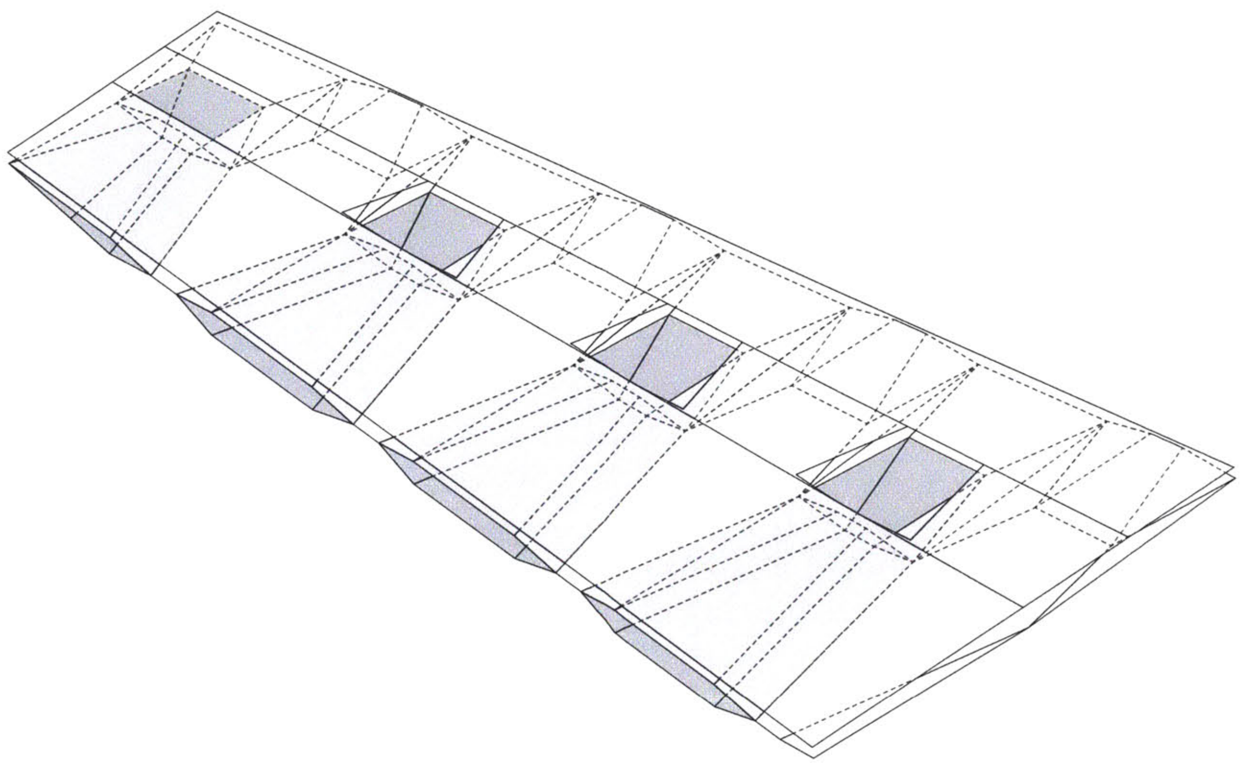


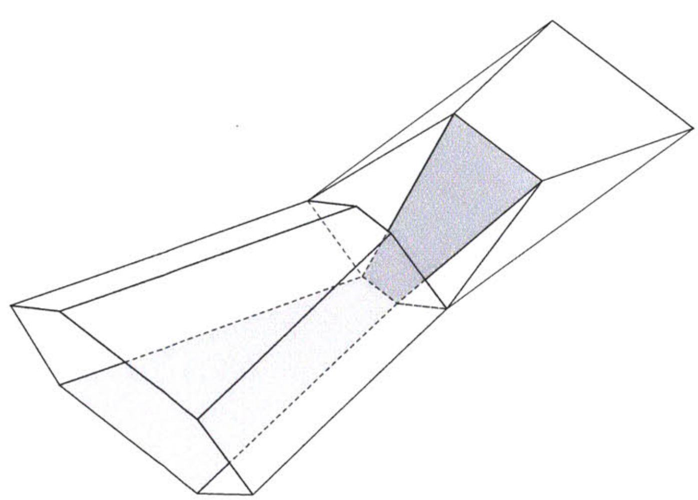
Iteration 3:
Detail of pools that serve as bridges over the canal.

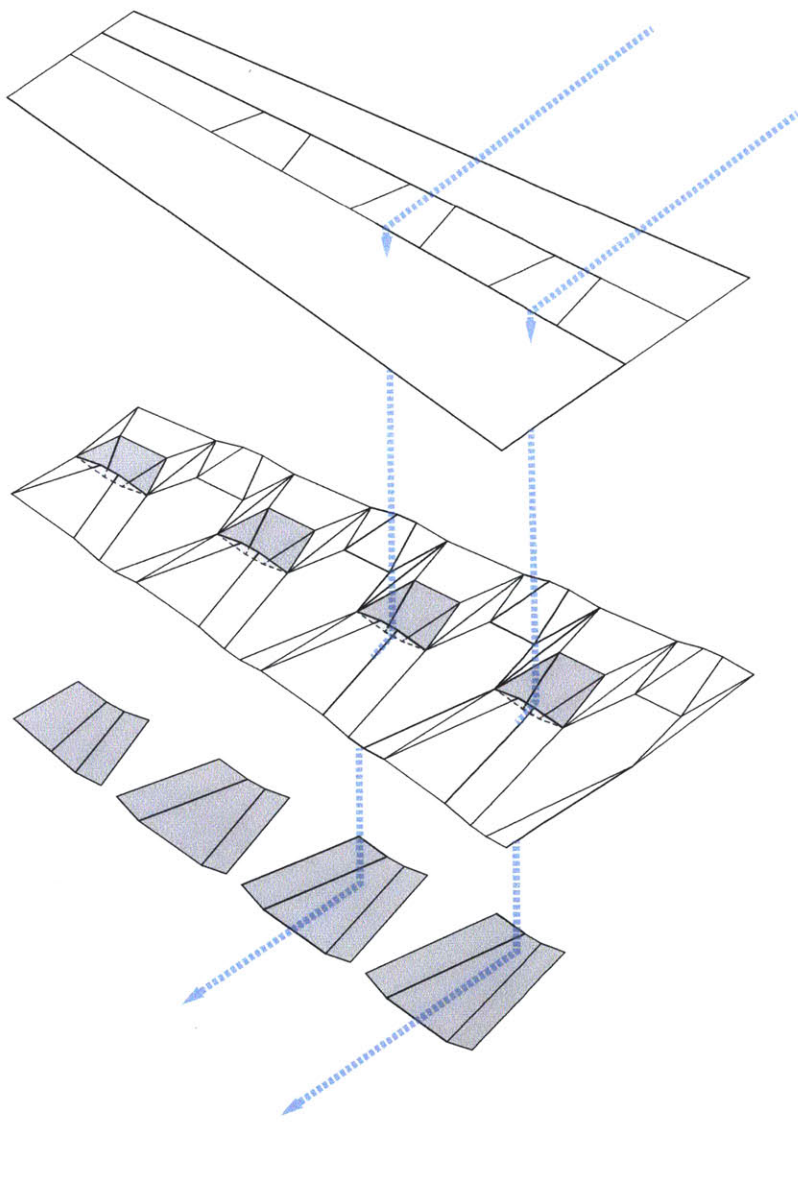


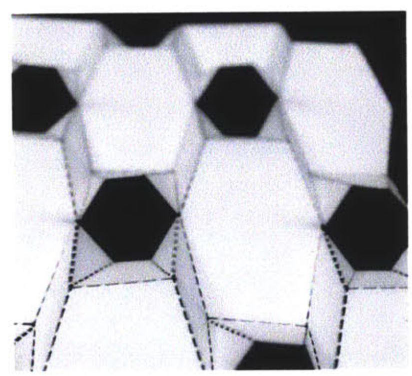
Bio-Pool Spa Final Design Scheme

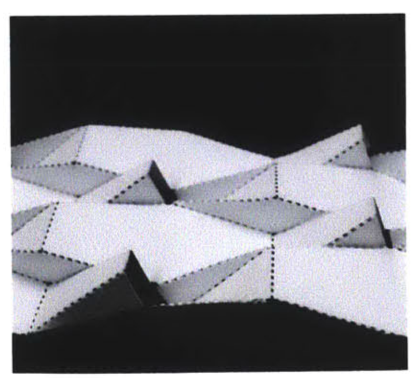
tion of the bio-pool spa is generated from the earlier set of surface studies. The folded patterns are used at a macro-scale to guide spatial organization of the building.

