Rethinking the Response to Disaster Relief Housing

by

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The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled “Rethinking the Response to Disaster Relief Housing” by Heather Swetnam in partial fulfilment of the requirements for the degree of Master of Architecture.

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ABSTRACT

This thesis examines disaster-relief-housing and identifies some of the challenges faced by the traditional housing response. Focusing on relief efforts as a second responder, an alternative process for housing displaced populations is proposed and demonstrated through a specific proposal for disaster-relief-housing for the town of San Vicente, El Salvador. Working within the discipline of architecture, the proposed project will provide beneficiaries with an increased ability to cope in the face of disaster. It does so by design and implementation of self-build housing that transitions from a temporary to a permanent state/location, by using bamboo as a primary construction material, and by providing an adaptable solution that is environmentally and culturally responsive. The building of a community laundry facility by the affected population facilitates this process by serving both as a technological teaching tool and as an inspirational building for the use of bamboo in quality construction.

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CHAPTER 1: INTRODUCTION

Executive Summary

This thesis looks at secondary response disaster relief housing and identifies some of the challenges faced by the traditional approaches. It then demonstrates an alternative process through a hypothetical but specific disaster relief housing project for the town of San Vicente, El Salvador.

The proposed housing serves populations most vulnerable to disaster, increasing their ability to cope in the face of future disasters. This population includes those living in sub-standard housing with limited resources on marginal land where the interface between human settlement and natural hazard create conditions particularly susceptible to disaster.

The general problem identified in too many disaster relief housing responses is that the solution offered is not sensitive enough to local climates, building cultures, and sociopolitical realities. As a result, supposed beneficiaries revert to building vulnerable houses on vulnerable land. Specific problems may include:

1. Poor location: New homes located far from tenants means of livelihood and familiar support systems.

2. Inflexible design: repetitive units lack adaptability and cannot accommodate the range of family structures requiring shelter.

3. Poor climate response: design and materials do not accommodate local environmental conditions.

4. Technological dependence: foreign materials and technologies prevent users from maintaining and upgrading their own shelters.

5. Alien building culture: foreign materials, technology and design do not accommodate local living customs.

6. Lack of civic dimension: relief settlements lack community infrastructure contributing to a lack of civic identity.

The process proposed addresses the identified housing challenges first by taking time during the primary or emergency relief phase to evaluate local conditions and then by providing aid that reflects conditions and furthermore, that is open to local input and adaptations.

1. Location: housing is transportable

2. Inflexibility: grid system is open to different room sizes and is easily cut and reassembled.

3. Climate: cladding provides ventilation, cool roof, rainwater capture/storage to augment unreliable supply, and seismic safety.

4. Technological dependence: bulk of materials are local, system takes advantage of local skill, critical elements are supplied (e.g. tools for working with bamboo, barrel for water storage, sink, cord, and shovel – all of which are very versatile and open to local appropriation).

5. Building culture: Although the materials are local, they are used in a new way. For this reason training is essential and the resulting construction has to inspire uptake of the learned skills.

6. Civic dimension: community building of a laundry facility both creates a civic space as well as teaches building system for self-build housing that follows.

The proposed alternative to the traditional disaster relief housing response highlights a recommended process for secondary response. Activating the proposal requires:

1. Persuade the aid agencies: their concerns are housing the most amount of people for the least amount of money – they need to be convinced that investing in the proposed strategy will improve the population's ability to cope and recover from disaster in the future.

2. Persuade regional authorities: their concerns focus on immediate relief rather than long-term solutions which are stalled by financial and land tenure issues – they need to be convinced of the benefits of a strategy that, from the start, addresses long-term relief and disaster risk reduction.

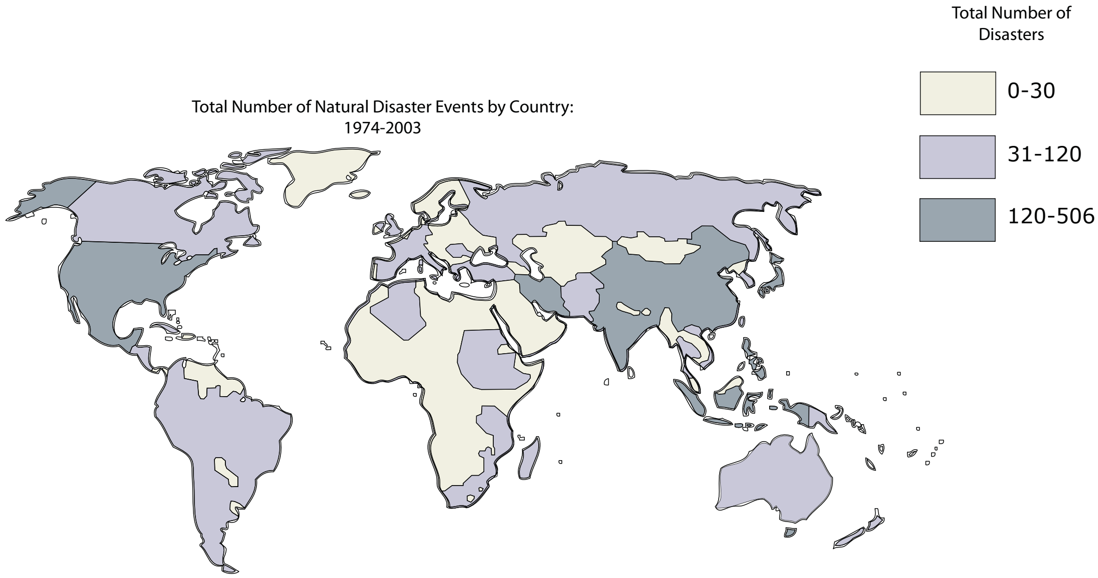
Ultimately, testing the housing strategy before a disaster to see what works and what doesn't and how the idea could go forward would be ideal. If it does work, then the housing will protect people before a disaster, which would be an even greater achievement.

