Phasing Sustainability
low tech sustainable housing prototype

A THESIS
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Hypothesis Statement

Mexico, like many developing countries, is in urgent need of housing solutions that incorporate sustainable technologies. While living in Troncones, Mexico for four months, I observed mismanagement of fresh water resources, under-utilized potential of passive solar energy, and a lack of waste management. There was no attempt to conserve resources or to recycle waste. The waste that is produced is burned in backyards, releasing harmful toxins into the atmoshere and detracting from the natural aesthetics of the community. The people of Troncones, Mexico and other developing countries need to be exposed on sustainable practices that form a partnership with nature, revealing the interconnection of technology with the natural world. Losing sight of this connection desensitizes a community's understanding of nature. Architecture and society in general needs to be based on the eco-centric belief that we must be accountable for the well being of all the Earth's inhabitants.

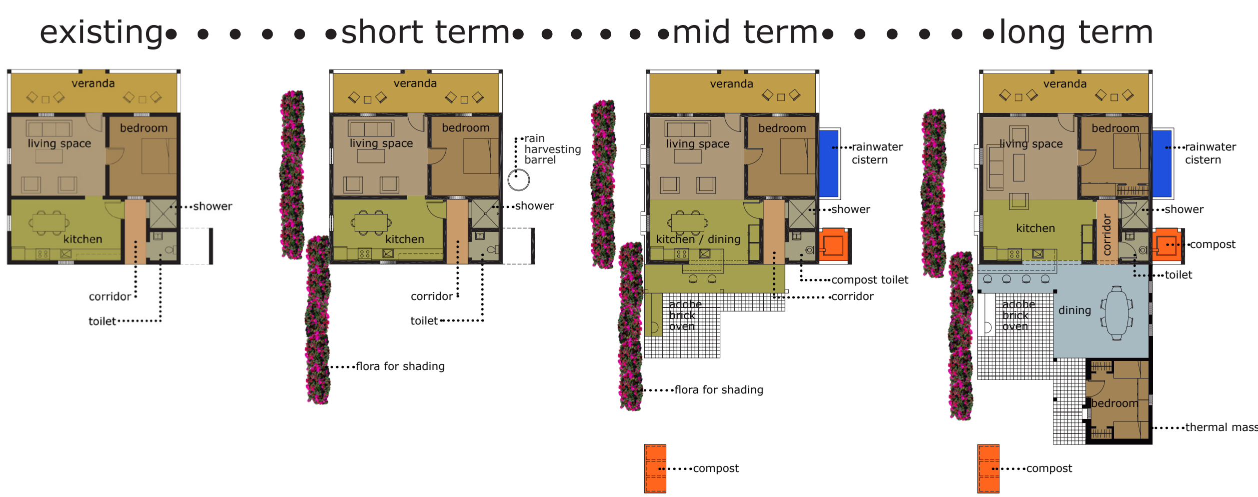
1.1 River in Troncones
mismanagement of fresh water resources

1.2 Existing House
hot and segmented living spaces

Thesis Statement

"It is time to stop designing in the image of the machine and start designing in a way that honors the complexity and diversity of life itself." -- Stuart Cowan

This thesis proposes a low tech[1] sustainable housing prototype for communities similiar to Troncones. The prototype begins with an existing housing condition and reaches a sustainable (ecological) housing condition[2] through phasing. The main goal is to design a successful, repeatable and ecologically sustainable housing prototype that will focus on producing thermal and water technology similar to those produced by the University of Texas design/build program, BaSiC Initiative[3] The housing prototype is intended to help train local inhabitants in cooperative construction techniques that express the interconnected cycles of technology with nature.



2.1 Phasing Sustainability
phasing from an existing condition

Research Statement

An existing dwelling in Troncones was chosen to apply the proposed prototype. The dwelling has neglected some of the existing design vernacular of some of the older dwellings. Indigenous adobe brick has been replaced by fired clay brick. The dwelling does not seem to take advantage of the opportunity for passive cooling and has poor infrastructure for water and waste. Existing knowledge gathered on Design-build case studies that focused on low-tech sustainable housing solutions helped to inform this Thesis. Material use and construction methods were examined that could be applied in Troncones and applied to a wider application of similar conditions in various developing countries.

The first precedent that was reviewed, BaSiC Initiative, explores the use of indigenous materials while teaching Design-build methods to architecture students and local inhabitants. Sergio Palleroni, Co-founder and Director of BaSiC Inititive, started the program in 1986 as a program to assist poor indigenous farmers in central Mexico. The BaSiC Initiative program has several case studies which where done in Mexico, using a concrete post and beam structure with adobe brick infill. Similiar methods and materials will be used in Troncones.

3.1 Existing Housing Condition.
This dwelling in Troncones was chosen to apply the proposed prototype.

3.2 BaSiC Initiative
Post and beam housing prototype that is repeatable and sustainable.

The second precedent, the architecture of Hassan Fathy,[4] explores the use of appropriate technology to provide passive cooling solutions. Fathy's use of adobe brick to create thermal mass, ventilation strategies, and his methods for training local inhabitants are low tech sustainable solutions which will be applied in Troncones.

The third precedent, Practical Action,[5] examines the use of new technologies and local resources in order to develop a housing prototype. The prototype is refined and improved by working with indigenous people who are familiar with locally sourced materials. Troncones has similar conditions to the case studies that were researched. The proposed prototype will use local indigenous materials to make adobe bricks and Micro Concrete Roofing tiles (MCR).

4.1 Hassan Fathy: Stopplaere House
Fathy incorporated dense brick walls and traditional courtyard forms to provide passive cooling.

4.2 - 4.3 Micro Concrete Roofing Tiles
Practical Action's goal is to help the local inhabitants use new technologies and bring sustainable improvements to people's lives.

Research and Scholarship in the Field

Three architectural precedents were examined so that existing design research could be used to inform this thesis by providing examples of issues explored, methods used, and the results of those methods. Useful knowledge gained from the review of these precedents was used to create a thesis that extends existing knowledge of low tech sustainable housing. The use of indigenous materials, passive cooling, and water management are further explored through a series of phased solutions.

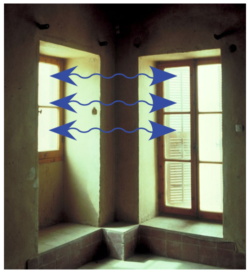
In the first precedent, BaSiC Initiative, used a concrete post and beam system to provide structural rigidity. This is typical practice in Mexico, although indigenous adobe brick is used instead of fired clay brick. Some local builders of Troncones know how to make adobe bricks, but it is not practiced because of the availability of fired clay bricks. This thesis reintroduced the use of adobe brick as a primary building material. Adobe bricks can be produced on site because of ideal soil composition and is a cost effective method because labor is so affordable.

The second precedent, the architecture of Hassan Fathy, used extruded window openings, vents just above the floor, exhaust vents in high vaulted areas, and the traditional courtyard to improve air flow. All of these methods were used in this thesis as a passive cooling method to improve thermal comfort.

5.1 Local Indigenous Materials
BaSiC Initiative teaches the local inhabitants and students how to use locally available and sustainable building materials.

Earth, straw, and water are used to make sun-dried adobe bricks.

5.2 Hassan Fathy - Stopplaere House
Window placement provides good cross-ventilation.



5.3 Hassan Fathy - Shahira Mehrez Apartment
Hot air exhaust is located in high vaulted areas.

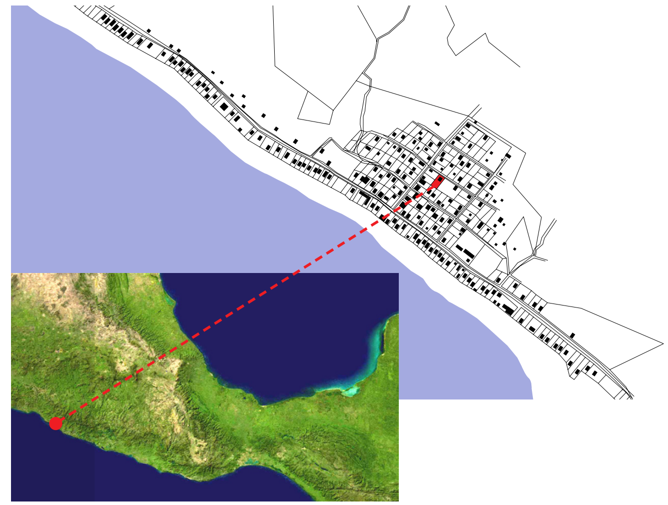
The third precedent, Practical Action, used Micro Concrete Roofing tiles (MCR) a new technology which is easy to make, with local resources, is half the weight but just as strong as fired clay roofing tile. MCR's are recommended for use in roof repair, ridge venting, and roof addition applications in this thesis.