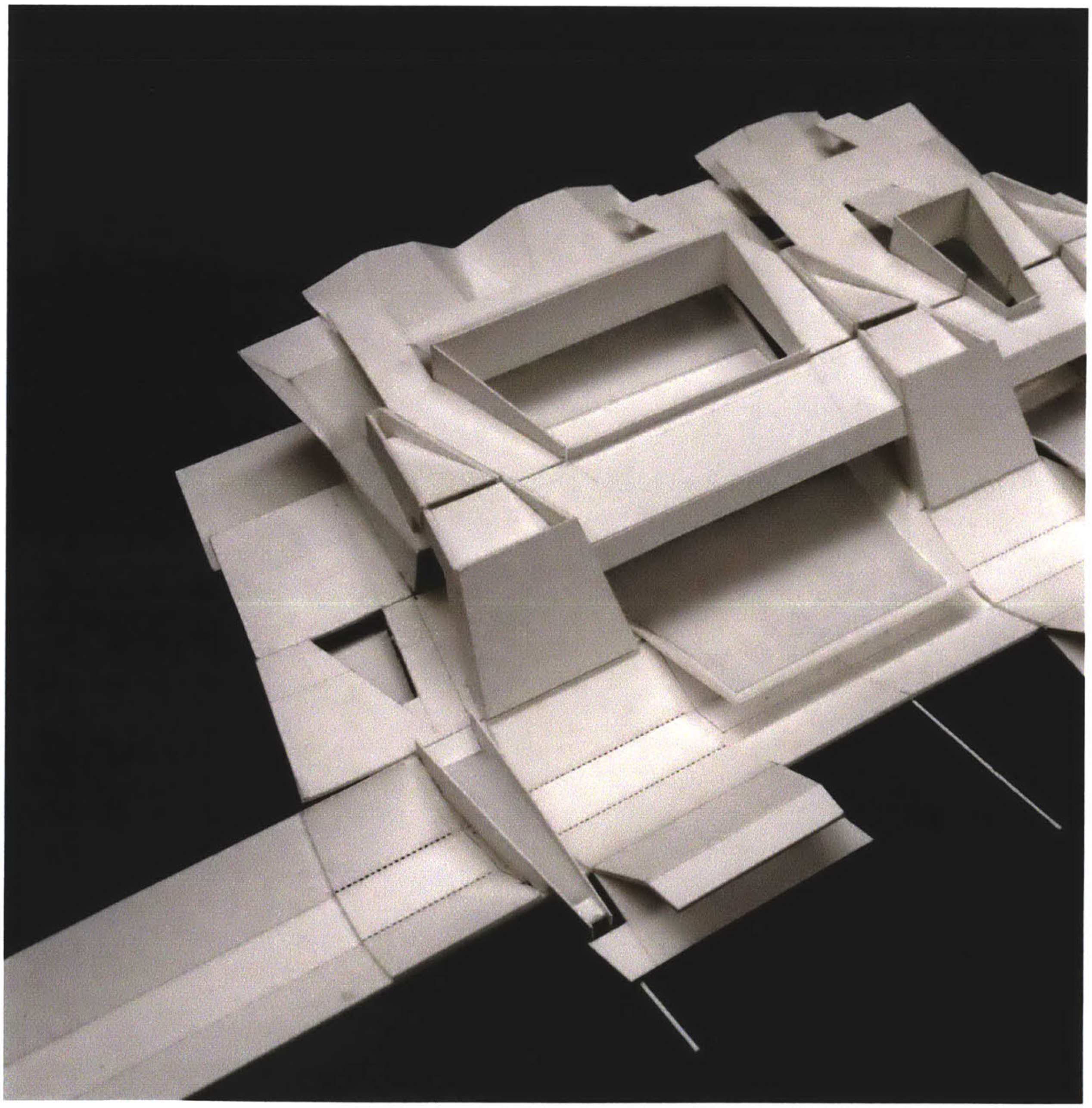


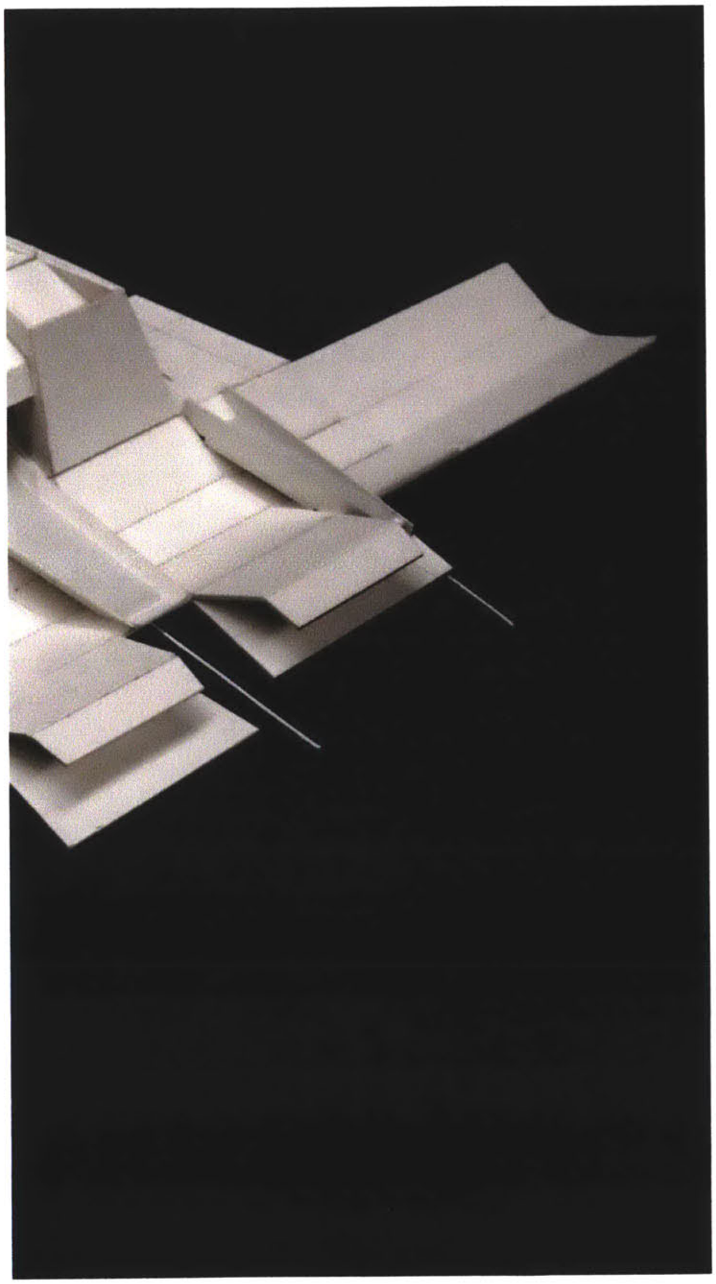




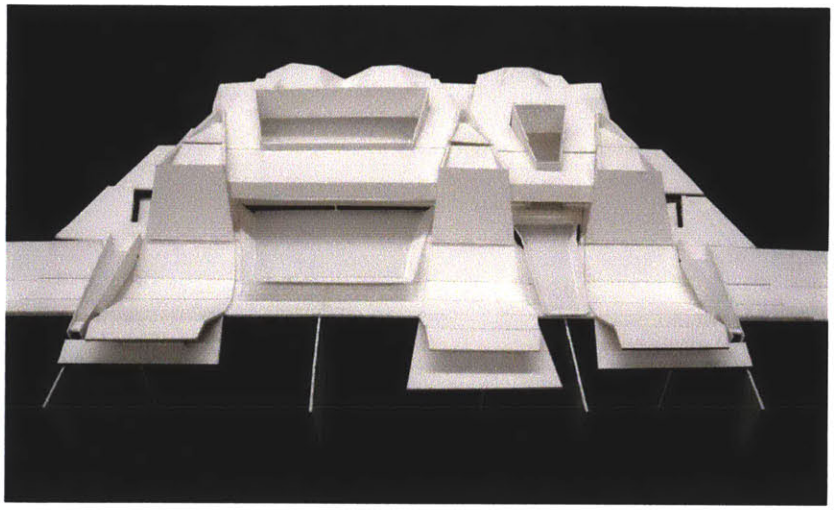






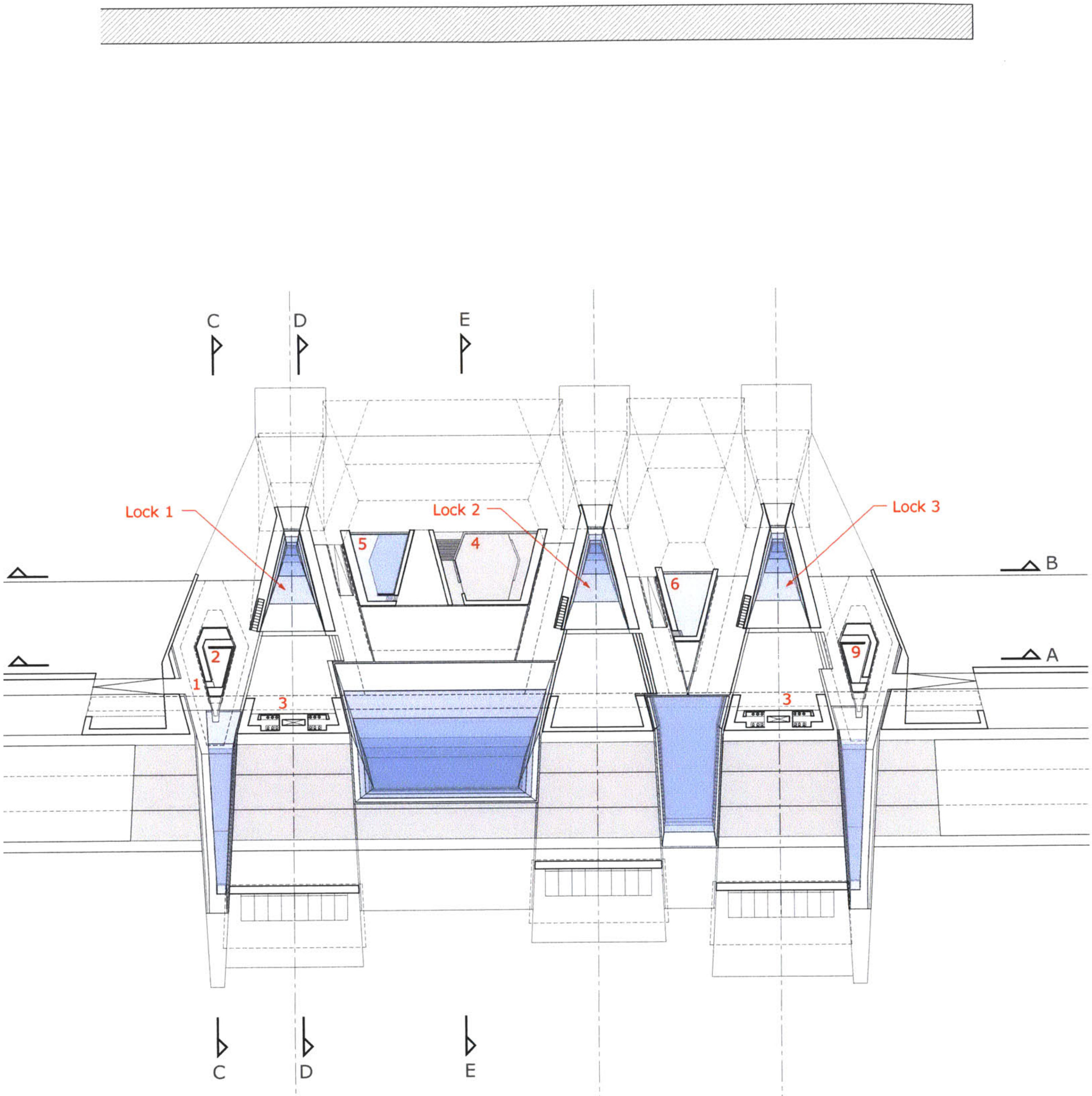


BIO-POOL SPA FINAL DESIGN SCHEME

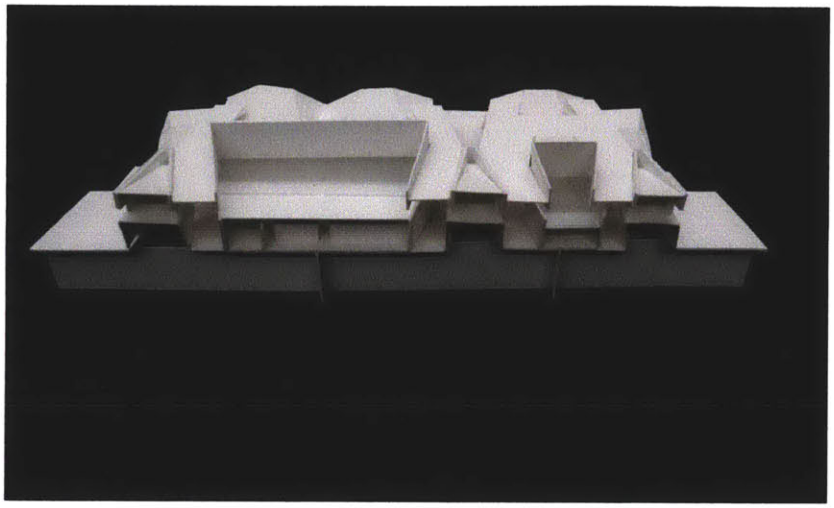


FP-01 Legend

1. Lobby
2. Change
3. Restrooms
4. Cafe
5. Fire Bath
6. Cold Bath
7. Change

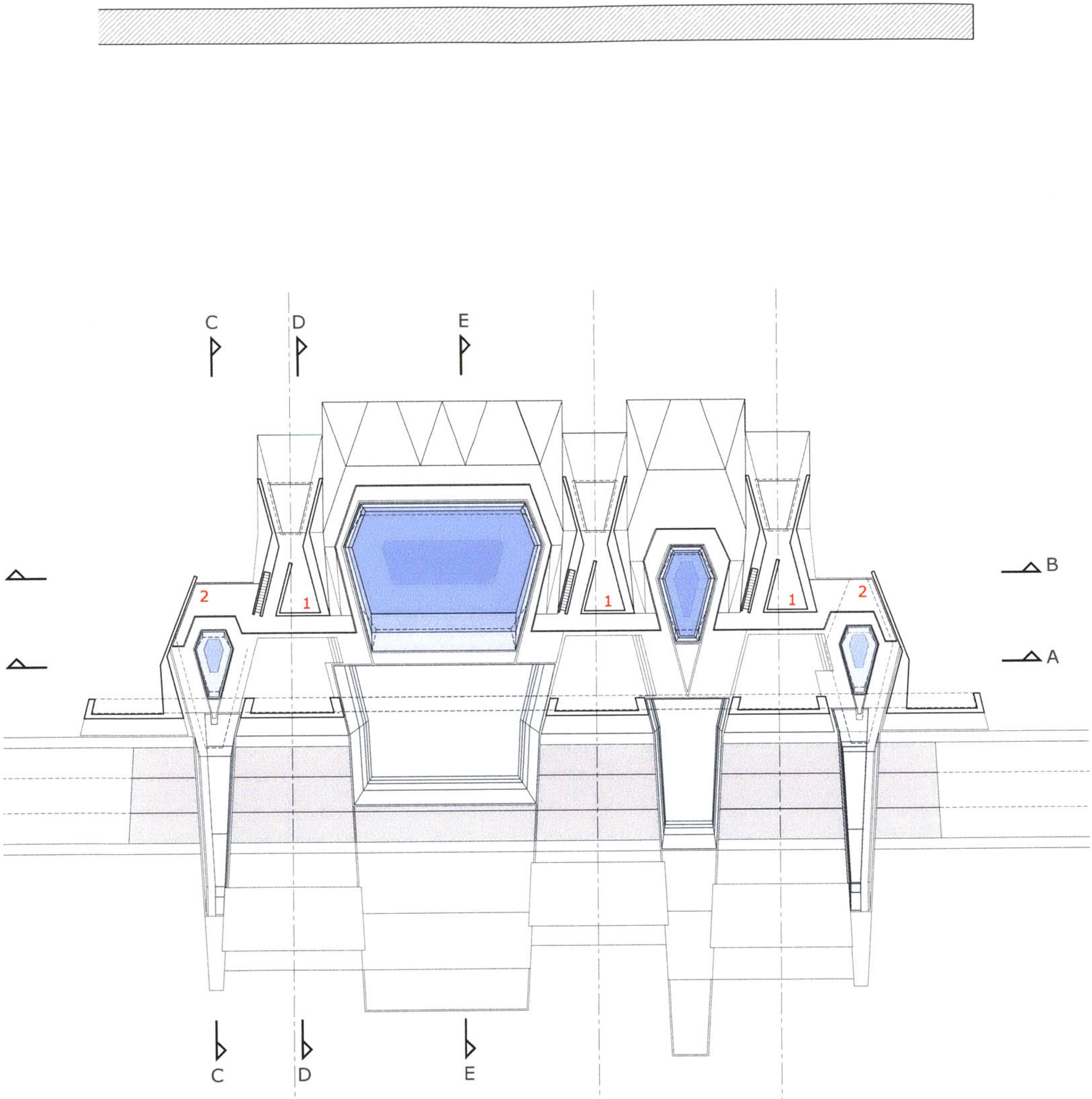

C
D
E
Lock 1
Lock 2
Lock 3
5
4
6
B
A
2
9
1
3
3
C
D
E

BIO-POOL SPA FINAL DESIGN SCHEME

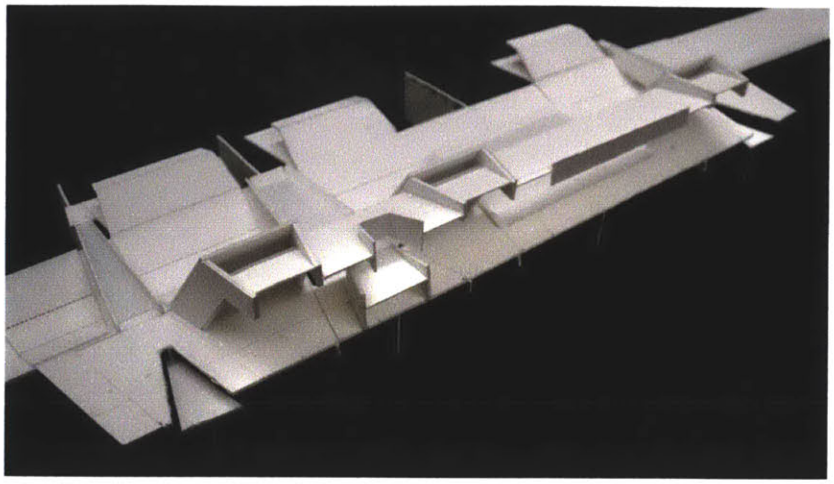


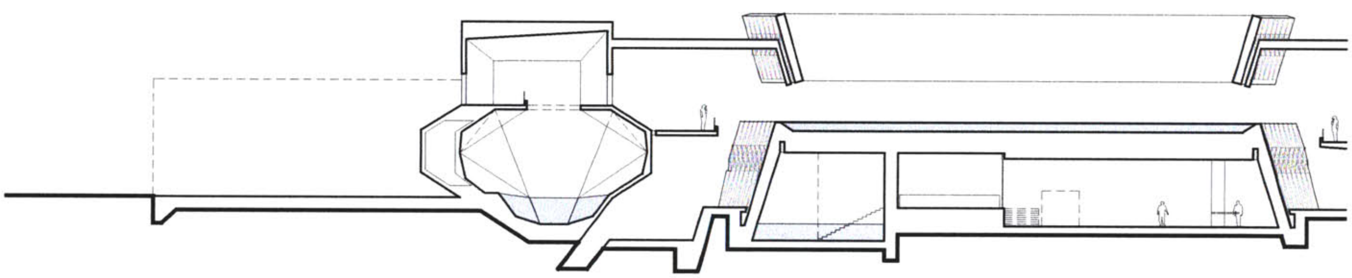