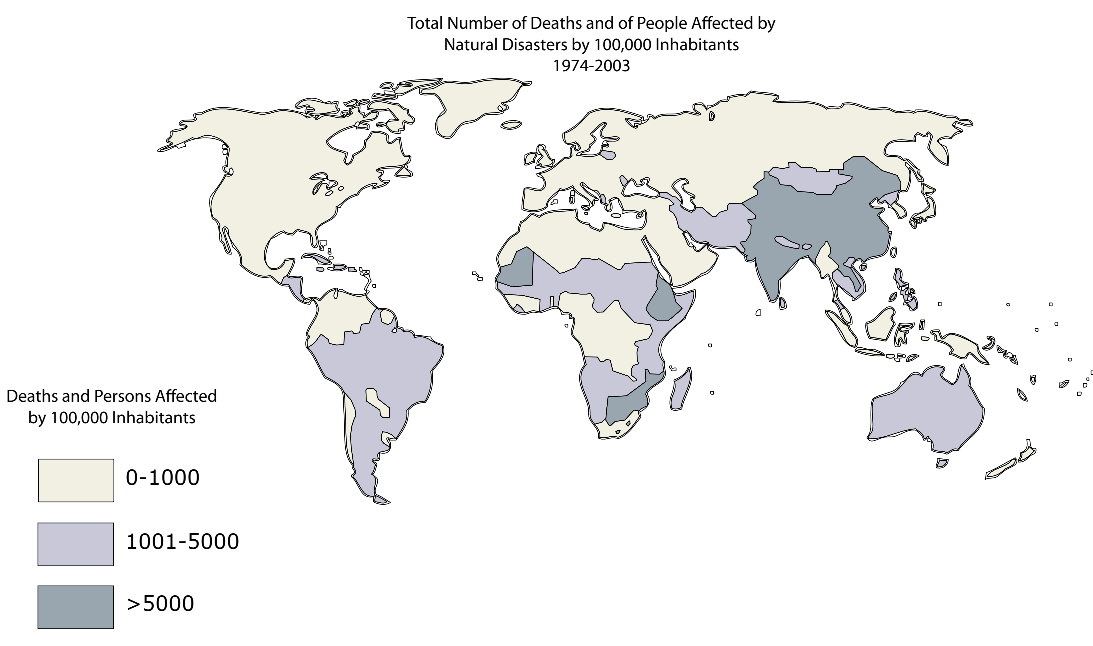
“Natural” Disasters and Vulnerability

Global Context

A natural disaster is most commonly thought of as any event or force of nature that has catastrophic consequences; however, the term is somewhat misleading. While the event itself may be a natural phenomenon, as Ian Davis mentions in his book, *Shelter After Disaster*, “the best definition of a disaster is the interface between a natural or man-made hazard (for example an earthquake) and a vulnerable condition (badly constructed housing in a dangerous location)” (Davis 1978, 2). There is really nothing natural about the disaster part of a natural disaster. What turns a so-called natural hazard or event into a disaster is the human element.

In 2010, natural disasters displaced 42 million people, which is more than double the 17 million displaced the previous year (CBC World News, 2011). Of those affected by disaster in the past two decades, 98% come from the developing world (Sinclair and Stohr 2006, 52). There are a number of factors at work that contribute to the growing number of people affected by natural disasters recently, paramount among these is an increase in vulnerable populations. While some attribute the increase to climate change, “human and material losses from natural hazards increased over the 20th century without conclusive evidence of a corresponding rise in the frequency and severity of such events” (Bankoff 2004, 30). Why the increase in vulnerability and what characterizes this population?

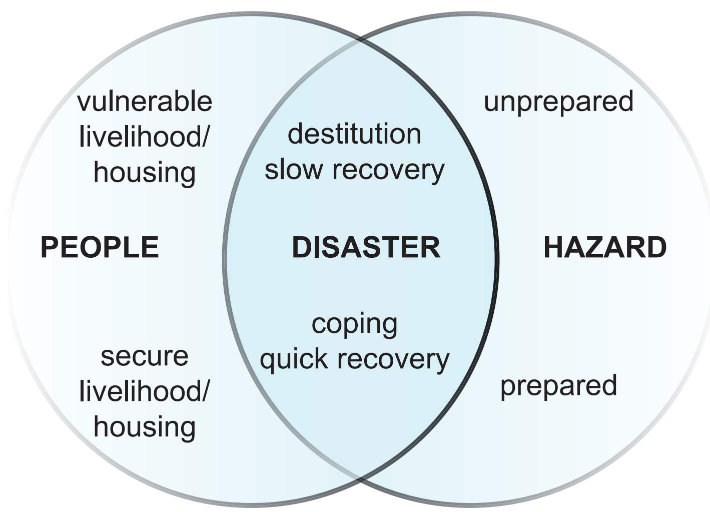




Natural disaster events by country (above) as compared to number of deaths and people affected by natural disasters (below)
[per 100,000 inhabitants, 1974-2003]
(from EM-DAT: The International Disaster Database 2009)

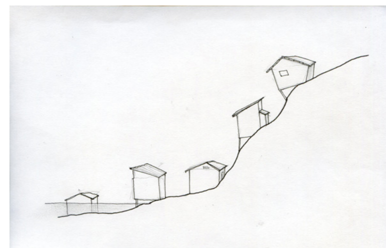
According to Wisner, Blaikie et al. describe vulnerability as “reduced or inadequate ability to anticipate, cope with, resist, and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone’s life and livelihood is put at risk by a discrete and identifiable event in nature…” (Wisner 2001, 266).

Notwithstanding the root causes of vulnerability, its physical manifestation appears as settlements established on risk-prone land, most often self-built shelters made of inappropriate materials and construction techniques and unable to stand up to strong wind, rain, flooding, or tremors. The conditions that led to the establishment of these settlements to begin with also inhibit their inhabitants’ ability to cope with and recover from damage incurred due to natural hazards. Those that are least able to cope are living in areas that are most exposed to such risks.

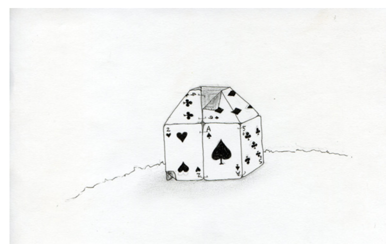


Venn diagram explaining the intersection between people and natural hazards that leads to disaster