It is important for the local indigenous people to participate in low-tech and low-cost sustainable building methods through a series of phased strategies. People need to be involved in the building process because they can help advise on the architectural condition and function of spaces, as well as help provide the experience of traditional design vernacular while creating a sustainable housing condition. An existing house is phased towards a sustainable condition, starting with short term conditions which are the easiest to change and lowest cost. The house is then phased to mid term conditions which are larger scale low-tech solutions that are more expensive and labor intensive. Finally, the house will be phased to long term conditions that are the most expensive and labor intensive of all sustainable solutions.

6.1 Micro Concrete Tiles (MCR)
Roofing alternative that reduces cost and uses local resources.

Phasing Sustainability: The Village of Troncones

The Village of Troncones is located in the state of Guerrero, Mexico on the Pacific coast. Nine hundred and twenty permanent residents live in this beach community, which caters to vacationers in beach-front rental properties and vacation homes. A majority of the residents live within the impoverished inner-city in small single family homes. Troncones has no infrastructure for water or sewer so septic systems and water storage tanks are used. The village is very hot and humid with a dew point averaging above 70°F. Lack of water management and poor dwelling design relating to thermal comfort have inspired this thesis. The existing house that was chosen to phase sustainability is centrally located within the village.

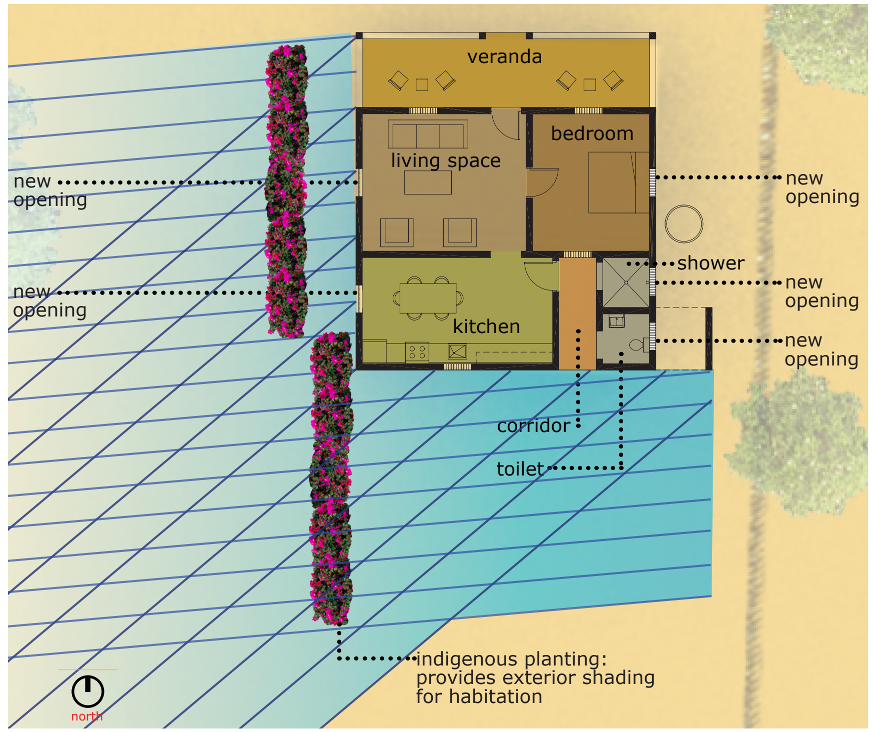


7.1-7.3 Images of Troncones
Troncones, Guerrero, Mexico
Latitude:17 39'N, Longitude: 101 33'W

Thermal Comfort - Short Term Phase

Examining the existing thermal comfort issues of the house reveals insufficient ventilation and solar control. The house has few openings on the west side of the house where prevailing winds could help to cool interior spaces. There is no flora or trees close to the house to provide shading.

Windflow studies[6] on the existing conditions with the proposed added openings show a vast improvement in airflow through the interior spaces. The amount of inlet area for proper ventilation was calculated. Venting and windows were added to bring cool air into the house and ridge venting was installed at the roof for hot air to escape.



8.1 Short Term Floor Plan
Prevailing winds range on average from 265° west to 230° southwest

calculated sizing required for venting
total opaque wall area x Uwall x outside design temp / total floor area
1157x.41x15/690=10.3 Btu/h sf
total roof area x Uwall x outside design temp / total floor area
740x.72x35/690=27 Btu/h sf
total = 37.3 Btu/h sf

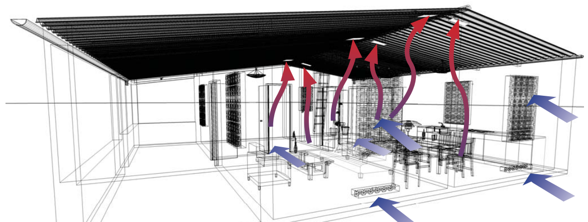
2.5% (29 sf) of wall area needs to be inlet for ventilation

proposal: adding cross-ventilation
add 3'-0"x4'-0" open celled block windows (2)= 12 sf of venting
add 3'-0"x6" low inlet vents (2) = 3 sf of venting
add 3'-0"x1'-4" venting (3) at east wall
15 sf + existing 14 sf = 29 sf for venting

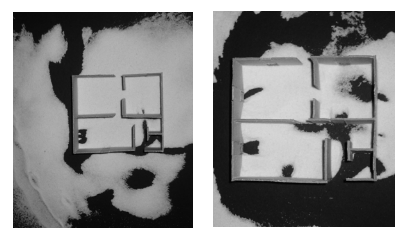
8.5 Ventilation Calcs
venting existing house

Results

cross-ventilation:
increased ventilation surface area by 200%, 37.3 Btu/h sf



8.4 Airflow Diagram
Cool air enters low, hot air exits at ridge vent



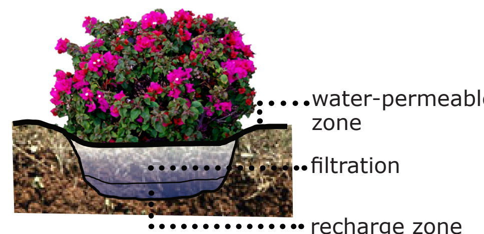
existing condition proposed openings

8.2-8.3 Windflow Studies
Prevailing winds from 265° west

Using indigenous flora as a low tech solution for solar control was the short term proposal. Sun path studies[7] were performed during the intense heating period of 10:00 am-4:00 pm on winter and summer soltice to reveal the extreme conditions the sun had on the house. Studies of the existing and proposed conditions provided the necessary information to determine flora placement. The indigenous flora is a low cost solution that will provide shaded exterior spaces for habitation and cooler building surfaces.

9.1-9.2 Sun Path Studies
Summer solstice during intense heating period

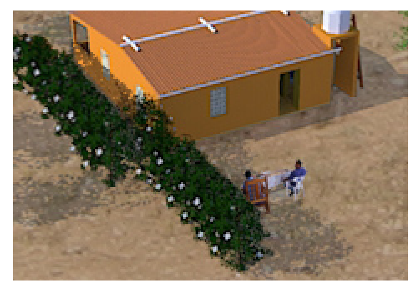
indigenous flora: Camellia
grows to 8'-10' high
provides shade
slows down water flows (runoff)
and allows the rain to soak into
the ground



9.3 Indigenous Flora
Camellia: Grows to 10' high

Results

flora for shading:
304 sf of native flora added, providing exterior cooling pockets and shaded building surfaces


9.4 Low Tech Solar Control
Cooler spaces for habitation

Thermal Comfort - Mid Term Phase

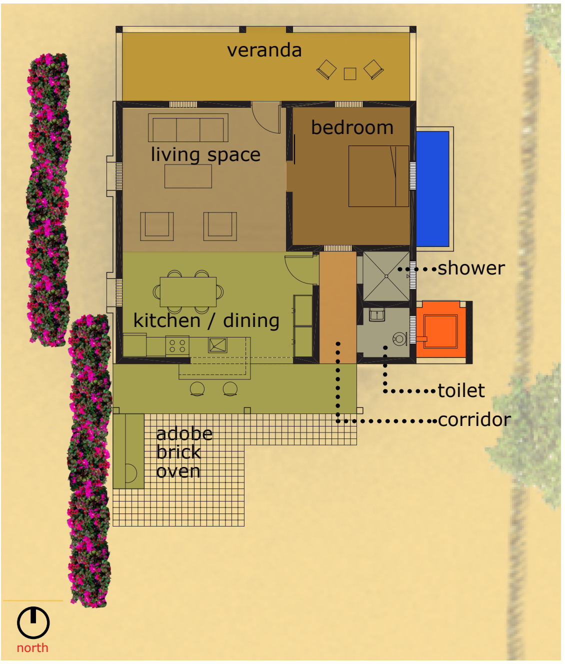
Mid term thermal comfort conditions focus on phasing wall removal and solar controls to the house. The existing house has hot segmented spaces with poor natural lighting.

10.1 Hot Segmented Spaces
View from the existing kithen/ dining into the living room.

10.3 Extending Interior
View from living room into the kitchen/dining.

Windflow studies show a vast improvement in airflow through the interior spaces by removing walls. Opening the exterior south wall and the interior wall between the living space and the kitchen allows the southwest winds to flow deep into the dwelling.