FP-02 Legend

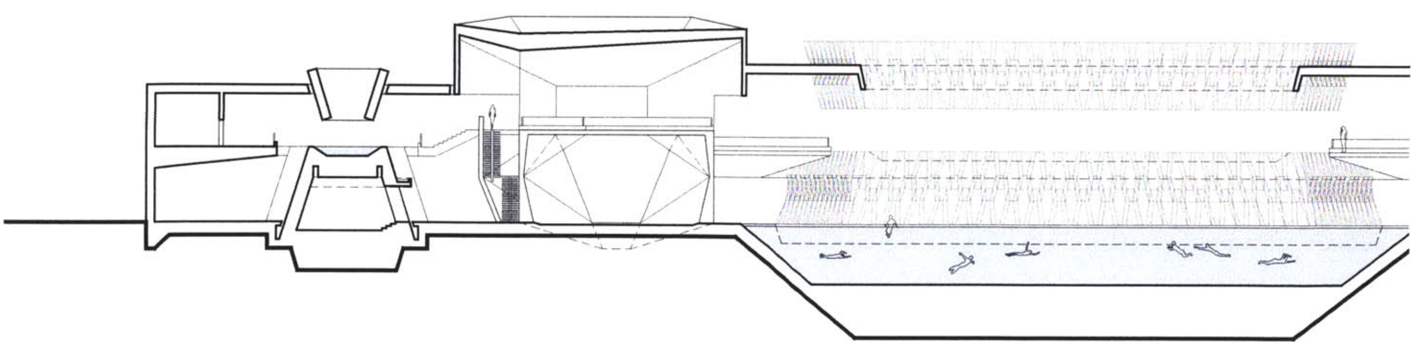
1. Treatment Rooms
2. Sauna

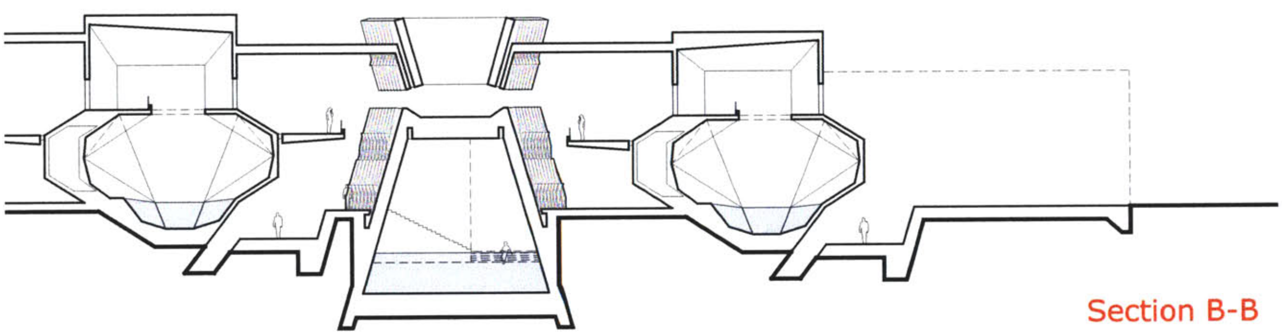

C
D
E
B
A
2
1
1
1
2
C
D
E

BIO-POOL SPA FINAL DESIGN SCHEME

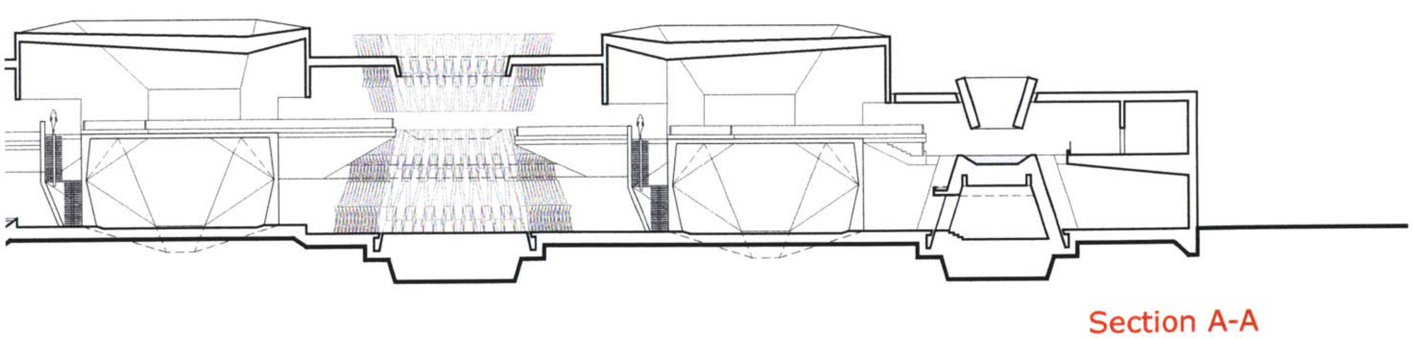






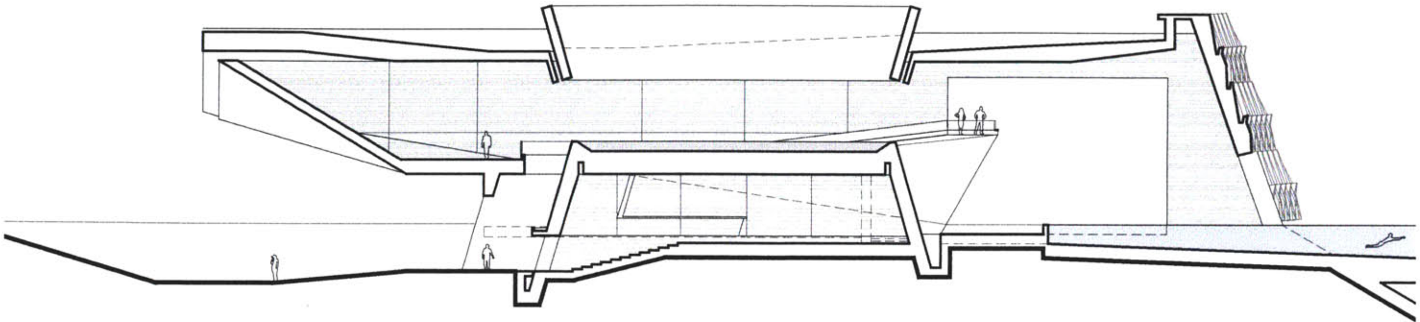


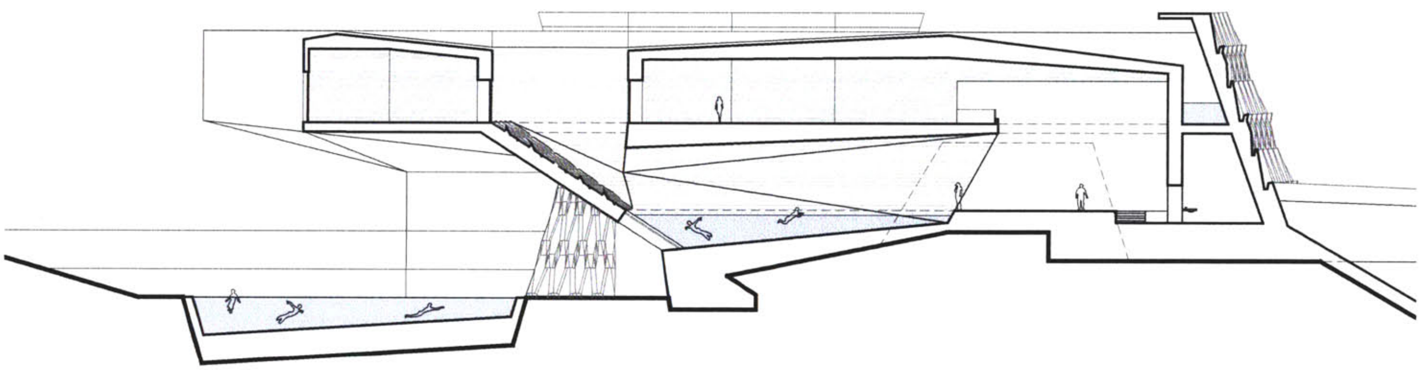
Section B-B

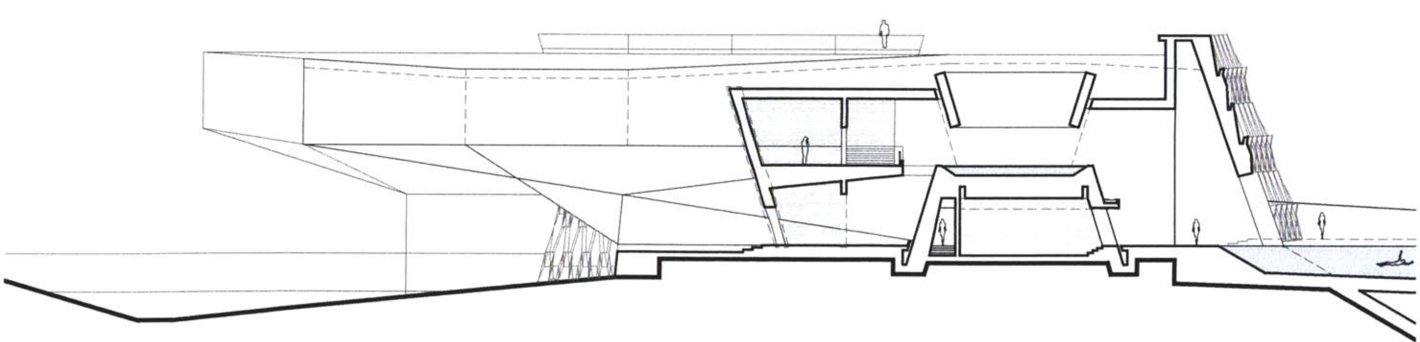


Section A-A

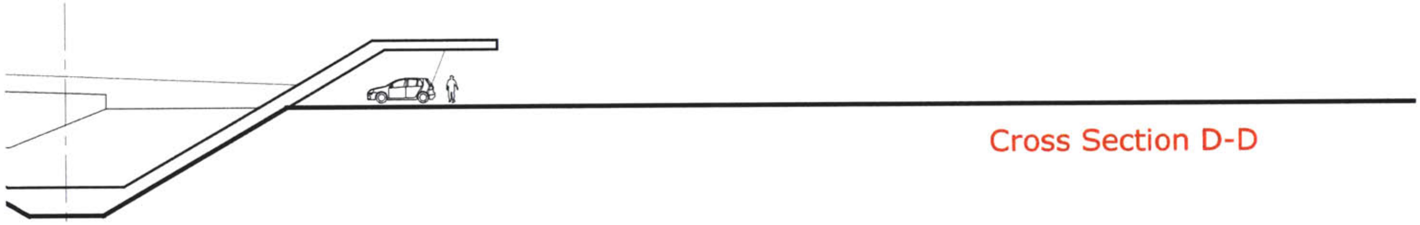
BIO-POOL SPA FINAL DESIGN SCHEME







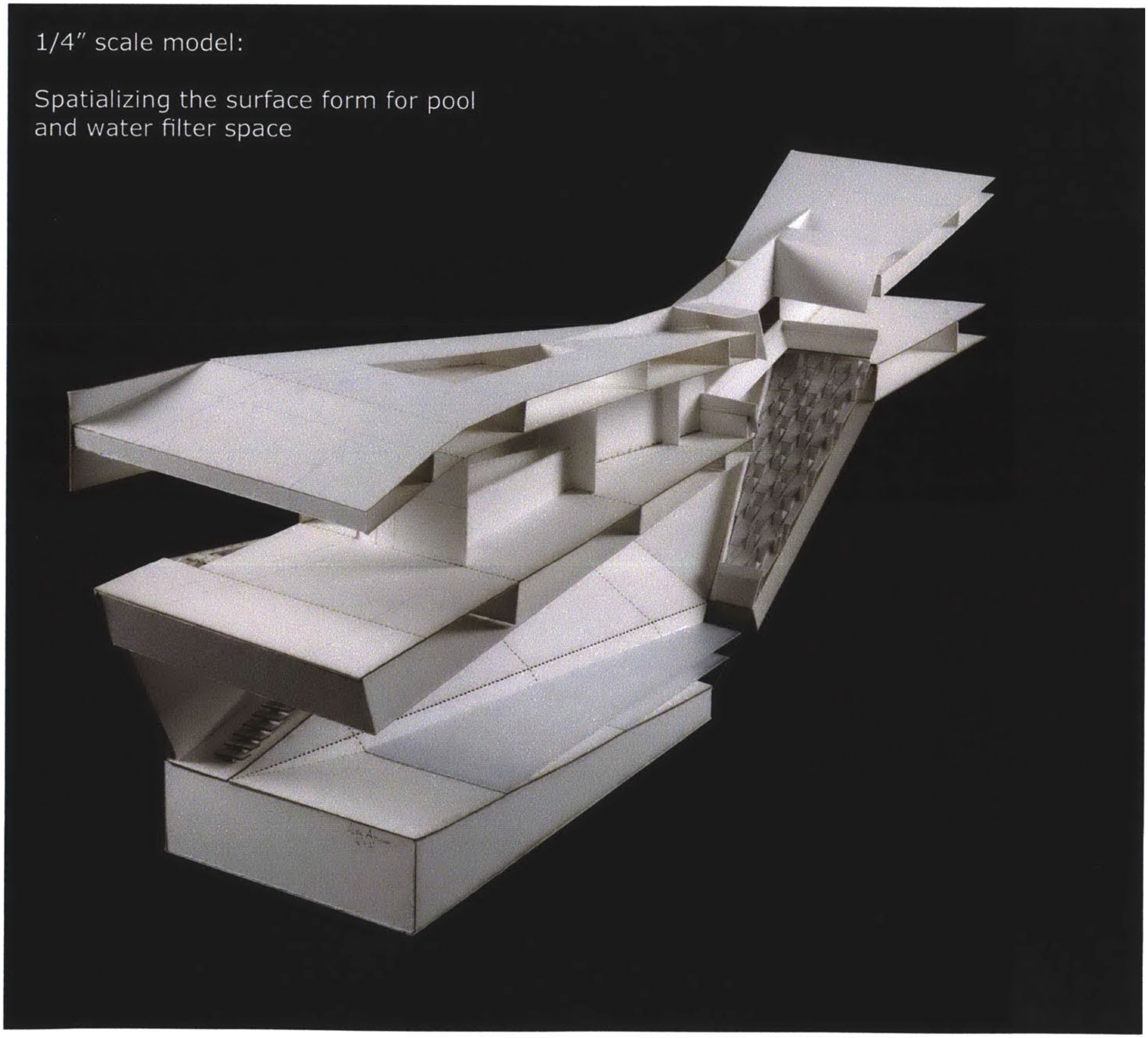
Cross Section E-E