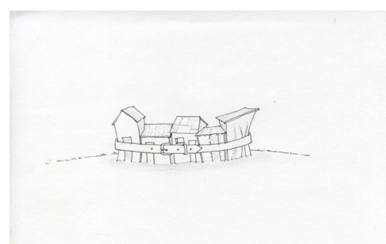
Rapid urbanization



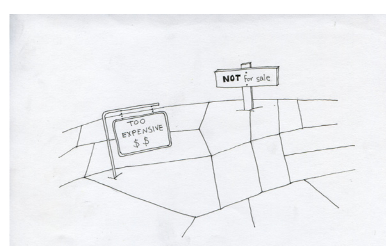
Poorly sited homes



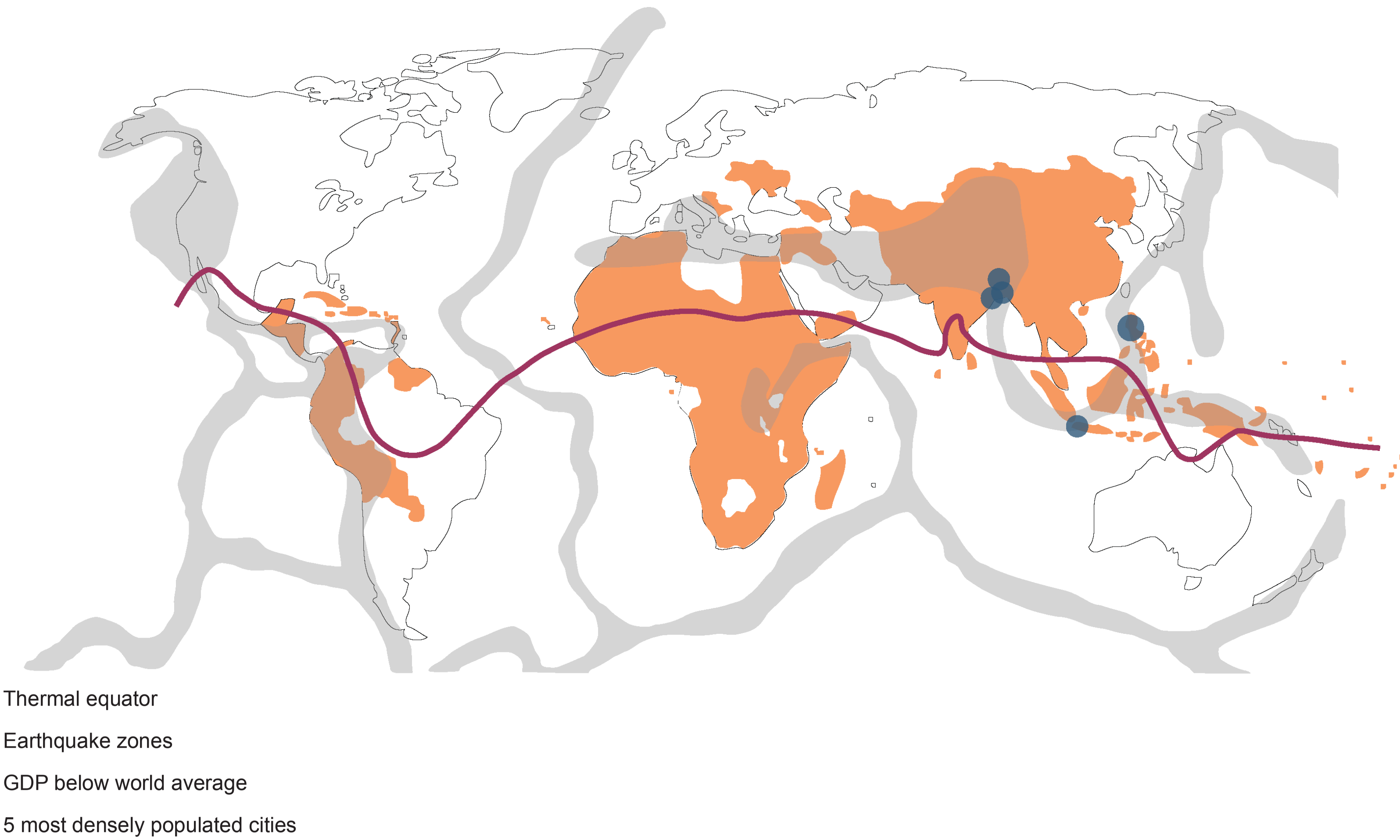
Poorly constructed homes



Overcrowding and poverty



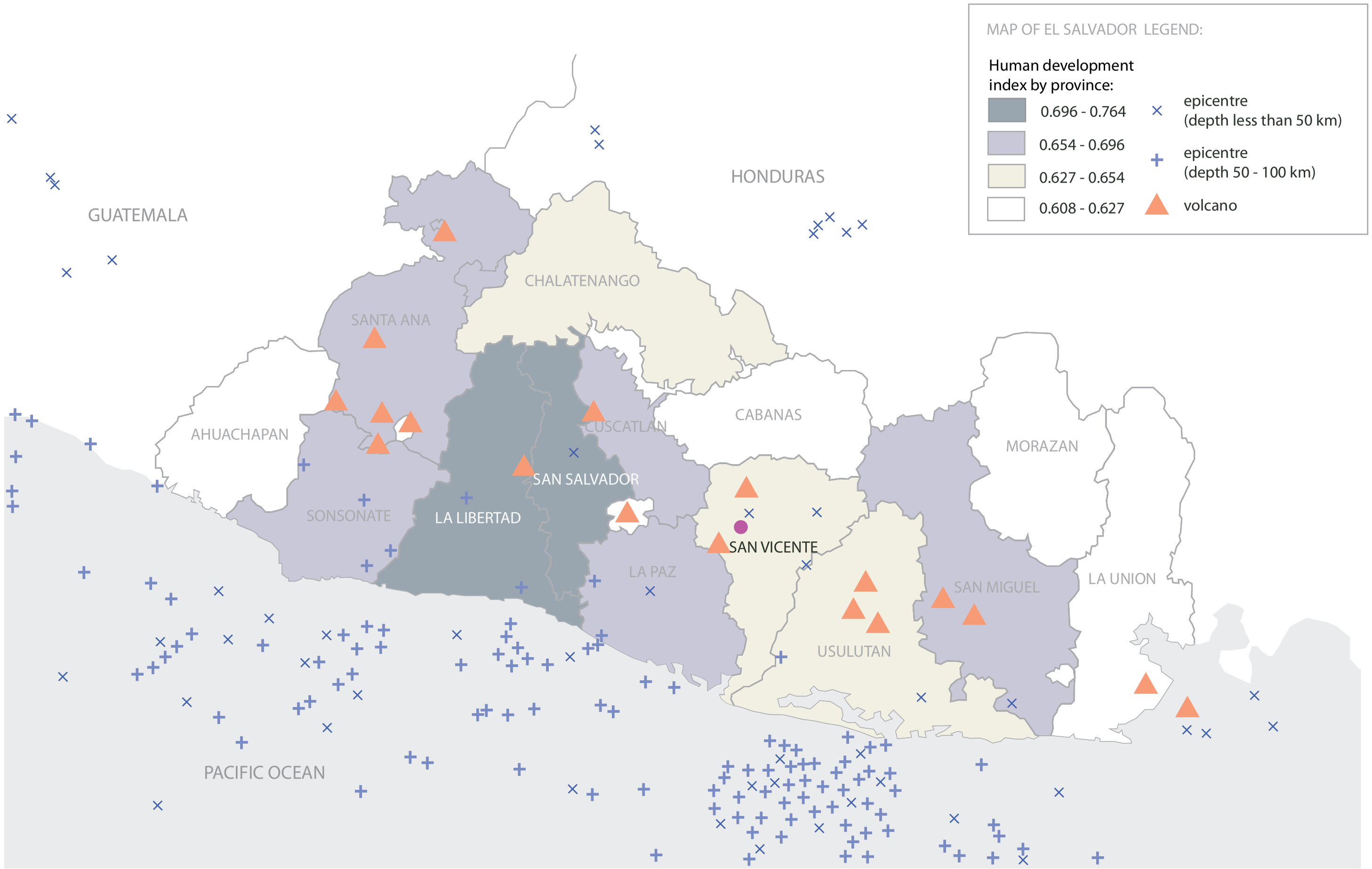
Lack of access to safer land



Composite map showing intersection of several vulnerability factors on a global scale
(thermal equator indicates vulnerability to drought, heavy rains and tropical storms).
(Davis 1978, 82)

Country Scale: El Salvador

The Central American isthmus is one of the most disaster prone areas in the world. As part of that region, El Salvador is susceptible to a myriad of natural hazards such as hurricanes, earthquakes, volcanic eruptions, landslides, floods, and drought as well epidemics of cholera, malaria and dengue (Wisner 2001, 252). El Salvador is the smallest and most densely populated country in Central America, bordered to the north by Guatemala, to the south and east by Honduras, and to the south and west by the Pacific Ocean. It was conquered by Spain in the early 16th century and, along with the other Central American provinces, it declared independence in 1821. While El Salvador's early history as an independent state was marked by frequent revolutions, patterns of settlement were "originally dictated by fertility and water availability on the volcanic slopes in the Great Interior Valley" (Rose et al 2004, 1). In 1881, then president Zaldivar expropriated the communal land so that a small group of coffee producers could expand their operations effectively changing land use and ownership and placing productive land in control of a few families leaving most of the people without their own land and livelihoods. This led to extreme rural poverty with many Salvadorans migrating to the capital city of San Salvador or abroad, eventually culminating in civil war from 1980 to 1992. After the loss of over 75 000 lives and severe environmental degradation, the war ended with the signing of a peace accord. The accord promised social and political reform, however, El Salvador's past as well as current conditions have left a large portion of the population exposed to disaster.



Composite map of El Salvador showing intersection of several natural hazards and vulnerability factors (volcanoes, earthquake epicenters 1964-2000, human development index).
(Rose et al 2004)

Wisner explains:

> The root of disaster vulnerability in El Salvador lies, therefore, in the long history of elite control of land and the wars that have resulted from it. These two fundamental historical factors have shaped the country's population distribution and settlement pattern, one which exposes two groups to very high risk: the urban poor, especially those living in and near the ravines (quebradas) that are common in the greater San Salvador metropolitan region, and the rural poor who live on steep slopes or near rivers, and also others living in drought-prone areas. (Wisner 2001, 254)

While president Zaldivar is ultimately the one who allowed the expropriation of land to occur, it would be remiss not to acknowledge the influence of the West whose capitalism encouraged the mega-production of coffee. By acknowledging 'our' role/contribution to events which have led to the current situation described, this also suggests that 'we' share responsibility to provide support - but also highlights the necessity to provide such support in a careful and considered manner so as not to repeat past mistakes and impose 'our' own assumptions and ideals on an existing population.