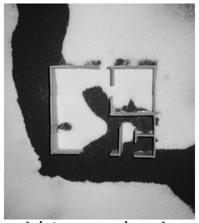
The integrity of the structural concrete post and beam frame is left intact and existing fired clay brick infill is removed to open spaces and extend the interior spaces into exterior areas of habitation. An adobe brick oven was added to provide an exterior cooking space, minimizing interior cooking and helping to provide cooler interior spaces.



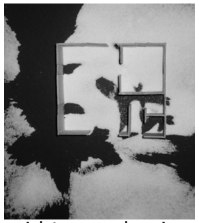
10.2 Mid Term Floor Plan

10.4 Longitudinal Section
Section at entry porch through the kitchen/dining.

10.5 Exterior Habitation
View through the kithen/dining into the living room.



mid term phasing
winds from 230°
southwest



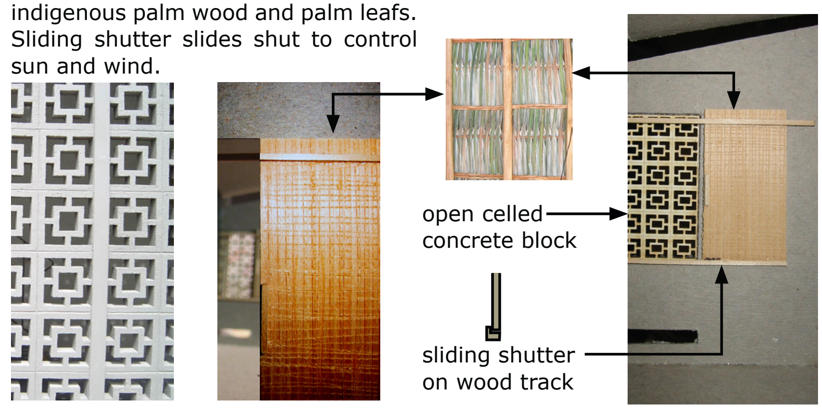
mid term phasing
winds from 265°
west

10.6-10.7 Windflow Studies
Prevailing winds

The traditional design of vernacular windows in Troncones are open celled concrete blocks within the window opening. The window is open to the sun, wind, and rain providing no solar controls.

Indigenous palm wood and leaves are used to make low tech sliding door and window shutter solar controls. The shutters can provide cooler interior spaces by preventing direct sunlight. The shutters can help provide warmer interior spaces protecting from wind and rain in cooler months.

Sliding shutter is constructed of indigenous palm wood and palm leafs. Sliding shutter slides shut to control sun and wind.



view through solar controls

sliding door at bedroom

solar controls at west wall

11.1-11.4 Solar Controls
Sliding window and door shutters

Results

wall removal:
280 sf of wall was removed at kitchen to improve interior airflow
>37.3 Btu/h sf (>30 Btu required)

sliding shutter:
24 sf at windows
21 sf at door
controls airflow/shade

Thermal Comfort - Long Term Phase

The existing house needed additional space in order to comfortably accommodate a family of four. Long term thermal comfort conditions were introduced in exterior living spaces. Indigenous materials were used for roof and thermal mass walls on the addition to the house.

Exterior living spaces were added to the house to provide cooler spaces of habitation. A dining area and a seated countertop at the kitchen were added areas that provided protection from direct sunlight. Windflow and sun path studies were used to help determine the orientation of the new spaces and window placement to maximize ventilation and shading.

12.4 Exterior Living Spaces
View at kithen and dining

Indigenous materials were used to add additional spaces and to repair existing spaces. Troncones has ideal soil compostion for making adobe bricks. The bricks were used to make thermal mass walls. Abobe bricks are cheaper then fired clay bricks and can be formed on site.

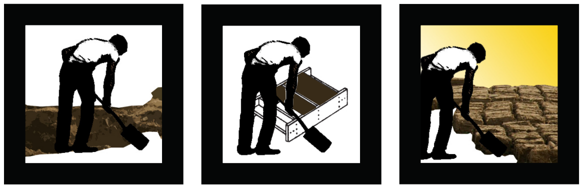
Troncones soil composition
Cambisol - sandy loam
Metamorphics - exposed subsurface rocks by soil erosion

desirable soils for brick-making:
soils classified as loamy sands, sandy loams or sandy clay loams contain sand, clay, and silt ideal for making adobe brick

12.5 Adobe Brick Data and Diagram
Soil composition and how to make bricks

procedure

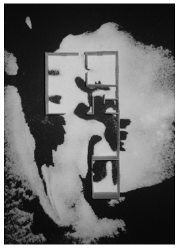
mix form cure



4.9 pesos per adobe brick (labor & mat'l)
7.1 pesos per fired clay brick (labor & mat'l)

31% cost savings

12.1 Long Term Floor Plan



long term phasing
265° west

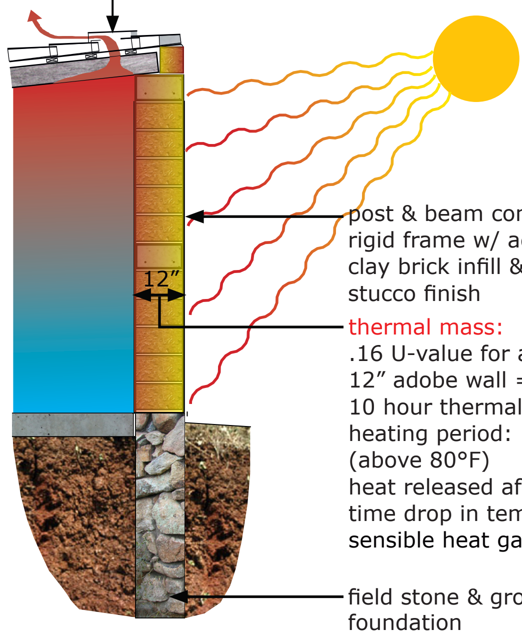
12.2 Windflow Studies
Prevailing winds

10 am Jun 21

12.3 Sun Path Studies
Intense heating period

Micro concrete roofing tiles (MCR) is a local resource that was used in lieu of traditional clay tiles on the house addition and on repairs. The concrete tiles are highly durable, lightweight, and reduce heat gain because they reflect UV rays.

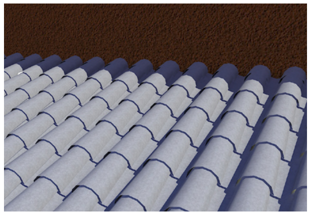
Thermal mass walls were used to increase the thermal lag.[8] The adobe brick wall absorbs the sun's heat during the intense heating period and releases the heat through the roof venting after the night time temperture drops. The wall thickness was increased to 12" to provide a 10 hour thermal lag period for solar heat to pass through the walls.



13.1 Thermal Mass
Night ventilation of thermal mass

Use:
indigenous roof
(repair and addition)

Micro Concrete
Roofing tiles (MCR):
reduced cost
local resource
reflects UV rays



Micro Concrete Roofing tiles (MCR)

Roofing	Weight (kg/m2)
Clay tiles	40–80
MCR tiles	25–30

13.3 Indigenous Roofing Data
Micro Concrete Roofing tiles (MCR)

13.2 East Perspective
Dining and bedroom addition using thermal mass

Results

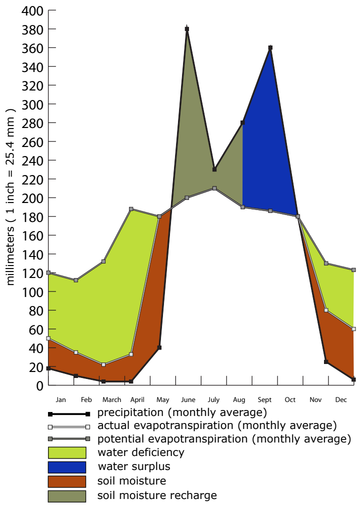
exterior living spaces:
exceeds 45 Btu/h sf required for a 2 bedroom dwelling

indigenous materials:
adobe brick: 31% cost savings
MCR tiles:lightweight & reflects UV rays

thermal mass:
.16 U-value = 10 hour thermal lag
sensible heat gain =1,906 Btu/h

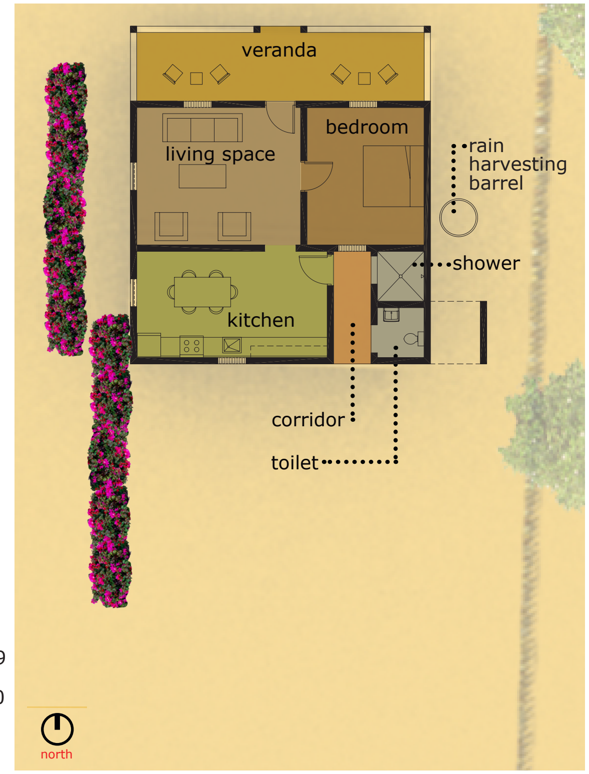
Water Management - Short Term Phase

Water availability in Troncones is of major concern. The only time it rains is during the rainy season from June through September. Troncones has no infrastructure for domestic water. Non-potable water is delivered by truck on a weekly basis. Bottled water must also be purchased for potable use. Water costs on average of $704.00 per person per year.