Cross Section D-D

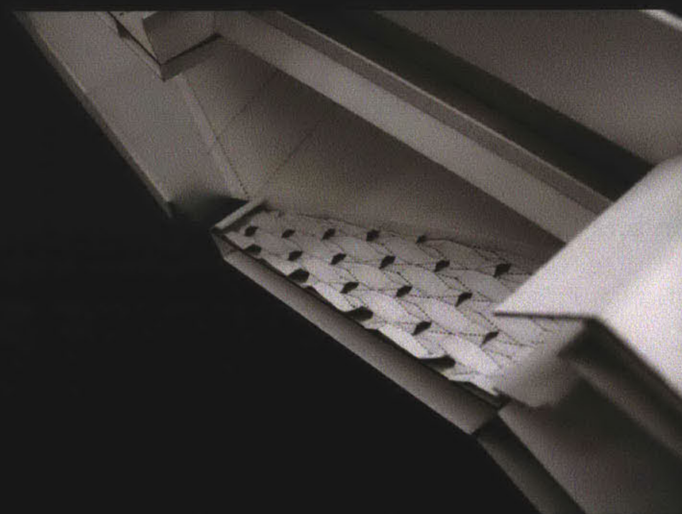
Cross Section C-C

BIO-POOL SPA FINAL DESIGN SCHEME

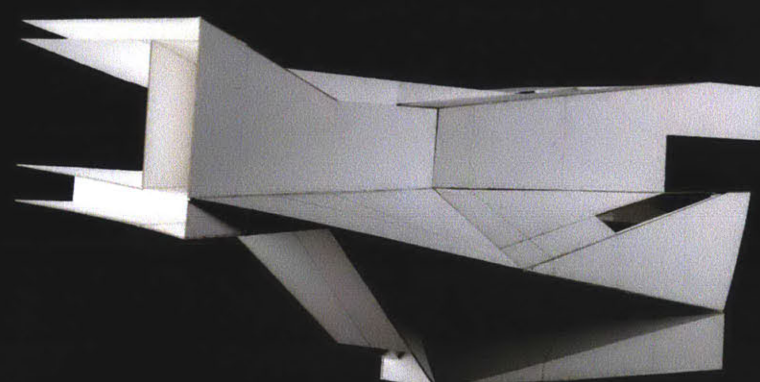


1/4" scale model:

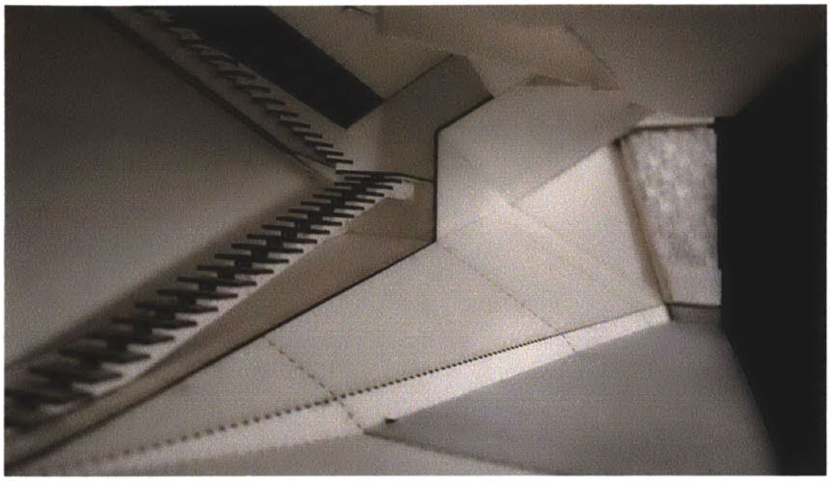
Spatializing the surface form for pool and water filter space



Articulated surface that performs as water filter for rainwater runoff

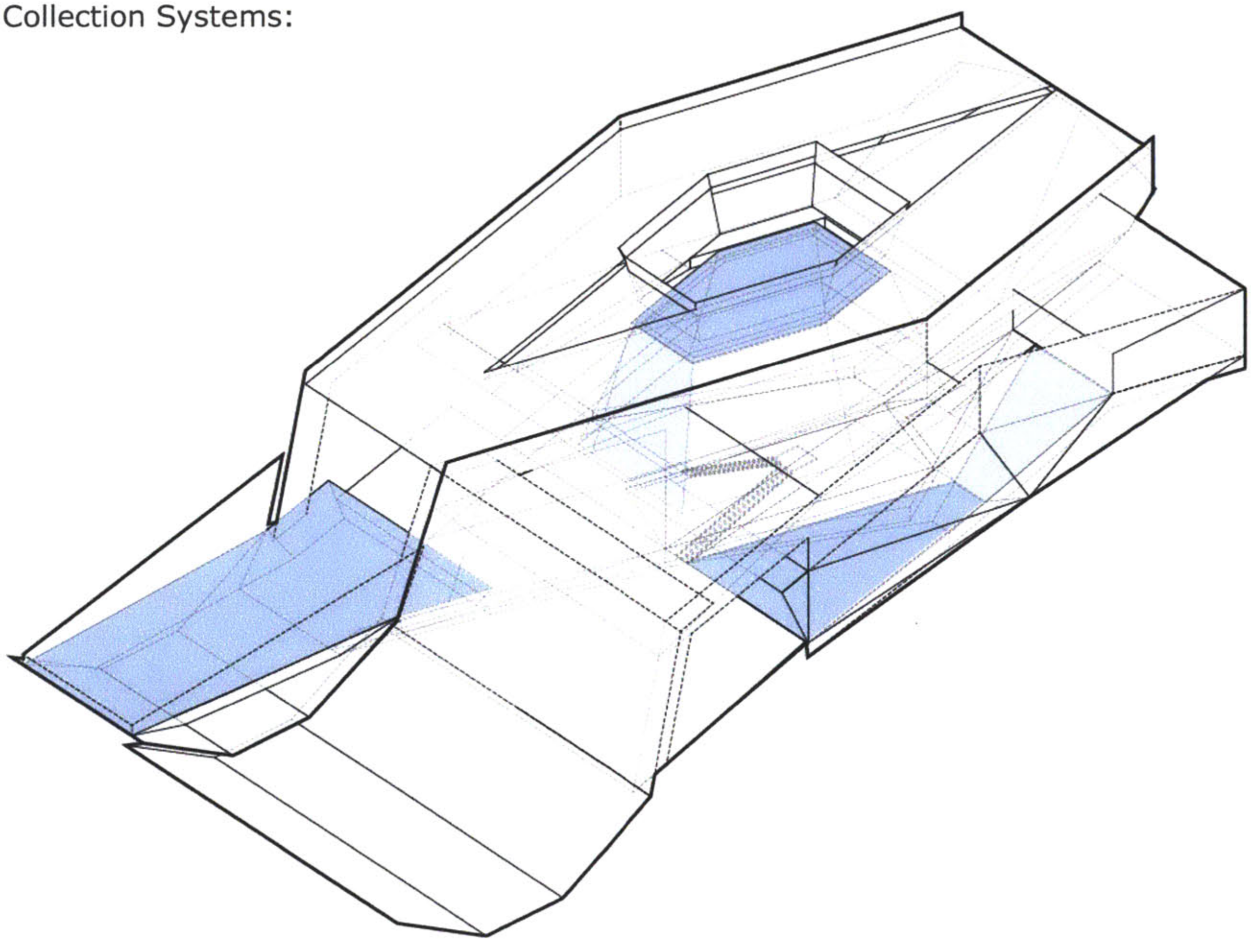


Exterior View of Surface Form



Perspective view through model space of the water collection tube

Section and Exploded Axonometric of Water Collection Systems:

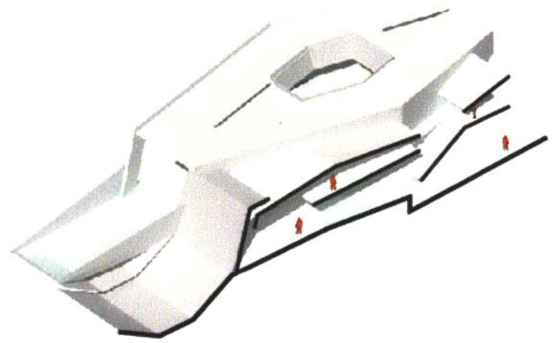


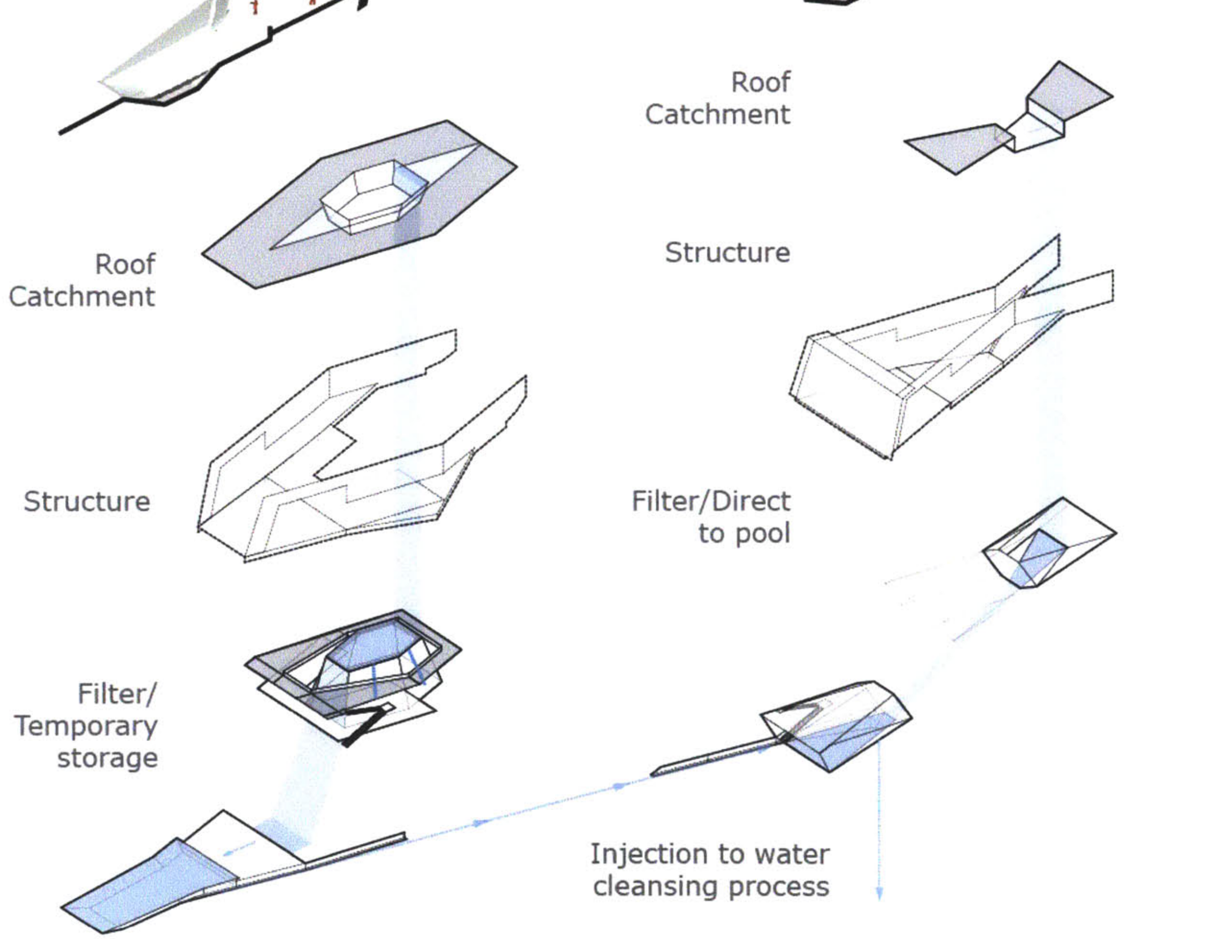
System 1: Lightwell

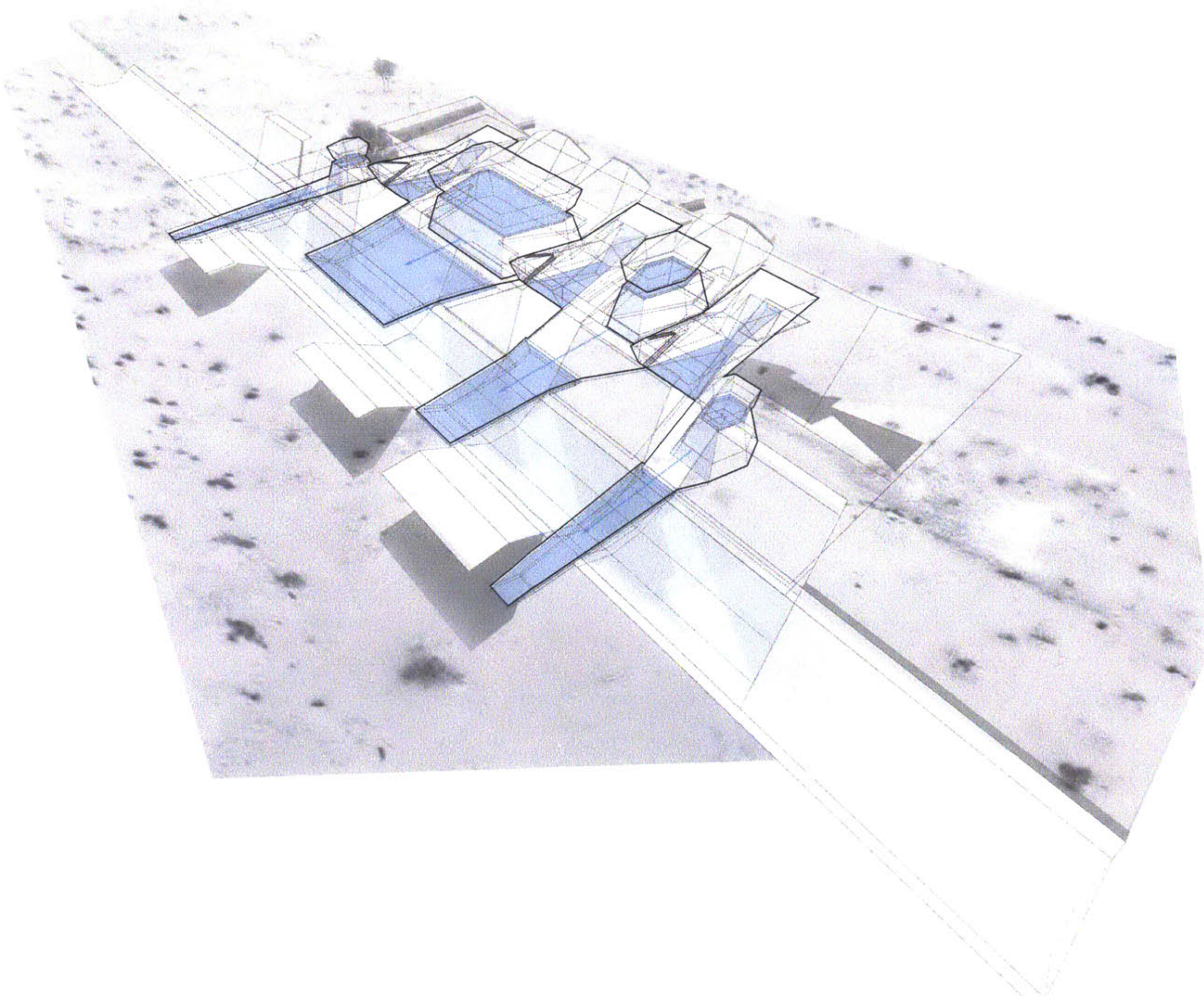
Rainwater runoff is directed and stored in a shallow pool for temporary storage. Water Overflows from the shallow pool flow into a filtered surface that is then directed to a swimming pool.

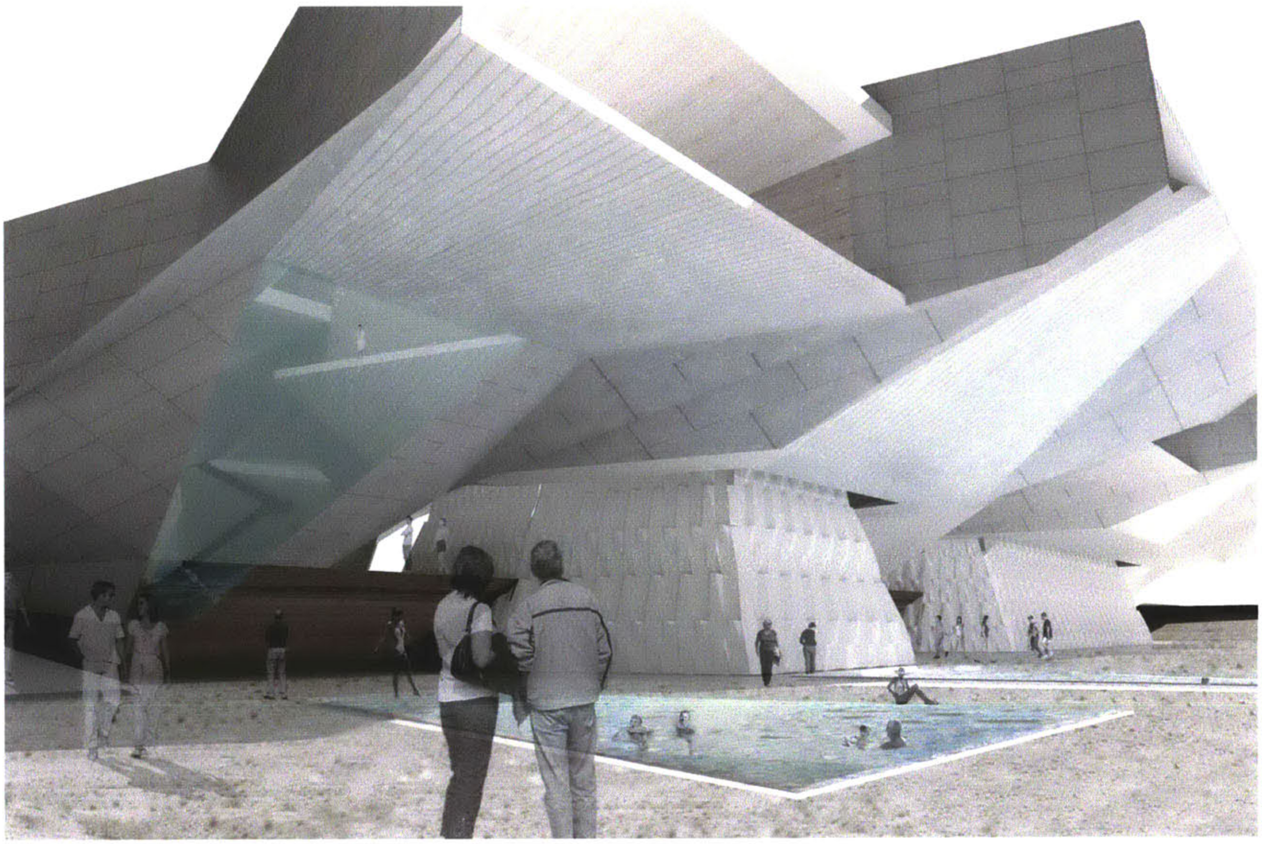
System 2: Water-scoop

Rainwater is directed and filtered, through a performative surface, to a swimming pool and then injected to cleansing process.