In addition to land control issues and unrest, adoption of the US dollar as currency in 2001 meant loss of control over monetary policy and was a difficult transition for many. The change in currency was particularly difficult for the informally self-employed who had a hard time pricing their products, which generally led to an overall decrease in income, which then also contributes to the economic vulnerability of that population. Despite El Salvador's relatively low unemployment rate of 7.2% (2010 est.), the underemployment rate is significant, with 37.8% (2009 est.) of the population living below the poverty line.

The combination of political and social factors described above together create a population in El Salvador that, like similar populations in other developing countries, is particularly vulnerable to disaster: thus, the paradox whereby the basic need for human survival draws people to live in vulnerable situations that then impedes their ability to survive in the face of natural hazards.

Housing in El Salvador

Introduction

In order to attempt to develop a socially appropriate housing solution for disaster victims, it is not only important to understand the social norms of the community, but also to understand what housing exists at present and how/why the current situation evolved as it did.

In El Salvador the majority of dwellings are constructed out of adobe, bahareque, reinforced brick masonry (mixto), wood frames covered by thin metal sheets (lámina), and wood frames covered by palm fronds (ranchos) (Lopez et al. 2004). Reinforced concrete is increasingly being used in dwellings, primarily in urban centers by more wealthy citizens and for public buildings (see Appendix B for tables showing housing breakdown by type, by department, and by roof and wall materials, as well as a graph showing the change in number of houses by type from 1993 to 1999). In addition, soil-cement block masonry and precast concrete are being used in similar situations. These relatively new forms of construction are designed according to the current seismic code regulations whereas private dwellings, particularly those in rural areas, are mainly adobe or bahareque structures and are not built according to any seismic code regulations.

While new construction materials and technologies are both a product of progress as well as foreign influence (the 2011 estimate of the ratio of males to females from birth to age 15 is 1.05 male(s)/female, the ratio then drops to 0.89 male(s)/female for those aged 15-64 years. The decline in the male population is reflective of the migration of working-aged males abroad, mostly to the USA, in search of a means to provide for their families by way of remittances. In 2009, remittances accounted for 16% of GDP, and about a third of all households receive these transfers (CIA World Factbook 2011). In addition to the transfer of money, this also affords the opportunity for a transfer of technology which likely contributed to the changes in housing typology observed; indigenous housing in El Salvador consists mainly of adobe and bahareque construction (and to a lesser extent ranchos) – a product of available materials and developed technologies.