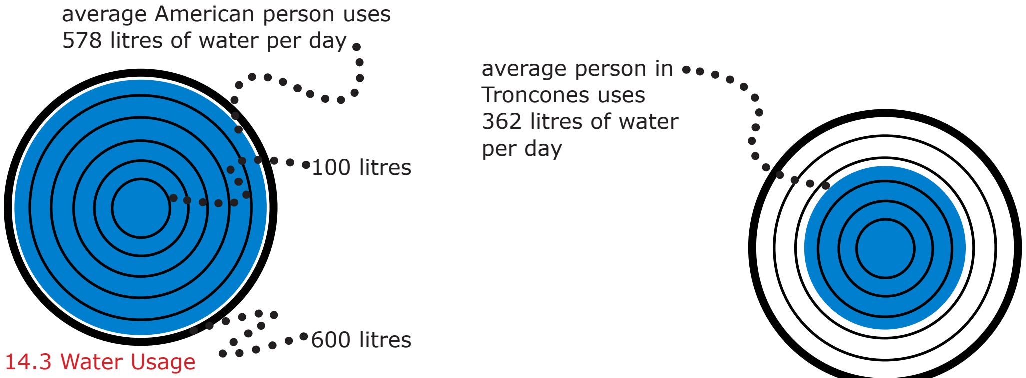


14.4 Troncones Water Cycle
Water balance data

Troncones residents do not use rainwater as a resource. Rainwater collection was the focus during the short term phase for irregation use. The water cycle patterns and domestic water usage of Troncones has been reviewed. Civic leader Victor Lopez was interviewed to determine the average daily water usage patterns of Troncones. The water cycle patterns were determined using Global Historical Climatology Network[9] and C.W. Thornthwaite water balance data.[10]



14.1 Short Term Floor Plan



14.3 Water Usage
Average person daily usage

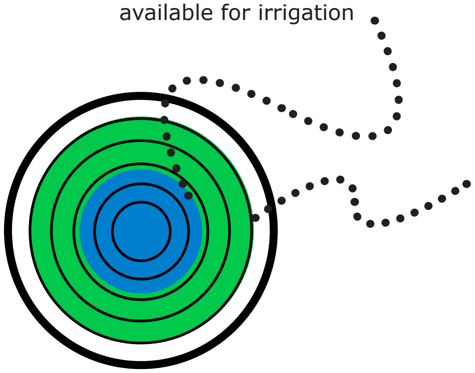

14.2 Water Delivery
Water storage tank being filled

The existing roof was used as the catchment area to collect untreated rainwater for irrigation use. Rainwater harvesting calcs were used to determine the percentage of reduced water usage. A rainwater scupper and downspout system was installed to collect water in a rainwater barrel. A spigot in the barrel allows for water to be collected into multiple barrels or to a hose for irrigation use. The rainwater harvesting calcs revealed that the catchment area will provide enough rainwater to reduce water usage by 25%.

rainwater harvesting calcs:

g/cd x population=gpd
70.37x4=281.48 gallons per day
gpd x 365 days=gal/year
281.48x365=102,740.20 gallons per year
annual precipitation = 59.35
design precipitation = 39.53
catchment area (existing)= 1,292 sf
roof catchment supplies 25% of total usage
25,685 gallons supplied by roof yearly
25% total reduced usage

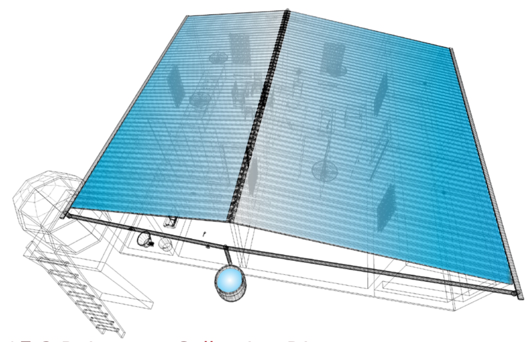
15.1 Rainwater Calcs
Existing roof - rain harvesting



15.5 Water for Irregation
Harvested rainwater is used for irrigation

untreated rainwater for irrigation:

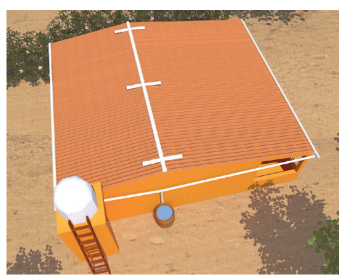
catchment area (existing)= 1,292 sf
roof catchment supplies 25% of total usage
53% of irrigation supplied
by untreated rainwater



15.2 Rainwater Collection Diagram
Short term phase - rain harvesting

Results

rainwater collection:
25% total reduced usage
53% of irrigation supplied
by untreated rainwater



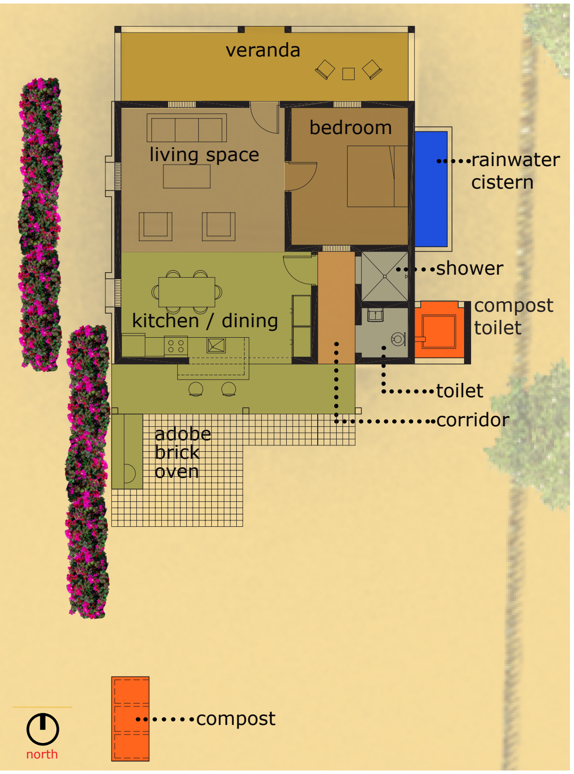
15.4 Rainwater Collection
Rain harvesting barrel

15.3 East Perspective
Short term phase - rain harvesting

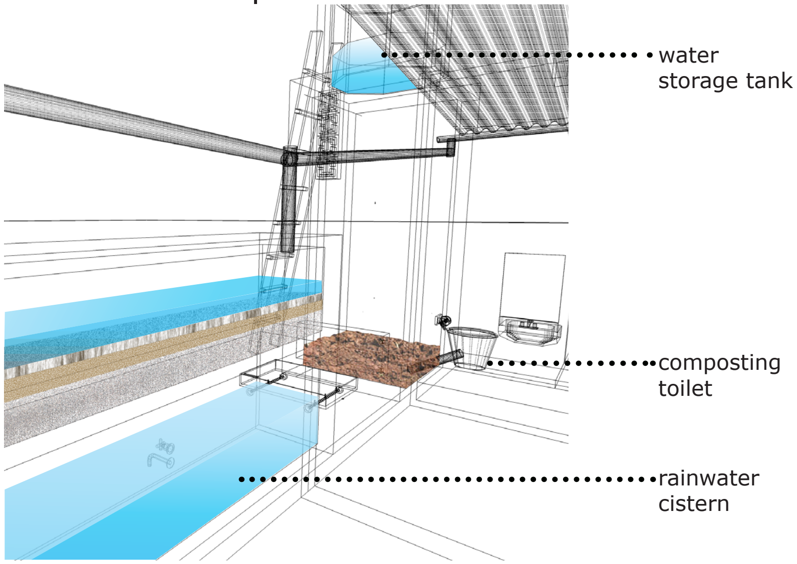
Water Management - Mid Term Phase

The average person in Troncones is paying over 11% of their income for water. Mid term phasing will focus on reducing water usage by using harvested rainwater and a waterless toilet.