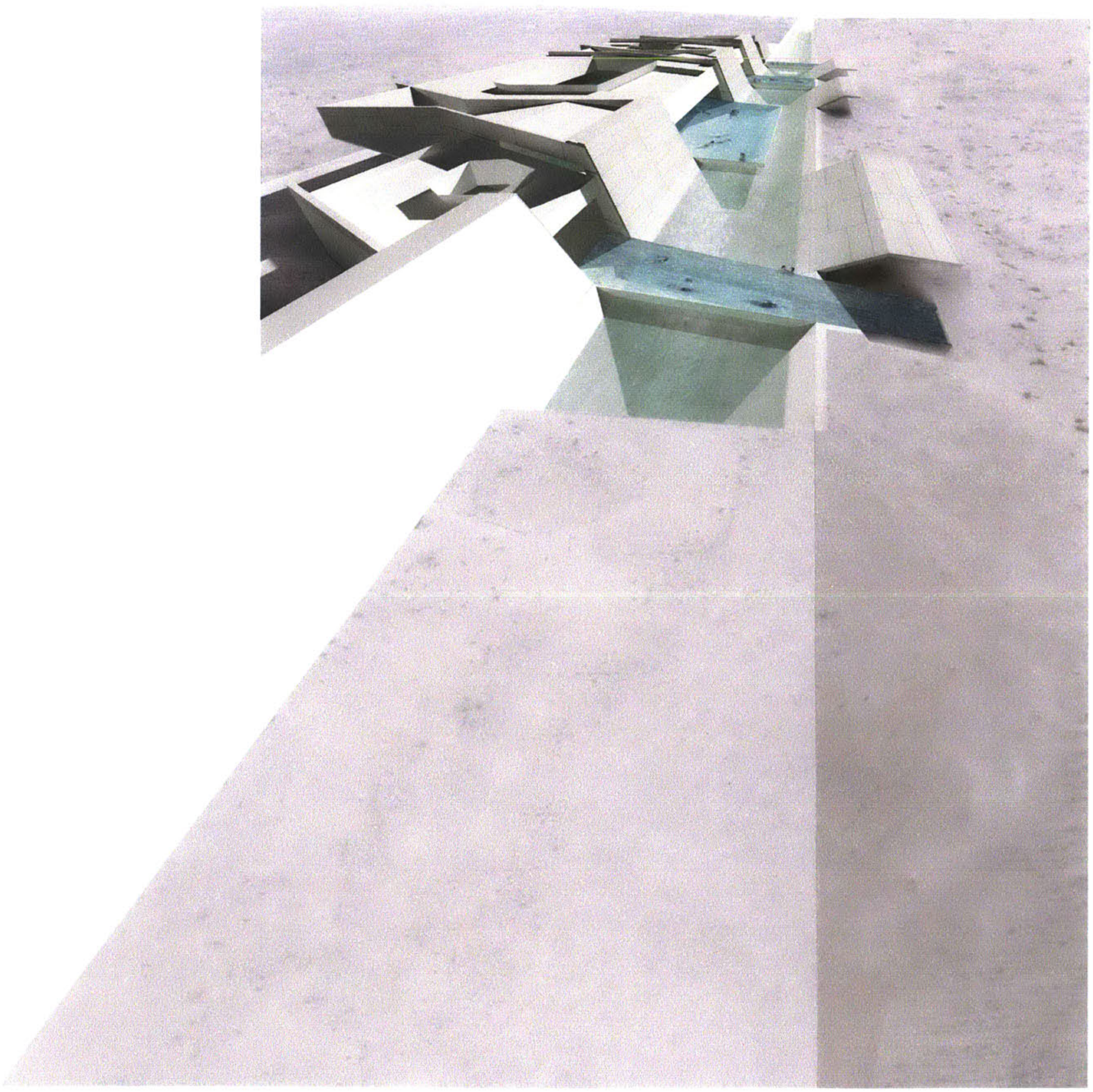


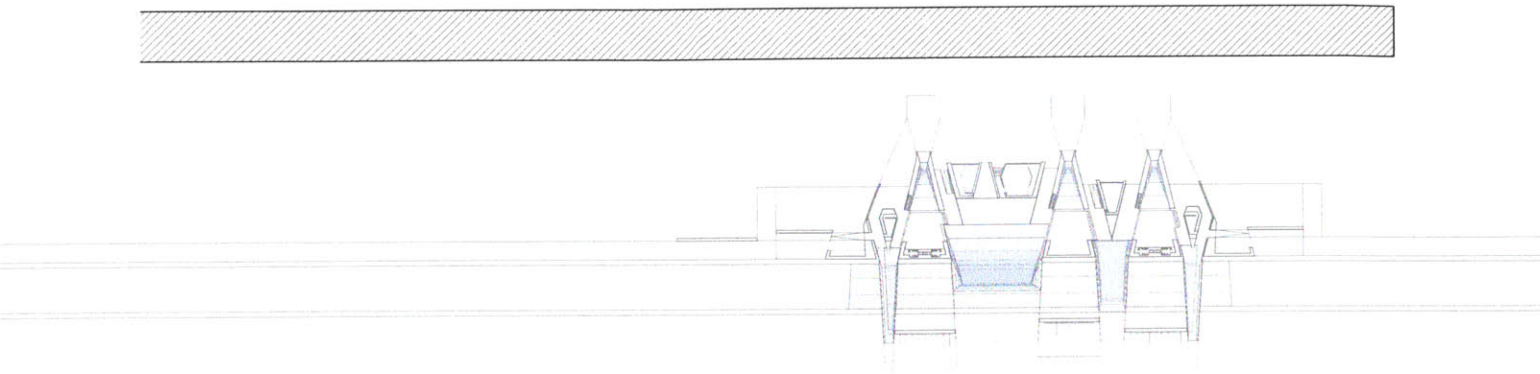


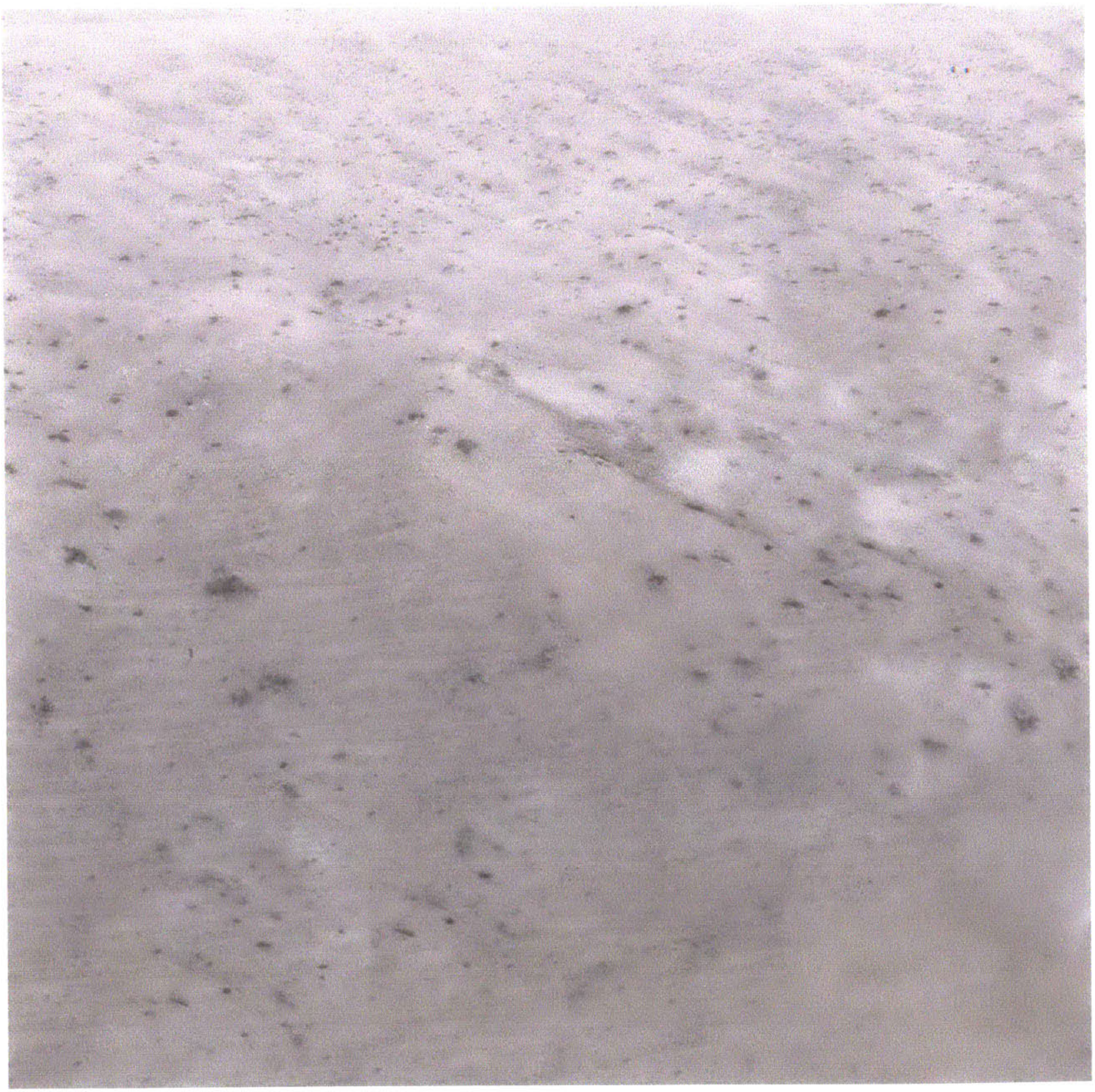
Bio-Pool Spa Walkthrough

BIO-POOL SPA WALKTHROUGH

Aerial view as one approaches along the canal. Option to park under shaded structures (on right) provide people with the option of driving to this attraction.



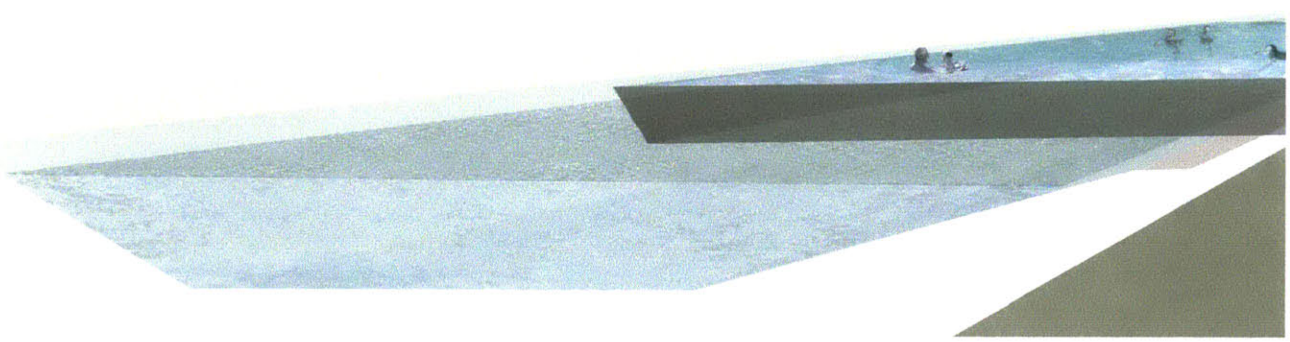


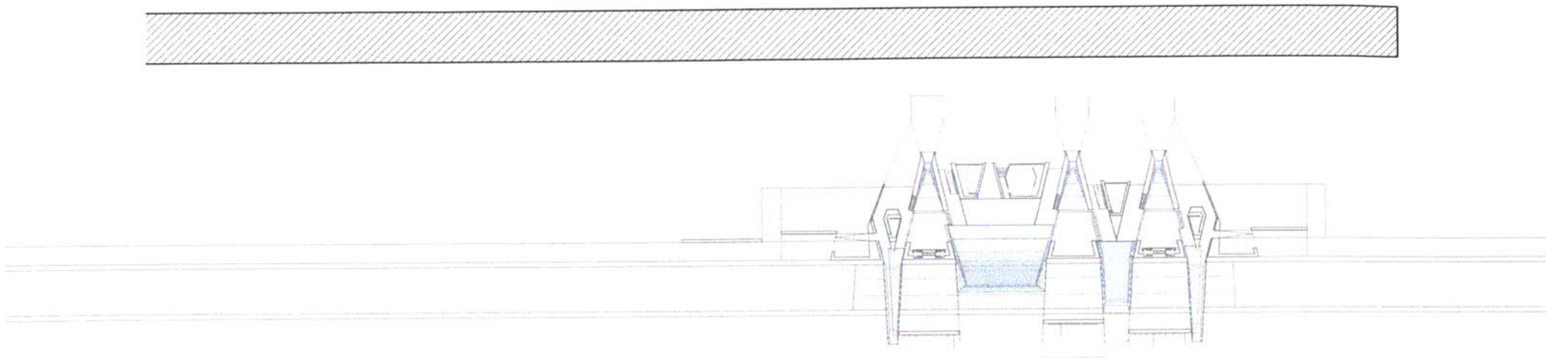


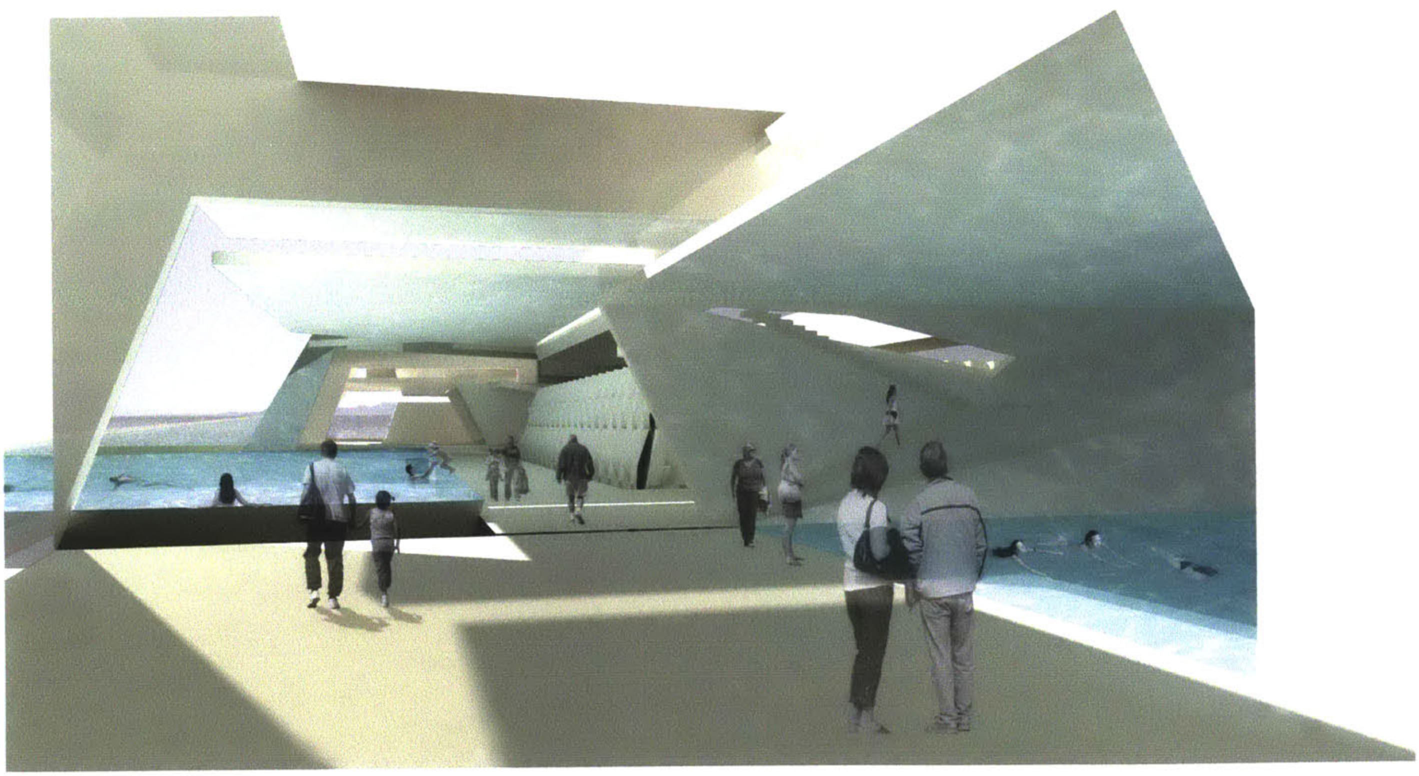
BIO-POOL SPA WALKTHROUGH

Upon entering the building and circulating through a changing room, one enters a spacious corridor that is flanked by a series of pools.

These pools extend outward and cantilever over the canal to create a spatial relationship with the canal.