Adobe house with tile roof in El Salvador
(Lopez et al., 2004)

Adobe

Slavadoran adobe construction is characterized by walls of adobe bricks and mortar (made from a combination of sand, lime, clay, and pumitic ash). Roofs are constructed from metal sheeting and/or clay tiles supported by wooden beams or trusses, or thatched roofs supported by wooden purlins.

Houses of this type found in rural areas are generally single-family homes with an average of five occupants;

they are relatively small one-story structures (approximately 5 x 6m in plan). Adobe houses are found less frequently in urban areas. The Vice Secretary of Housing has banned the construction of adobe housing in San Salvador due to its poor seismic performance – adobe houses are only allowed in regions declared as ecological areas; however, in such areas they are generally larger in plan, wall height, and wall thickness (Lopez et al, 2004). Because of the accessibility of material procurement and relative ease of construction, a large portion of adobe dwellings are built by their owners and service a low to very low income population.

Adobe housing in El Salvador typically has not performed well in recent earthquakes due to poor load transfer between the roof (often made of heavy clay tiles) and walls. The walls support the lateral and vertical loads and tend to crack or fail at the corners and around openings in response to the strong lateral stresses of an earthquake. Evidence has shown that pre-colonial adobe homes perform better in an earthquake than newer adobe constructions, suggesting that "the traditional adobe construction culture has been lost since the Spanish colonization and the introduction of new building techniques" (Colbeau-Justin and Mauriol 2004, 446). Adobe housing was first addressed in El Salvador's building code in 1994; however, the code does not enforce building standards; it only provides recommendations for building better, safer adobe houses (Lopez et al, 2004).

Adobe house showing damage after an earthquake (Lopez et al. 2004)

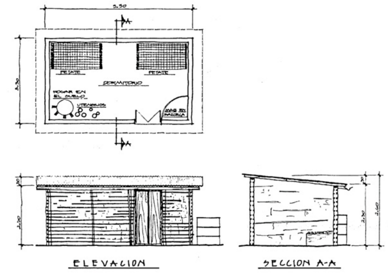
Bahareque dwelling in San Vicente showing damage after an earthquake (Lang et al. 2007)

Bahareque

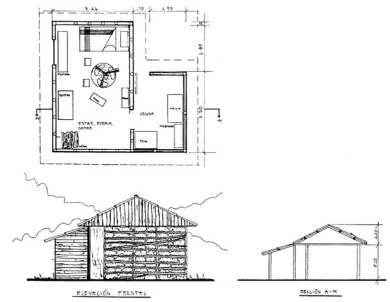
Bahareque was widely used as a means of construction in El Salvador prior to the Spanish invasion of Central America. Early versions of this system of construction consisted of small tree branches bonded with clay. With time, this system evolved to include a foundation of stone or clay (used to transfer loads to the ground and to provide separation of the walls from the ground humidity) into which vertical wooden posts were inserted (typically at the corners, on either side of an opening, and at intervals in longer wall spans) and attached to horizontal rods to form the frame. The cores of the walls were made from bamboo or cane elements and filled with mud. Pre-colonial roofs were made from wood frames covered with palm fronds. This system's flexibility provided the dwelling good seismic resistance; unfortunately, the Spanish introduced tile roofs to the bahareque system, an addition that significantly reduced their seismic performance due to the weight of the tiles and their lack of integration with the walls.

Present day bahareque structures in El Salvador are most often made with wooden studs, wooden braces or wooden grids with bamboo strips or barbed wire infilled with mud, mud with pebbles or stones, and/or mud with tile pieces. The walls are then most often covered with lime plaster. The majority of roofs continue to employ clay tiles.

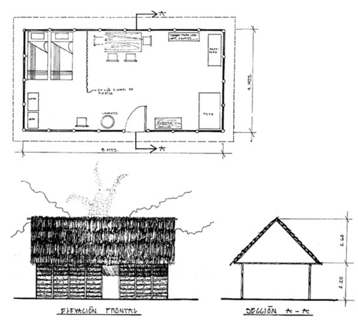
According to collected data, bahareque buildings comprised 33.1% of all buildings in El Salvador in 1971 but fell to 11% in 1994, and continue to decline with only about 5% recorded in 2004 (Lang et al., 2007). The majority of bahareque structures are single-story, single-family residential dwellings found in rural areas.



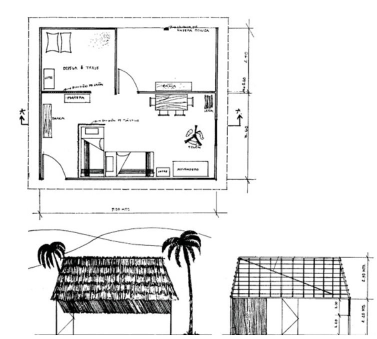
Rural residential bahareque building with sheet metal roof (Lang et al., 2007)



Rural residential bahareque building with wood annex (Lang et al., 2007)



Rural residential bahareque building with piched palm roof (Lang et al., 2007)