A low tech rainwater cistern was used to provide treated water that could be used for domestic purposes but is not intended for potable use. Bottled drinking water needs to be purchased. The cistern was constructed of adobe brick with a plaster finish on the interior and exterior surface. The cistern collects water from the roof catchment area and is slowly drained by gravity through a biological filter system of sand and gravel to remove bacteria and small particles. The water works its way into the storage compartment for consumption. Rainwater harvesting calcs determined that the water usage could be reduced by 25% because the cistern could provide 265 litres of treated water (daily).



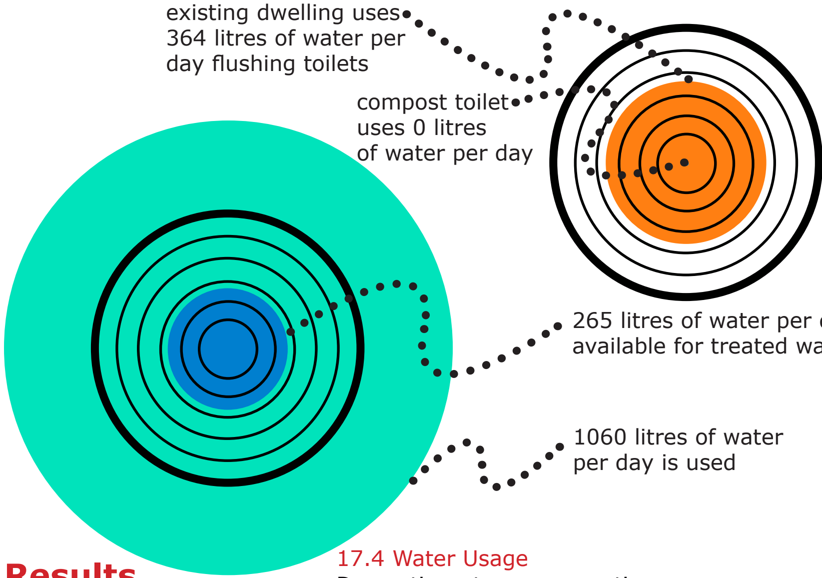
16.1 Mid Term Floor Plan



16.3 Water Management Diagram
Mid term phase - rainwater treatment and waterless toilet

16.2 East Perspective
Rainwater treatment and cistern

Changing to a waterless toilet has reduced water usage 364 litres per day for a family of four because of the water saved from toilet flushing. Thermophilic composting decomposes organic matter until it is broken-down into nutrient rich soil. The existing water storage tower was enclosed with adobe brick to create a compost storage bin. Oxygen, high temperatures, and a 12 month compost cycle destroys all pathogenic bacteria. Each compost bin was sized to hold 34 cubic feet of compost. Once the compost bin is full, the compost is transported to the multi-step compost bin. The compost will spend 4 months in each bin until the 12 month cycle is complete. The compost is then ready to be used as fertiliser.

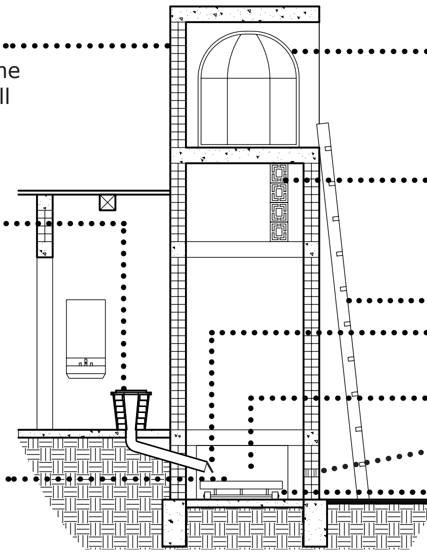


17.4 Water Usage
Domestic water comsumption

Results

rainwater harvesting:
25% total reduced usage of treated water

compost toilet:
25% total reduced usage and provides fertiliser



17.1 Section at Compost Toilet
Water tower and compost storage

17.2 SouthEast Perspective
Backyard of house

17.3 Multi-Step Compost Bin
12 month cycle composting

Water Management - Long Term Phase

Observing the Troncones daily water usage data, cost data, and the mismanagement of water resources reinforced the importance to construct a long term, low tech solution that would maximize water harvesting with new roof catchment areas. The new roof addition at the expanded exterior kitchen counter and the roof of the compost bin collected untreated rainwater in barrels for irrigation use. The rest of the roof catchment areas drained rainwater into the cistern for domestic water use. The treated water is then pumped up into the gravity fed storage tank using a hydraulic ram pump. 638 sf of new roof catchment area and 1,292 sf of existing roof catchment area reduced water usage by 37% because of rainwater harvesting. Water usage was reduced by 25% with the use of a waterless toilet. An average of 394 litres of rainwater was available daily. The long term conditions provided 62% less water usage.

18.1 Long Term Floor Plan

Troncones daily water usage:
kitchen faucet 9.5 litres per min.
(4 minute average) = 38 litres
bathroom faucet 9.5 litres per min.
(2 minute average) = 19 litres
showerhead 12 litres per min.
(7 minute average) = 84 litres
toilets 13 litres per flush
(7 flushes per person) = 91 litres
cooking and drinking water
(consumed per person) = 5 litres
irregation (flora) = 125 litres
362 litres total per person

water cost for trucked water:
.045 pesos per litre, water tank
holds 10 cubic meters (450 pesos)
.65 pesos per litre of bottled
potable water, 20 litres per bottle
(13 pesos)

19.32 pesos per person/day

18.4 Daily Water Usage Statistics
Troncones average usage per person

rainwater harvesting calcs:
g/cd x population=gpd
70.37x4=281.48 gallons per day
gpd x 365 days=gal/year
281.48x365=102,740.20 gallons per year
annual precipitation = 59.35
design precipitation = 39.53
catchment area (existing & addition)= 1,930 sf
roof catchment supplies 37% of total usage

38,014 gallons supplied by roof yearly

37% total reduced usage

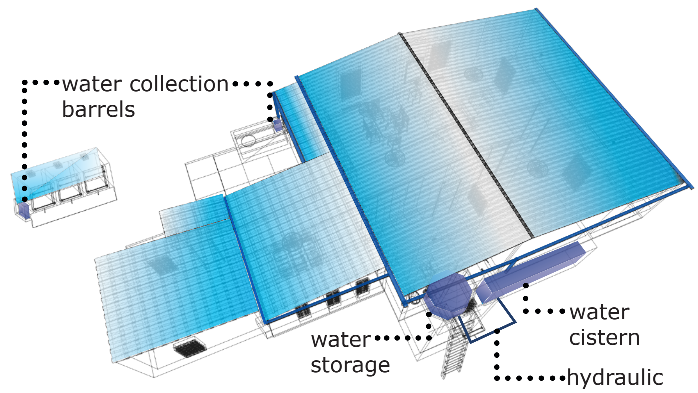
18.3 Rainwater Harvesting Calcs
New and existing catchment area

hydraulic ram pump uses water pressure to move water to gravity fed storage tank

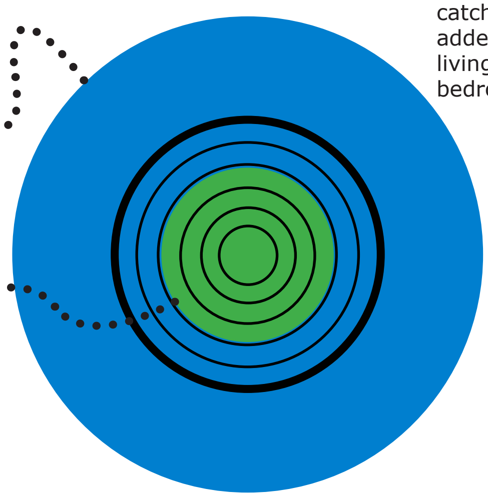
18.2 Water Pump
Hydraulic ram pump

Water cost was reduced to $7.34 pesos (.73 cents) per person per day and $2,680 pesos ($268.00 dollars) per person per year. $4,365 pesos ($435.50 dollars) equals 62% savings in water cost per person per year.

Cost savings from reduced water usage and indigenous material use will help provide extra money to maintain and improve the low tech ecological building solutions what were applied to this existing house.



19.1 Rainwater Collection Diagram
New and existing roof catchment area



19.3 Rainwater Collection
Reduced usage

19.2 Perspective at Rainwater Harvesting
New and existing roof catchment area

Results

rainwater collection:
37% total reduced usage
compost toilet:
25% total reduced usage
total reduced usage:
62% less water usage

water cost reduced:
Cost is 7.34 pesos per person/day (.73 cents)
$2,680 pesos ($268.00) per person per year
$4,365 pesos ($435.50) saved per person/year
62% less cost

Conclusion

The intent of this thesis was to design an ecologically sustainable housing prototype by phasing short term, mid term and long term solutions to an existing condition. These terms are meant to be a sequenced implementation and progression towards a long term goal. An existing dwelling in the Village of Troncones, Mexico was chosen to phase a series of low tech sustainable solutions for thermal comfort and water management. The dwelling was chosen because of a number of issues. It seemed to neglect some of the traditional design vernacular from the region because it did not use indigenous materials. The interior of the house had hot and humid segmented spaces with no ventilation or solar controls. The cost of water was very expensive because there was no infrastructure for water or sewage and the opportunity for collection of rainwater for reuse was ignored.