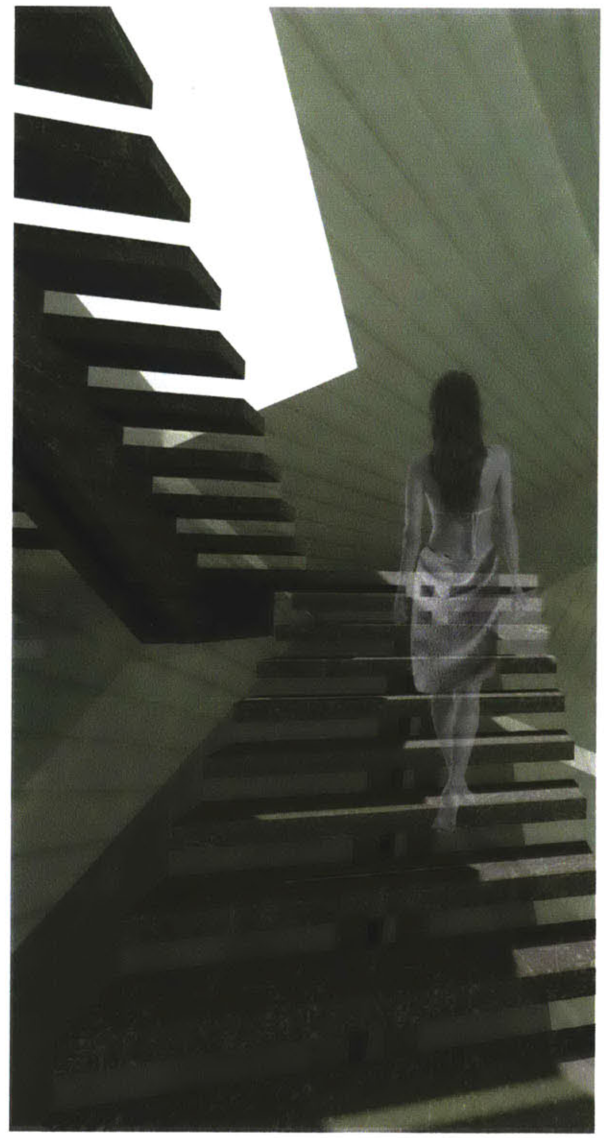


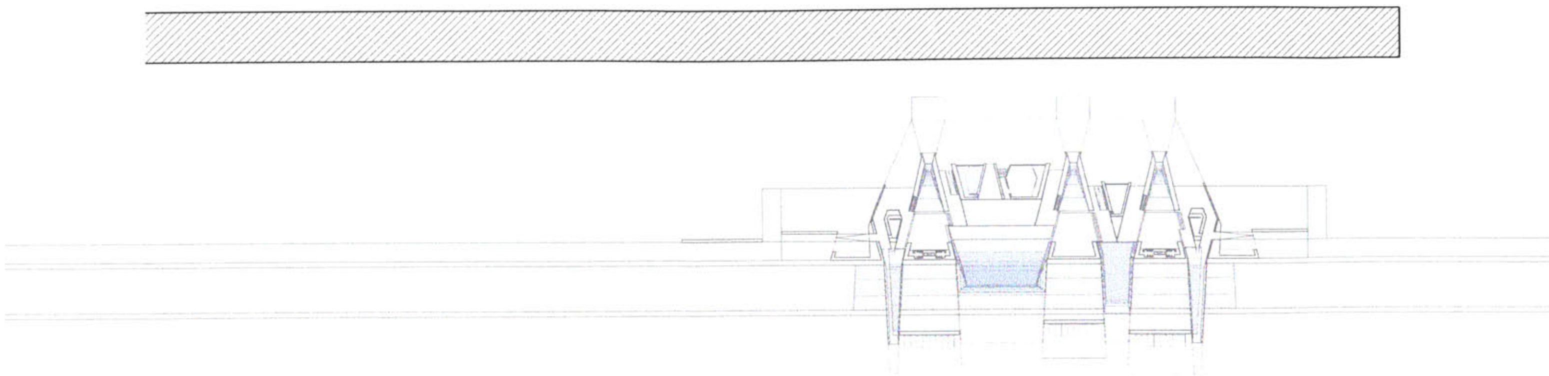


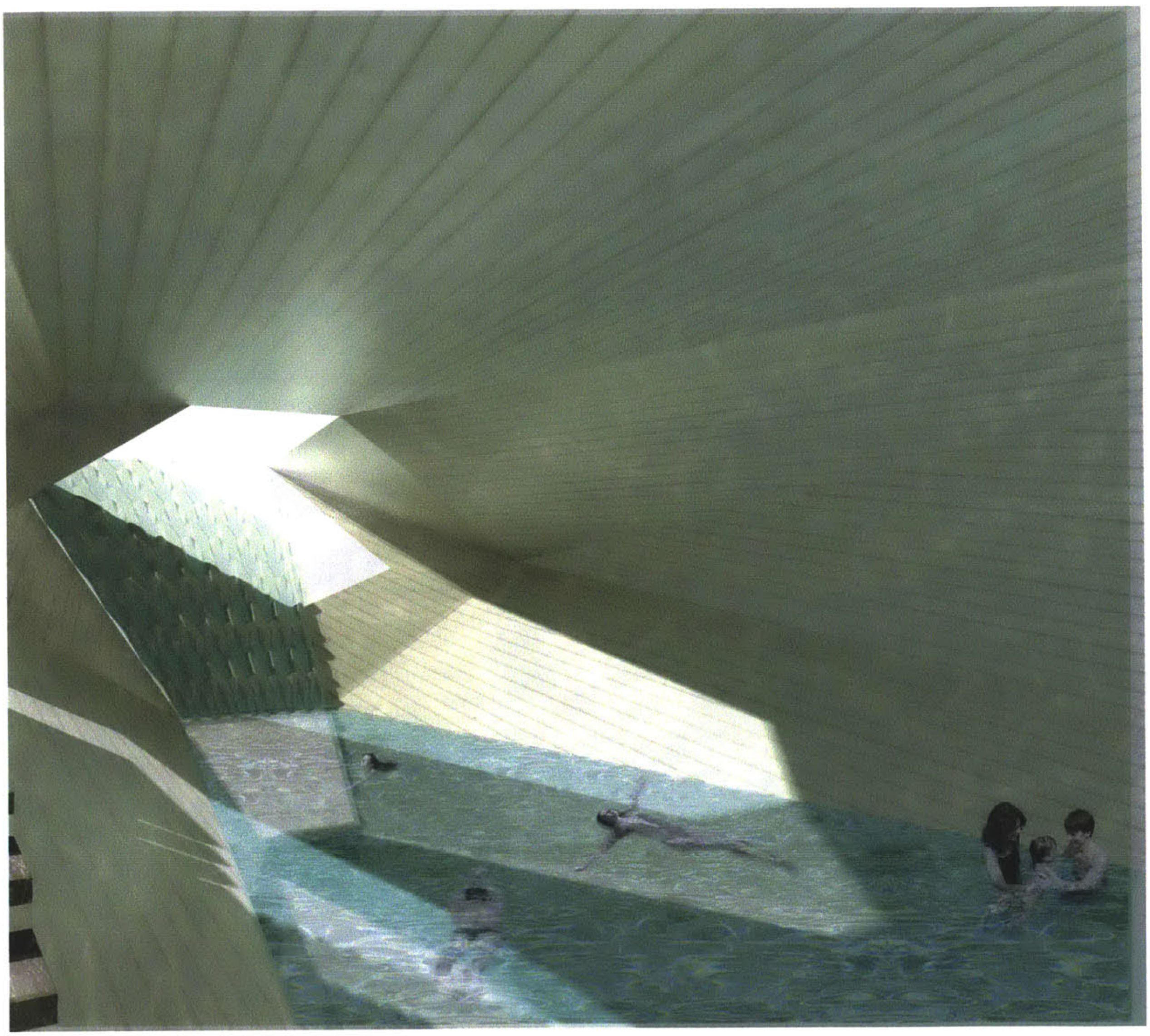
BIO-POOL SPA WALKTHROUGH

Surrounding the corridor of pools are "Waterscoop" spaces that bring in rainwater via a sloped wall of articulated surfaces (which act as cleansing filters).

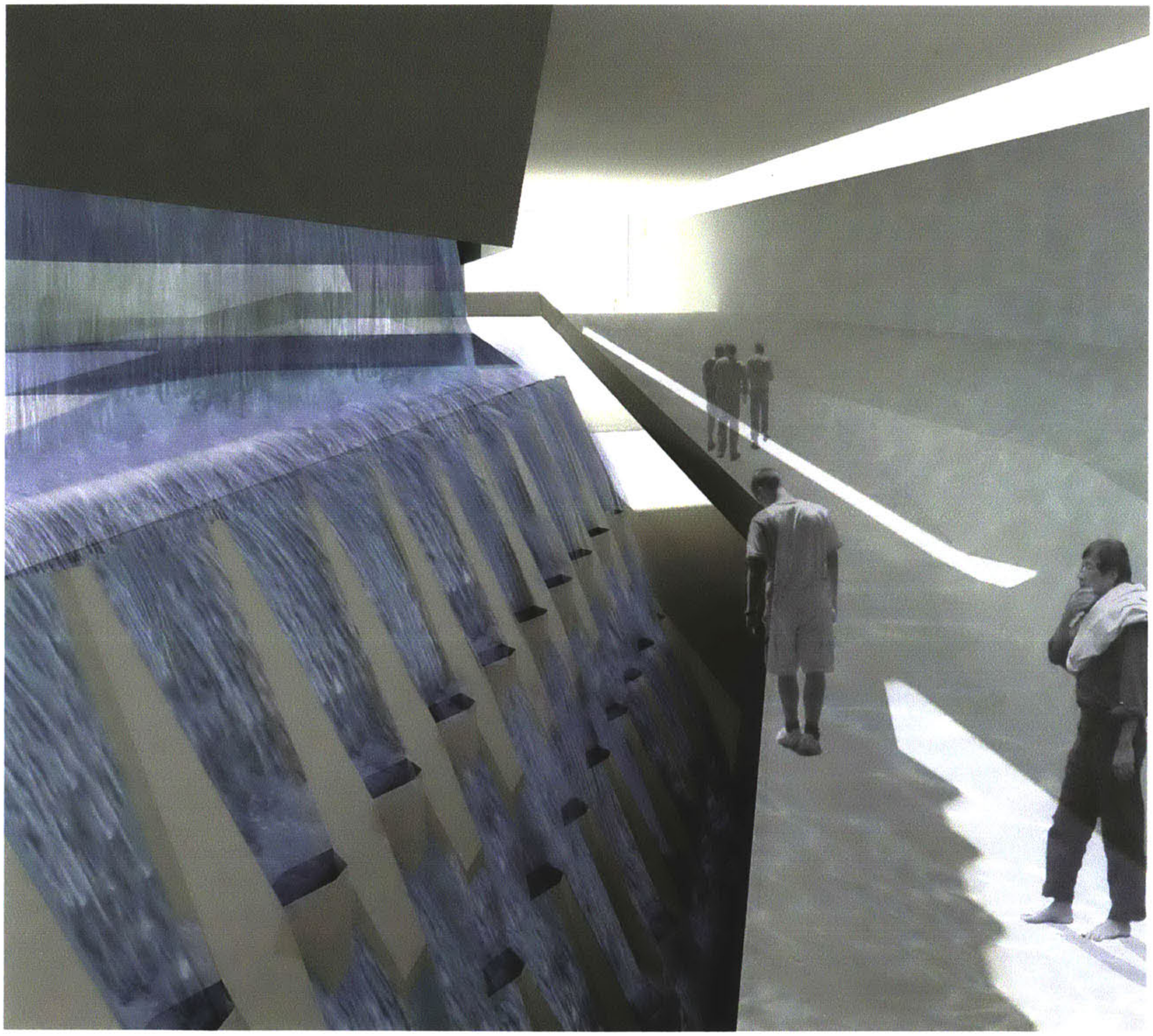
These waterscoop spaces double as circulation cores for one to pregress to the seconfd floor.

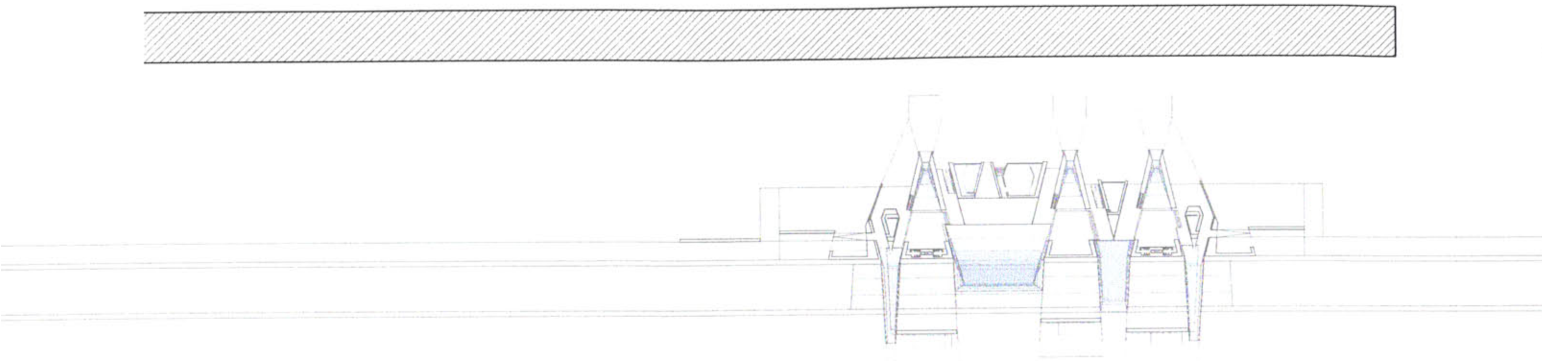






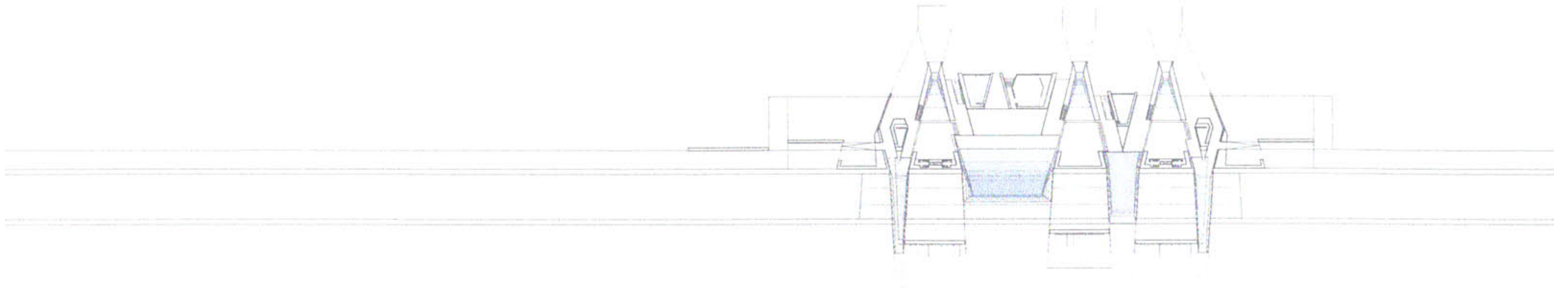
The lightwell acts as a vertical space and a showcase of water and light. Below is a heavy rain scenario. Water flows in from an opening in the roof, is filtered as it falls down a wall of filters, finally is injected into the water cleansing process for further treatment.