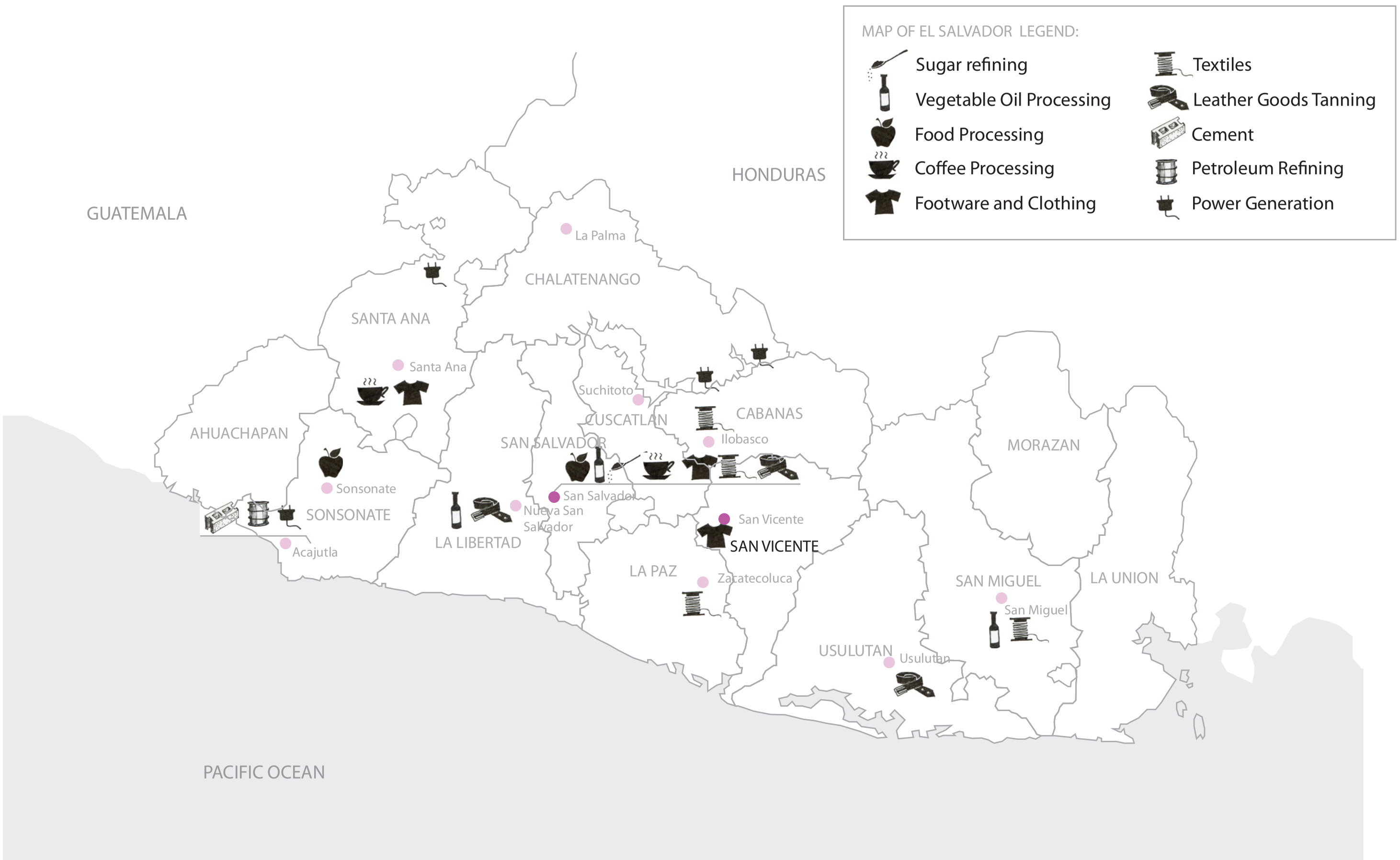
Rural residential bahareque building with covered courtyard (Lang et al., 2007)

Like adobe structures, because of the accessibility of material procurement and relative ease of construction, a large portion of bahareque dwellings are built by their owners and service a low to very low income population. The percentage of bahareque structures is higher in rural areas than in urban areas. They are constructed similarly, urban dwellings tend to have more elaborate plans, paint and plaster finishes, and a solid foundation. In comparison, bahareque structures found in rural areas tend to appear less finished, are more temporary, are smaller, and reflect a lower income population.

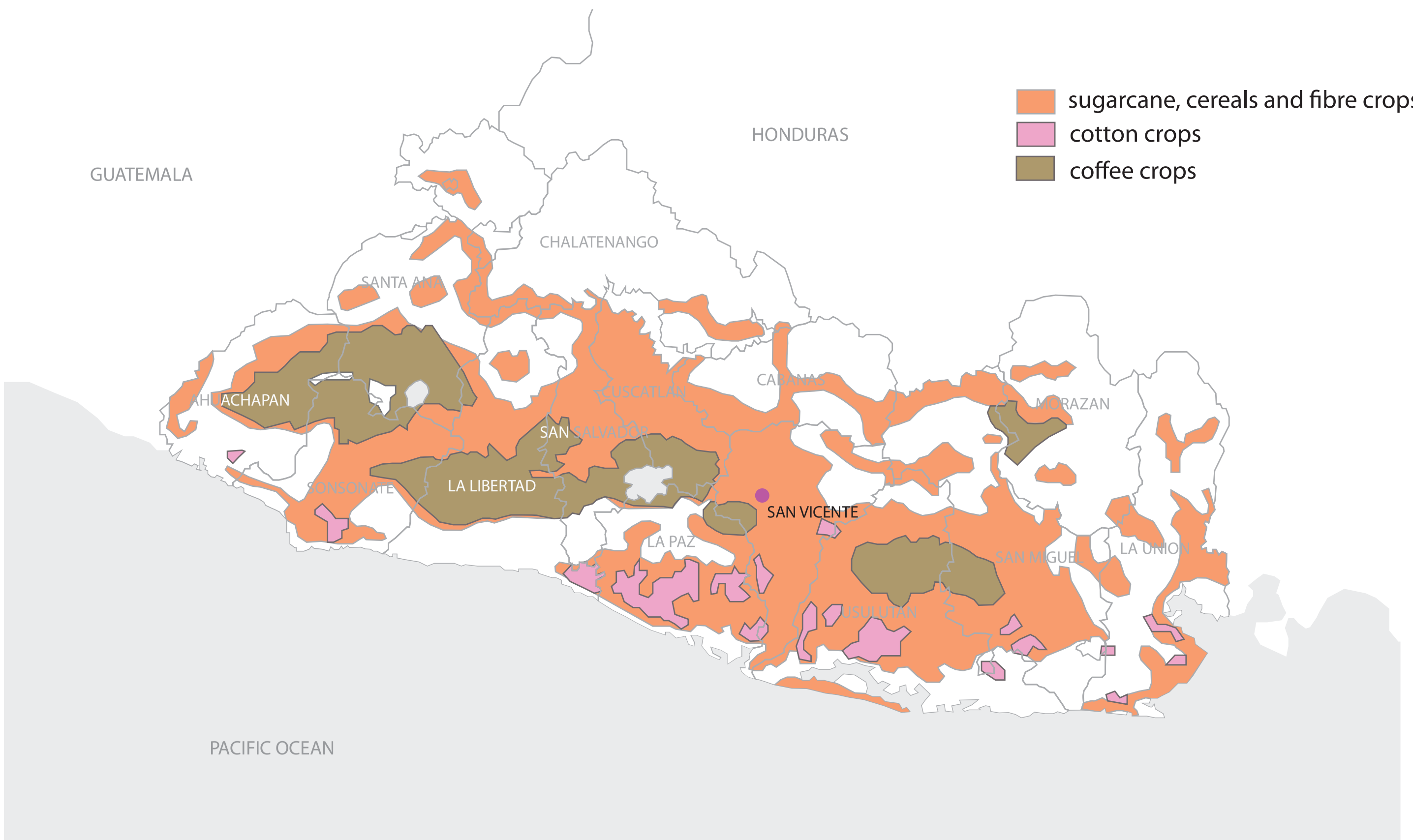
Available Resources

A socially appropriate housing solution requires not only an understanding of existing and traditional housing, but should also include an understanding of available skills and resources.