Implementing design solutions for all social classes will normalize and advance the technologies. Phasing existing sustainable technologies with the intent of learning more about the technology through experimentation, refinement, and an open dialogue with local indigenous people (who provide the experience of generations) hopefully will help to improve the technology. Evaluating the climatic data for the wind, sun, and rain, talking with the local villagers about water usage, water cost and material usage, and my personal experience of living in the existing conditions reinforced the direction of this thesis. It also has given me the aspiration to personally apply some of the proposed technologies to an existing housing condition in Troncones. Working on this thesis makes one realize how easy it is to waste water when it is readily available and it is not in ones mind-set to conserve as one goes about daily routines. The results that were learned from this thesis have made me think about the possibility of water treatment and reuse at the community scale and the infrastructure that would be necessary to service the entire village of Troncones.

This thesis has taught me to narrow my focus on a few specific topics and to provide the necessary evidence to clearly demonstrate a process that reveals results. This experience seems to bring to light a paradigm shift in architecture towards eco-design and a new awareness for all the Earth's inhabitants.

Endnotes

1 Low tech: technologically simple sustainable design strategies.

2 Existing housing condition: traditional design vernacular methods not involving sustainability.

3 BaSiC Initiative: University of Texas design/build program that teaches how to develop a sustainable housing prototype for community members and students. The BaSiC Initiative housing prototype is based on affordable, adaptable, and sustainable building techniques for housing communities in developing countries. See more about BaSiC Initiative at http://www.basicinitiative.org.

4 Hassan Fathy: in his book, *Natural Energy and Vernacular Architecture,* Fathy focuses on the use of natural energy to provide passive cooling.

5 Practical Action: was founded as ITDG (the intermediate Technology Development Group) by economist Dr. EF Schumacherto. Their goal is to help poor communities deal with the challenges of new technologies. See more about Practical Action at http://www.practicalaction.org.

6 Windflow studies: silica flour was blown with a hair dryer through a modeled replica of the house to simulate wind patterns at 265° west to 230° southwest.

7 Sun path studies: 3d computer renderings modeled sun conditions on the house during winter and summer solstice between the heating period of 10:00 am - 4:00 pm.

8 Thermal lag: a measurement of time that it takes solar heat to pass through a material.

9 Global Historical Climatology Network: monitors climate patterns, see http://www.ncdc.noaa.gov

10 C.W. Thornthwaite water balance data: the book, *Average Climatic Water Balance Data of the Continents,* analyzes average water cycles of the state of Guerrero, Mexico.

Fathy, Hassan. *Natural Energy and Vernacular Architecture : principles and examples with reference to hot arid climates.* **Chicago, Illinois: University of Chicago Press, c 1986.**
Hassan Fathy worked to re-establish the use of mud brick as an appropriate technology for housing for the poor. Fathy believed that countless experiments and the experience of generations of builders would aid in producing a successful solution to architecture. He focused on the use of natural energy to provide passive cooling for hot climates.

Kennedy, Joseph F. *Building Without Borders: Sustainable Construction for the Global Village.* **Gabriola Island, British Columbia: New Society Publishers, c 2004.**
Design/build methods for developing countries is the general focus of this book. The book provides discussion about shelter and sustainable development using low tech building technologies. The primary material discussions deal with using local resources to develop thermal mass systems with adobe brick. Practical Action (ITDG) addresses problems with housing, resources, and environmental restoration.

Van Der Ryn, Sim. *Ecological Design.* **Stuart Cowan. Washington, D.C.: Island Press, c 1996.**
Ecological Design discusses the much needed response to the environmental crisis by making connections between nature, culture, values, power relationships, and technology. It stresses the importance of creating a designed environment that reveals the interconnection of technology with the natural world. The book focuses on ecological design that minimizes environmentally destructive impacts by integrating itself with living processes.

Palleroni, Sergio. "Basic Initiative", [electronic bulletin board] available from **www.basicinitiative.org**
Basic Initiative teaches design/build sustainable architecture at the University of Texas at Austin. Students work with community members in developing countries to provide a sustainable housing prototype that can be repeated in future projects. The design/build process focuses on the use of locally available and sustainable materials.

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5. Jenkins, Joseph. The Humanure Handbook: A Guide to Composting Human Manure. White River Junction, VT: Chelsea Green Publishing, 2005.

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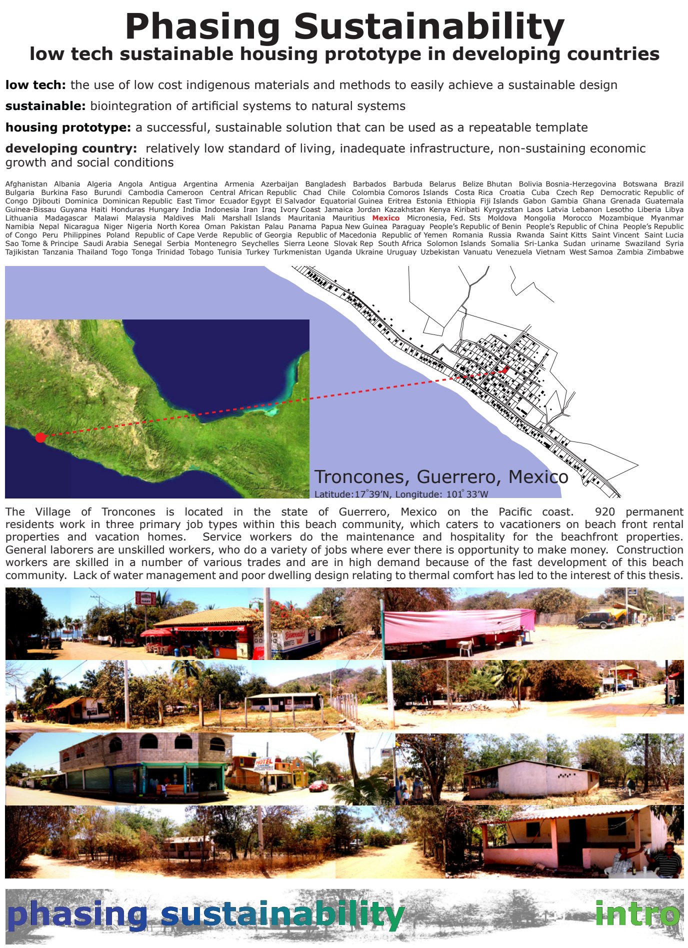
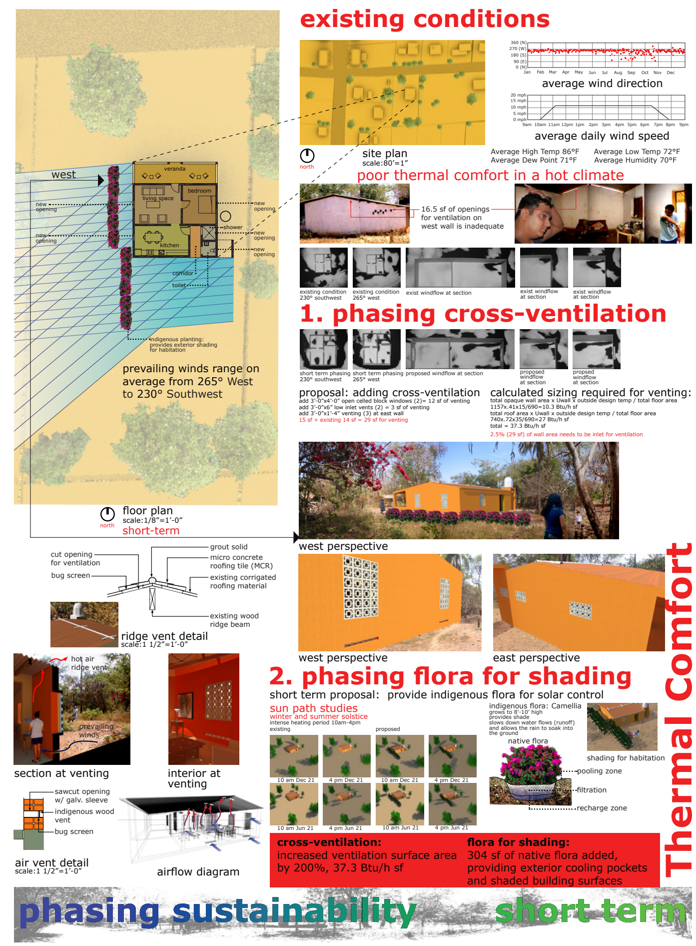
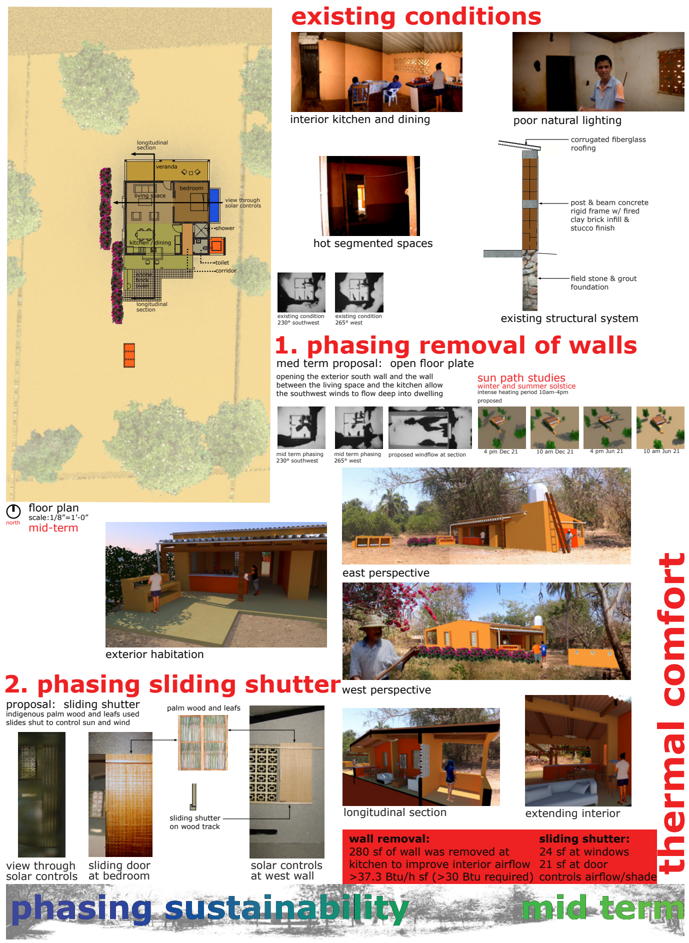
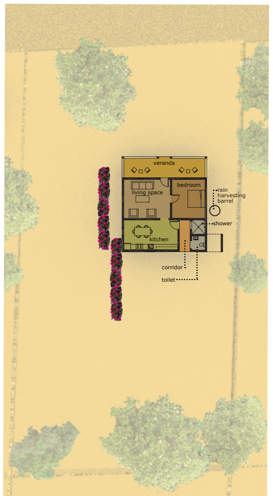
7. Yeang, Ken. Ecodesign: A Manual for Ecological Design. Great Britain: Wiley-Academy, 2006.