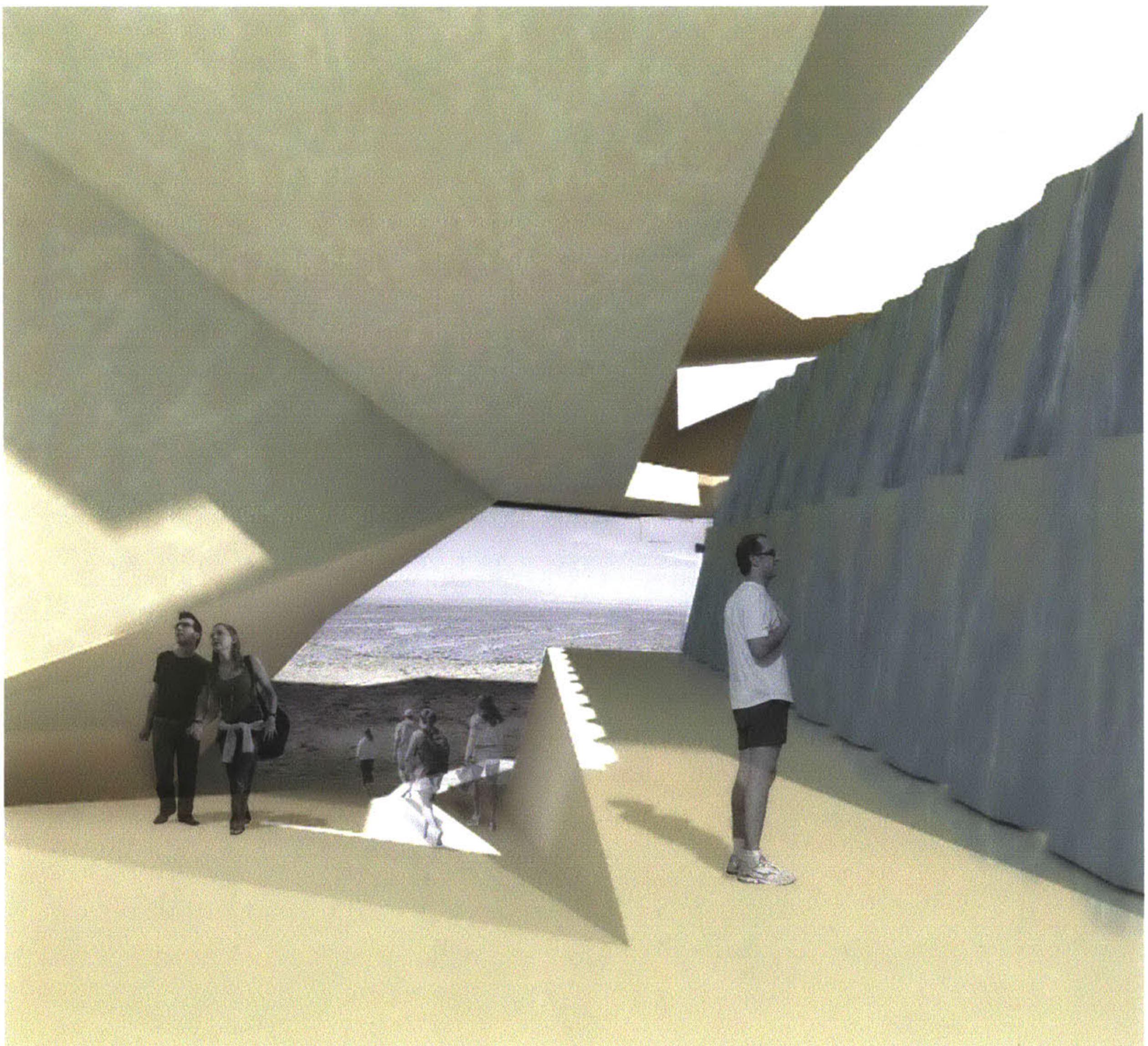




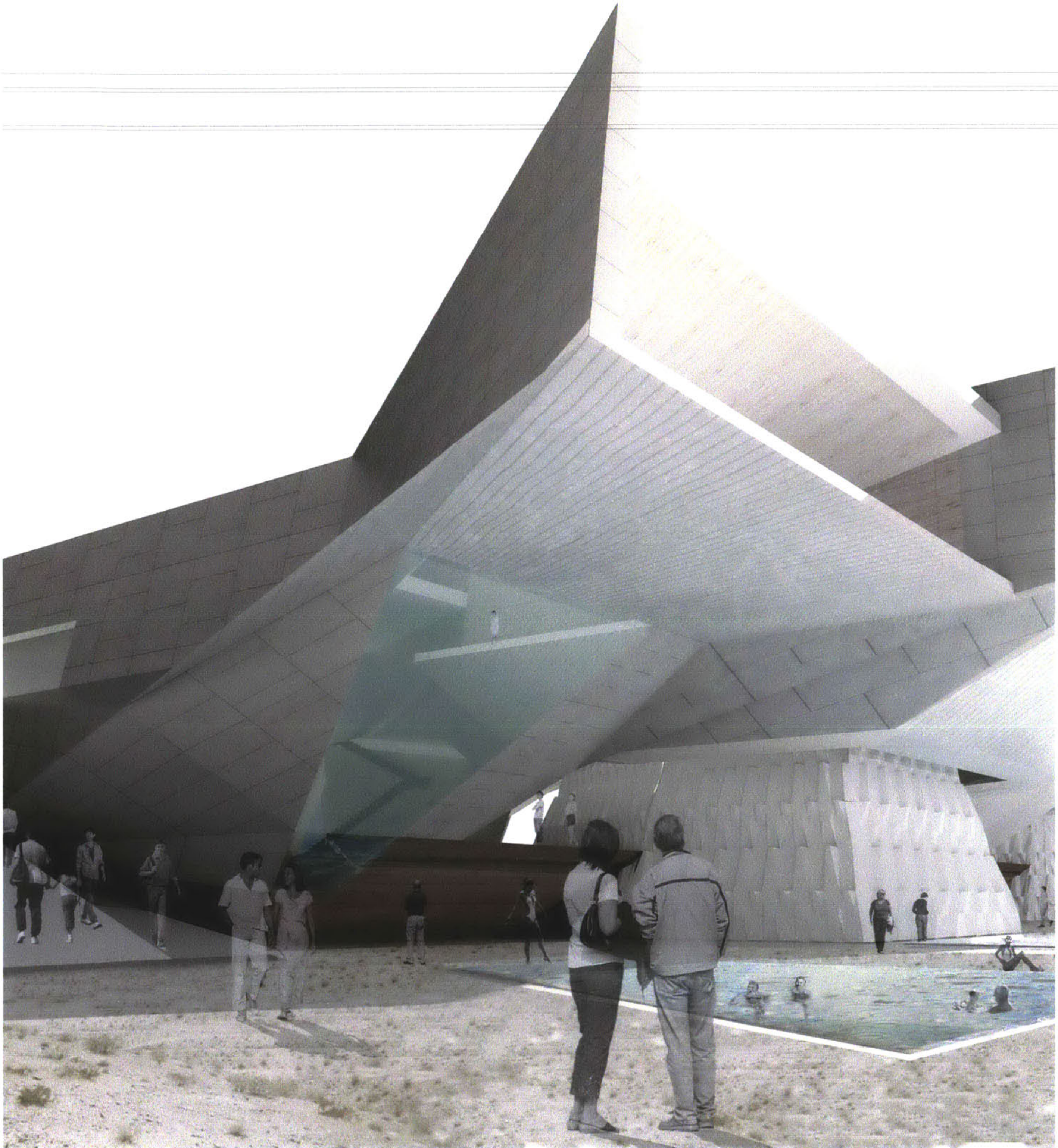
BIO-POOL SPA WALKTHROUGH

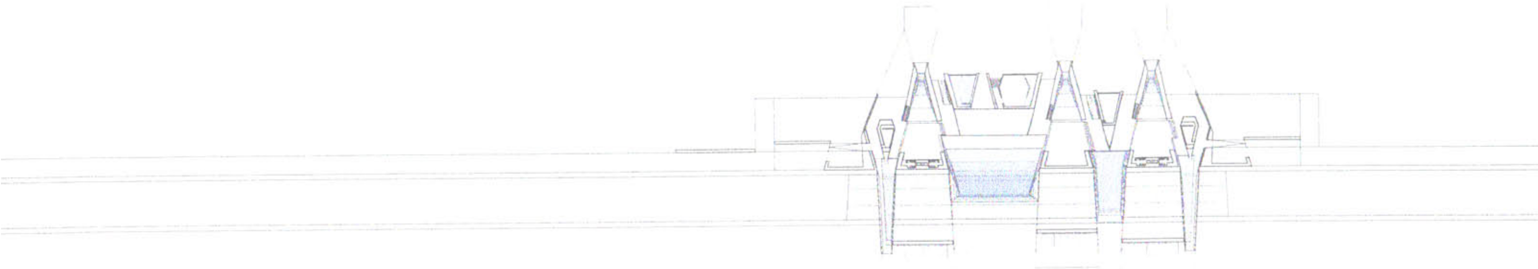
Exiting the builidng, one walks down a ramp where constructed ground meets desert sand.



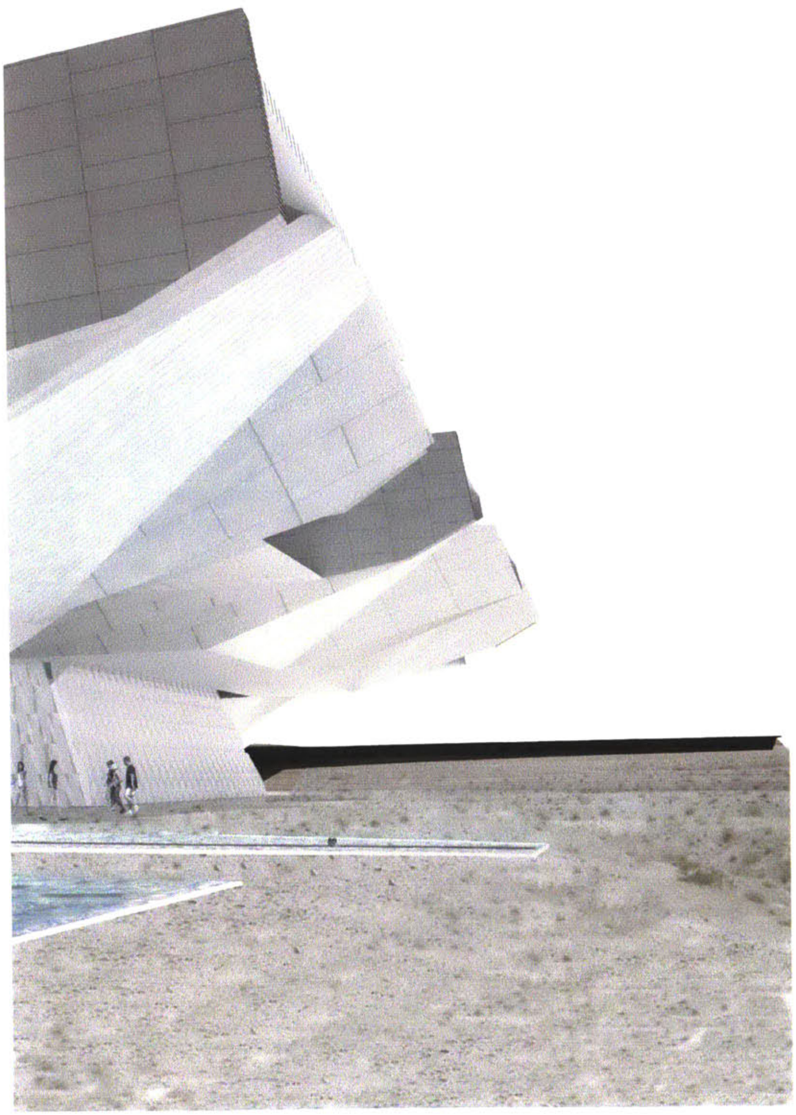


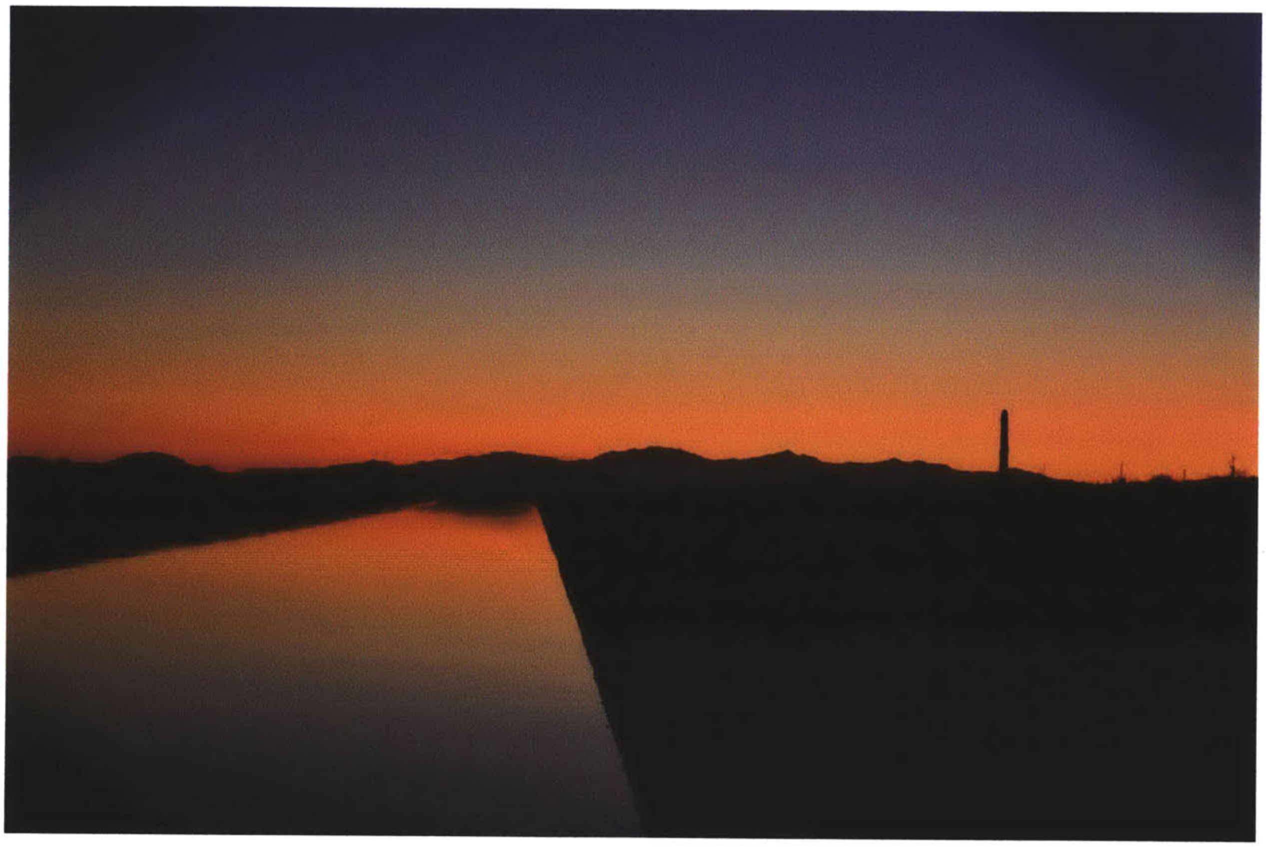
BIO-POOL SPA WALKTHROUGH





As one exits, through the rear of the building, they are shielded by a large roof structure. The monumentality of the roof is an expression of the amount of water it is capable of catching.





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