On a country scale, 58% of the labour force is employed in the services industry (which includes government activities, communications, transportation, finance, and all other economic activities that do not produce material goods), 21% in agriculture (which includes farming, fishing, and forestry), and 20% in industry (which includes mainly manufacturing, energy production, and construction) (CIA World Factbook 2011). Coffee and sugar are the main agricultural exports, with cotton, oilseed, corn, rice, beans, and sorghum also produced in significant quantities. In terms of industries, textiles and food processing account for the majority of production, with energy, petroleum, beverages, fertilizer, furniture, and light metals accounting for most of the rest. Extrapolating from the above lists, one can infer what skills and materials are available in-country. The proceeding maps show the locations of such resources in relation to San Vicente (the location of the proposed housing).



Map of El Salvador showing economic activity
(CIA World Factbook 2012, Economic Activity)



Map of el Salvador showing location of major agricultural activities
(CIA World Factbook 1980, 2012, Vegetation and Land Use, Economic Activity)

Water In El Salvador

> All peoples, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs. (United Nations 1997)

Recommended Minimum Basic Water Requirements for Human Needs:
(liters per person per day)

Drinking water:	5
Sanitation Services:	20
Bathing:	15
Cooking and Kitchen:	10
Total:	**50**

(Gleick 1996, 83)

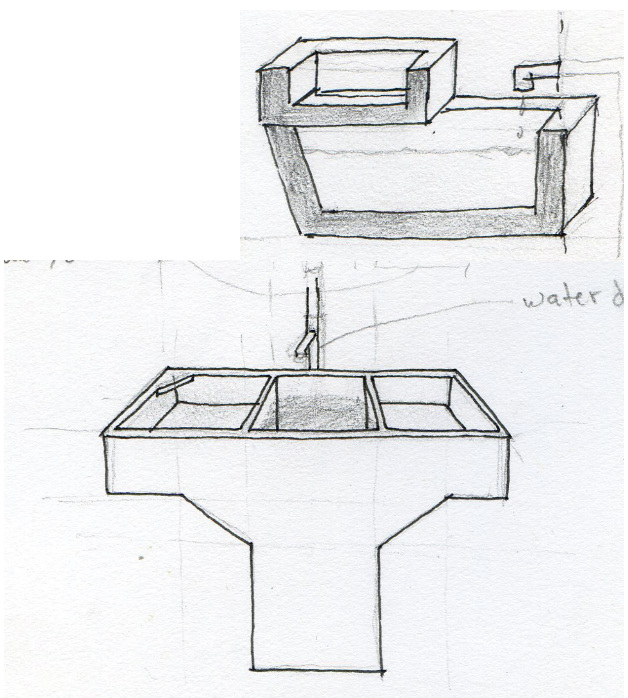
In El Salvador 32% of homes don't have access to water (the percentage is lower in urban areas and higher in rural areas). The main source of water supply in the country is groundwater since 90% of its surface water is contaminated (*Chronic Neglect* 2009). The remaining 68% receive piped water access from a state run company called ANDA (National Aqueduct and Sewer Administration). Water is distributed from large holding tanks and valves regulate flow. As Mr. Sigifredo Ochoa, president of ANDA explains, "we close some [valves] for 10 hours, or a certain time, to one part of the city to give to another part. When we've given water to the first we close the valve to give to the other" (*Chronic Neglect* 2009). This means of distribution results in unreliable and inconsistent water supply. The supply of water may vary from sixteen hours to less than four hours a day or even once every four days. Additionally, inconsistency and lack of water pressure in the delivery system means that, even while valves are open, distribution of water is inconsistent and unreliable. For example, within the same neighborhood some households received water beginning at 8pm while others waited until 9, 10, or even 11pm to begin receiving water. Also, the time of day and length of time when water is available within a household is not consistent and the amount of water each house is able to collect during the period of time it is available also varies. Water delivery is particularly scarce to communities living at higher altitudes, at the base of a hill or on the fringes of the city; such communities are generally informal settlements with a low-income population. Whether or not water is delivered, residents with pipe connections must still pay their monthly fees.

Those whose water supply does not meet their daily needs or who do not have a piped connection through ANDA can buy their water from trucks or self-supply in some way (water trucks are owned by ANDA and supply by truck is more expensive than pipe, also the sale of bottled water represents 65% of the income of ANDA). For the 25% of the population whose income is lowest, self-supply equates to spending 10% of their income on water (if they spend 10% of their salary they spend $10 a month just on water). As one woman explained, "I buy barrels of water at $7.50 a barrel. We go through a barrel every two days and that's without doing laundry here at home" (*Chronic Neglect* 2009). The cost for water is subsidized by the government (the cost of production of one cubic meter of water by ANDA is $0.50 and the cost for the user is $0.21-0.25 per cubic meter); however, this is true for all Salvadorans, regardless of ability to pay or use of water (whether it be for basic sustenance or to fill a backyard pool).

Carrying water in typical buckets (*Chronic Neglect* 2009)

Woman washing clothes using pila (*Water Charity* 2011)

As a result of the water supply conditions described, people will store water any way they can. This results in uncovered stagnant water that attracts mosquitoes and can lead to parasites and disease epidemics. As a means to collect and store water, many Salvadorans households have what they call a 'pila'. A pila consists of a tub area for holding water and one or two washing areas. These are generally made of concrete and kept just outside the back of the home. Water is collected from the tap and stored in the tub whenever it is available. One woman described waking every 1.5 hours between 10:30 and 3:30 am to check on water flow into her storage tub to make sure it didn't overflow (*Chronic Neglect* 2009). A gucal, which is a shallow plastic bucket, is used to extract water from the tub for use (it is important not to contaminate the gucal and thus the stored water). According to statistics, 12-15% of the productive time of Salvadorans in some communities is used to collect water; this number is higher among women and girls. In addition, some Salvadoran women burn 3,500 – 3,700 calories a day collecting water and cannot consume enough to replenish this loss, which leads to malnutrition (*Chronic Neglect* 2009).