Phasing Sustainability
low tech sustainable housing prototype in developing countries
low tech: the use of low cost indigenous materials and methods to easily achieve a sustainable design
sustainable: biointegration of artificial systems to natural systems
housing prototype: a successful, sustainable solution that can be used as a repeatable template
developing country: relatively low standard of living, inadequate infrastructure, non-sustaining economic growth and social conditions
Afghanistan Albania Algeria Angola Antigua Argentina Armenia Azerbaijan Bangladesh Barbados Barbuda Belarus Belize Bhutan Bolivia Bosnia-Herzegovina Botswana Brazil Bulgaria Burkina Faso Burundi Cambodia Cameroon Central African Republic Chad Chile Colombia Comoros Islands Costa Rica Croatia Cuba Czech Rep Democratic Republic of Congo Djibouti Dominica Dominican Republic East Timor Ecuador Egypt El Salvador Equatorial Guinea Eritrea Estonia Ethiopia Fiji Islands Gabon Gambia Ghana Grenada Guatemala Guinea-Bissau Guyana Haiti Honduras Hungary India Indonesia Iran Iraq Ivory Coast Jamaica Jordan Kazakhstan Kenya Kiribati Kyrgyzstan Laos Latvia Lebanon Lesotho Liberia Libya Lithuania Madagascar Malawi Malaysia Maldives Mali Marshall Islands Mauritania Mauritius Mexico Micronesia, Fed. Sts Moldova Mongolia Morocco Mozambique Myanmar Namibia Nepal Nicaragua Niger Nigeria North Korea Oman Pakistan Palau Panama Papua New Guinea Paraguay People's Republic of Benin People's Republic of China People's Republic of Congo Peru Philippines Poland Republic of Cape Verde Republic of Georgia Republic of Macedonia Republic of Yemen Romania Russia Rwanda Saint Kitts Saint Vincent Saint Lucia Sao Tome & Principe Saudi Arabia Senegal Serbia Montenegro Seychelles Sierra Leone Slovak Rep South Africa Solomon Islands Somalia Sri-Lanka Sudan uriname Swaziland Syria Tajikistan Tanzania Thailand Togo Tonga Trinidad Tobago Tunisia Turkey Turkmenistan Uganda Ukraine Uruguay Uzbekistan Vanuatu Venezuela Vietnam West Samoa Zambia Zimbabwe
Troncones, Guerrero, Mexico
Latitude:17°39'N, Longitude: 101°33'W
The Village of Troncones is located in the state of Guerrero, Mexico on the Pacific coast. 920 permanent residents work in three primary job types within this beach community, which caters to vacationers on beach front rental properties and vacation homes. Service workers do the maintenance and hospitality for the beachfront properties. General laborers are unskilled workers, who do a variety of jobs where ever there is opportunity to make money. Construction workers are skilled in a number of various trades and are in high demand because of the fast development of this beach community. Lack of water management and poor dwelling design relating to thermal comfort has led to the interest of this thesis.
phasing sustainability
intro

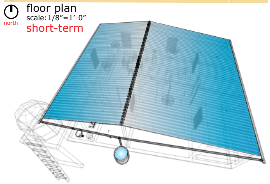

existing conditions
average wind direction
average daily wind speed
site plan
scale:80'=1"
north
Average High Temp 86°F
Average Dew Point 71°F
Average Low Temp 72°F
Average Humidity 70°F
poor thermal comfort in a hot climate
16.5 sf of openings for ventilation on west wall is inadequate
existing condition 230° southwest
existing condition 265° west
exist windflow at section
exist windflow at section
exist windflow at section
1. phasing cross-ventilation
short term phasing 230° southwest
short term phasing 265° west
proposed windflow at section
proposed windflow at section
propsed windflow at section
proposal: adding cross-ventilation
add 3'-0"x4'-0" open celled block windows (2)= 12 sf of venting
add 3'-0"x6" low inlet vents (2) = 3 sf of venting
add 3'-0"x1'-4" venting (3) at east wall
15 sf + existing 14 sf = 29 sf for venting
calculated sizing required for venting:
total opaque wall area x Uwall x outside design temp / total floor area
1157x.41x15/690=10.3 Btu/h sf
total roof area x Uwall x outside design temp / total floor area
740x.72x35/690=27 Btu/h sf
total = 37.3 Btu/h sf
2.5% (29 sf) of wall area needs to be inlet for ventilation
west
new opening
prevailing winds range on average from 265° West to 230° Southwest
floor plan
scale:1/8"=1'-0"
short-term
west perspective
cut opening for ventilation
bug screen
grout solid
micro concrete roofing tile (MCR)
existing corrigated roofing material
existing wood ridge beam
ridge vent detail
scale:1 1/2"=1'-0"
west perspective
east perspective
2. phasing flora for shading
short term proposal: provide indigenous flora for solar control
sun path studies
winter and summer solstice
intense heating period 10am-4pm
existing
proposed
10 am Dec 21
4 pm Dec 21
10 am Jun 21
4 pm Jun 21
indigenous flora: Camellia
grows to 8'-10' high
provides shade
slows down water flows (runoff) and allows the rain to soak into the ground
native flora
shading for habitation
pooling zone
filtration
recharge zone
hot air ridge vent
prevailing winds
section at venting
interior at venting
sawcut opening w/ galv. sleeve
indigenous wood vent
bug screen
air vent detail
scale:1 1/2"=1'-0"
airflow diagram
cross-ventilation:
increased ventilation surface area by 200%, 37.3 Btu/h sf
flora for shading:
304 sf of native flora added, providing exterior cooling pockets and shaded building surfaces
Thermal Comfort
phasing sustainability
short term


existing conditions
interior kitchen and dining
poor natural lighting
hot segmented spaces
corrugated fiberglass roofing
post & beam concrete rigid frame w/ fired clay brick infill & stucco finish
field stone & grout foundation
existing structural system
existing condition 230° southwest
existing condition 265° west
floor plan
scale:1/8"=1'-0"
north
mid-term
1. phasing removal of walls
med term proposal: open floor plate
opening the exterior south wall and the wall between the living space and the kitchen allow the southwest winds to flow deep into dwelling
sun path studies
winter and summer solstice
intense heating period 10am-4pm
proposed
mid term phasing 230° southwest
mid term phasing 265° west
proposed windflow at section
4 pm Dec 21
10 am Dec 21
4 pm Jun 21
10 am Jun 21
east perspective
exterior habitation
west perspective
2. phasing sliding shutter
proposal: sliding shutter
indigenous palm wood and leafs used
slides shut to control sun and wind
palm wood and leafs
sliding shutter on wood track
view through solar controls
sliding door at bedroom
solar controls at west wall
longitudinal section
extending interior
wall removal:
280 sf of wall was removed at kitchen to improve interior airflow
>37.3 Btu/h sf (>30 Btu required)
sliding shutter:
24 sf at windows
21 sf at door
controls airflow/shade
thermal comfort
phasing sustainability
mid term


existing conditions
sensible heat gain through existing wall system
q=UxAxDETD
4,886 Btu/h =.41x1157x10.3
thermal transmittance (U-value) for fired brick is .41 for a 8" thick wall
inadequate Thermal Lag:
5.5 hours
Design Dry-Bulb=89°F
Mean Daily Range=20°F
Lowest Dry-Bulb=89°-20°=69°
lowest mass temperature is 1/4 of mean daily range + lowest dry-bulb
5°+69°=74°
ideal conditions for night ventilation of thermal mass
existing condition 230° southwest
existing condition 265° west
veranda
living space
bedroom
rainwater cistern
shower
kitchen
corridor
compost
toilet
dining
bedroom
compost
1. phasing exterior living spaces
long term proposal: open floor plate
exterior dining and kitchen space allows the winds to flow through entire dwelling
sun path studies
winter and summer solstice
intense heating period 10am-4pm
proposed
long term phasing 230° southwest
long term phasing 265° west
4 pm Dec 21
10 am Dec 21
4 pm Jun 21
10 am Jun 21
east perspective
floor plan
scale:1/8"=1'-0"
north
long-term
2. phasing indigenous materials
adobe brick
Troncones soil composition
Cambisol - sandy loam
Metamorphics - exposed subsurface rocks by soil erosion
desirable soils for brick-making:
soils classified as loamy sands, sandy loams or sandy clay loams contain sand, clay, and silt ideal for making adobe brick
procedure
mix
form
cure
4.9 pesos per adobe brick (labor & mat'l)
7.1 pesos per fired clay brick (labor & mat'l)
31% cost savings
indigenous roof (repair and addition)
Micro Concrete Roofing tiles (MCR):
reduced cost
local resource
reflects UV rays
roofing
Roofing | Weight (kg/m2)
Clay tiles | 40–80
MCR tiles | 25–30
west perspective
3. phasing thermal mass
venting through roof tiles
post & beam concrete rigid frame w/ adobe clay brick infill & stucco finish
thermal mass:
.16 U-value for a 12" adobe wall =
10 hour thermal lag
heating period: 10am-8pm (above 80°F)
heat released after night time drop in temp.
sensible heat gain =1,906 Btu/h
12"
field stone & grout foundation
night ventilation of thermal mass
interior kitchen and dining
exterior living spaces:
exceeds 45 Btu/h sf required for a 2 bedroom dwelling
indigenous materials:
adobe brick: 31% cost savings
MCR tiles:lightweight & reflects UV rays
thermal mass:
.16 U-value = 10 hour thermal lag
sensible heat gain =1,906 Btu/h
thermal comfort
phasing sustainability
long term



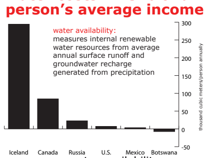
floor plan
scale:1/8"=1'-0"
north
short-term



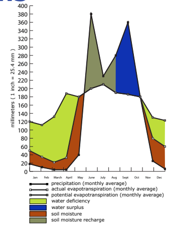
rain water collection diagram

existing conditions

Troncones daily water usage:
362 litres per person
water cost for trucked water:
19.32 pesos per day
7,044.50 pesos per person per year
water costs 11.3% of a person's average income



water availability

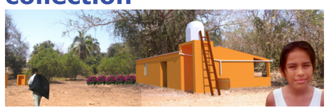


Troncones water cycle

all water is delivered by truck

rainwater is not collected

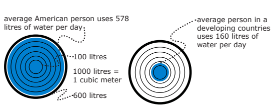
1. phasing rainwater collection



east perspective

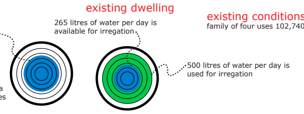
perspective at rainwater collection

rainwater harvesting calcs:
g/cd x population=gpd
70.37x4=281.48 gallons per day
gpd x 365 days=gal/year
281.48x365=102,740.20 gallons per year
annual precipitation = 59.35
design precipitation = 39.53
catchment area (existing)= 1,292 sf
roof catchment supplies 25% of total usage
25,685 gallons supplied by roof yearly
25% total reduced usage



existing conditions

existing dwelling



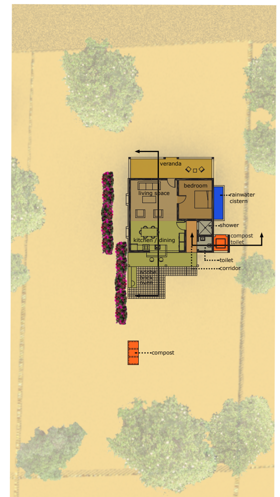
existing conditions
family of four uses 102,740.20 gallons per year

untreated rainwater for irregation:
catchment area (existing)= 1,292 sf
roof catchment supplies 25% of total usage
53% of irregation supplied by untreated rainwater

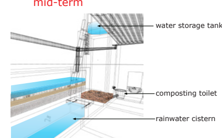
rainwater collection:
25% total reduced usage
53% of irregation supplied by untreated rainwater

water management

phasing sustainability short term

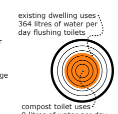


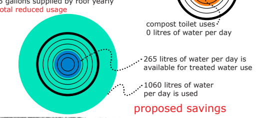
floor plan
scale:1/8"=1'-0"
north
mid-term



water management diagram

rainwater harvesting calcs:
g/cd x population=gpd
70.37x4=281.48 gallons per day
gpd x 365 days=gal/year
281.48x365=102,740.20 gallons per year
annual precipitation = 59.35
design precipitation = 39.53
catchment area (existing)= 1,292 sf
roof catchment supplies 25% of total usage
25,685 gallons supplied by roof yearly
25% total reduced usage





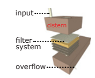
proposed savings

existing conditions

potable water used for toilet

1. phasing rainwater harvesting

east perspective



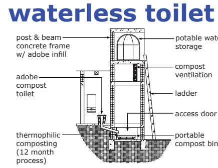
rainwater cistern:
reuse for non-potable use and irrigation

rainwater treatment

east perspective

2. phasing waterless toilet

compost toilet



section at compost toilet
scale:1/4"=1'-0"

12 month cycle compost bin

rainwater harvesting:
25% total reduced usage of treated water
compost toilet:
25% total reduced usage and provides fertiliser

water management

phasing sustainability mid term

floor plan
scale:1/8"=1'-0"
long-term

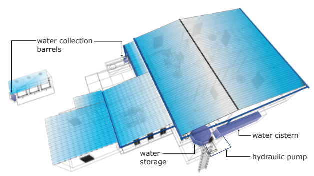
existing conditions

water truck route

Troncones daily water usage:
kitchen faucet 9.5 litres per min.
(4 minute average) = 38 litres
bathroom faucet 9.5 litres per min.
(2 minute average) = 19 litres
showerhead 12 litres per min.
(7 minute average) = 84 litres
toilets 13 litres per flush
(7 flushes per person) = 91 litres
cooking and drinking water
(consumed per person) = 5 litres
irregation (flora) = 125 litres
362 litres total per person

water cost for trucked water:
.045 pesos per litre, water tank
holds 10 cubic meters (450 pesos)
.65 pesos per litre of bottled
potable water, 20 litres per bottle
(13 pesos)
19.32 pesos per person/day

1. phasing additional water harvest



rain water collection diagram

638 sf of roof catchment area added with dining /living space and bedroom

perspective at rainwater harvesting

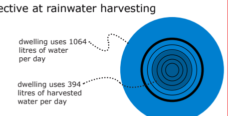
hydraulic ram pump uses water pressure to move water to gravity fed storage tank

hydraulic ram pump

1000 litres = 1 cubic meter
3.78 litres = 1 US gallon

rainwater harvesting calcs:
g/cd x population=gpd
70.37x4=281.48 gallons per day
gpd x 365 days=gal/year
281.48x365=102,740.20 gallons per year
annual precipitation = 59.35
design precipitation = 39.53
catchment area (existing & addition)= 1,930 sf
roof catchment supplies 37% of total usage
38,014 gallons supplied by roof yearly

37% total reduced usage



proposed savings

rainwater collection:
37% total reduced usage
compost toilet:
25% total reduced usage
total reduced usage:
62% less water usage
water cost reduced:
7.34 pesos per person/day (.73 cents)
2,680 pesos ($268.00)
per person per year
4,365 pesos ($435.50) saved per person/year

water management

phasing sustainability long term