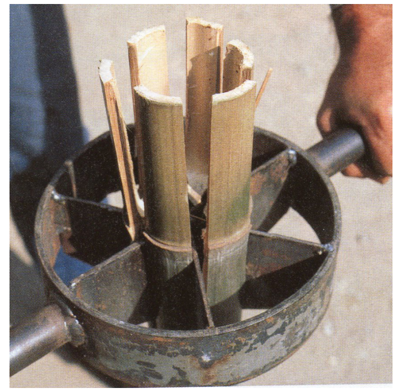


Sketches show typical pila construction with storage tub, washing surface, and water delivery tap.

Bamboo Architecture

Introduction

Bamboo serves many roles in Asian, African and Latin American countries, from food to consumer goods to construction material. In many places bamboo's role as a construction material has been replaced over time by "newer" "western" materials such as steel, concrete, and glass – a phenomenon which has given bamboo used in building the stigma of being the 'poor man's wood' (Kries and von Vegesack 2000, 9). However, as recent concerns with the impact of modern construction technologies are exposed, there has been a shift in thinking back toward sustainable regional solutions – a trend that has renewed interest in bamboo and its advantages as a building material.



Splitting bamboo poles, India (Kries and von Vegesack 2000, 170)

Bamboo poles for transport, Thailand (Kries and von Vegesack 2000, 170)

Drying bamboo poles (Kries and von Vegesack 2000, 170)

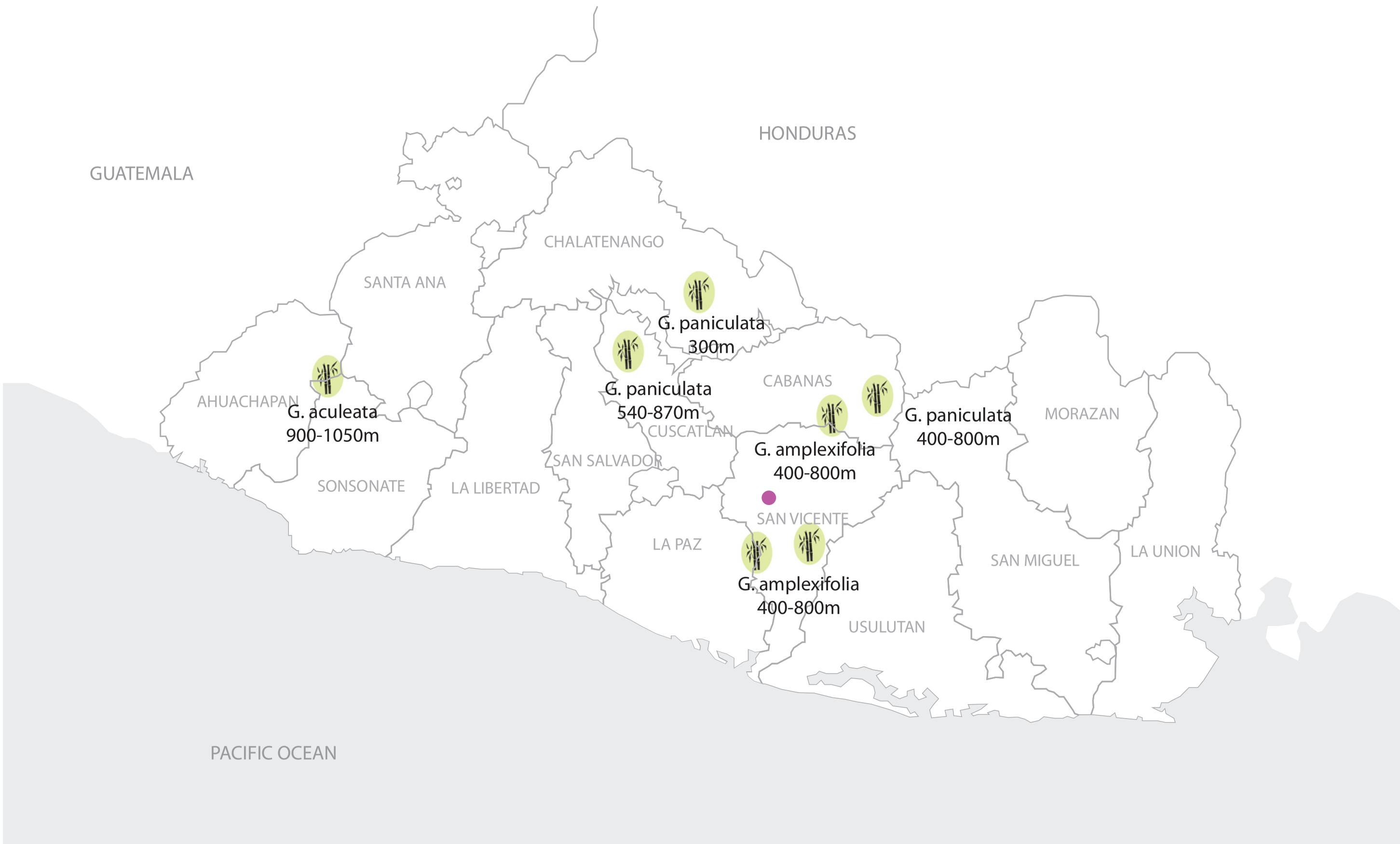
Cultivation, Harvesting, and Preservation

Bamboo grows naturally in "many parts of the tropical, subtropical, and mild temperate regions of the world, from sea level to altitudes of more than 13,000 feet" (Mohan and Narayanamurty 1972, 1). Culms mature in two to six years and are generally cut on a cycle of three to five years. They are selectively cut 250 to 500 mm above ground, just above a node (dead culms are removed with the exception of a few which are left to support younger culms). To reduce the susceptibility of the building material to insect attacks, culms are usually cut when their starch content is lowest. This generally occurs in the dry season or the early part of the cold weather (Mohan and Narayanamurty 1972, 6). In terms of curing, vertically stored bamboo takes approximately four weeks to dry while horizontally stacked bamboo can take twice as long but may minimize cracking. Once cured, additional measures can be taken to preserve the bamboo stalks such as smoking, soaking, and chemical treatments (some preservation techniques begin immediately after cutting) (Janssen 1995, 6-11).

Characteristics and Implications

The strength of bamboo varies depending on species, age, growth conditions, moisture content, and distance between nodes. In general, bamboo's strength is related to its density [coefficient * density (kg/m3) = allowable stress (N/mm^2)]. Bamboo has a relatively high strength to weight ratio, making it a naturally good material in terms of transportability. The relatively long longitudinal fibers of bamboo (approximately 20% longer than wood fibers) afford bamboo a relatively high tensile strength and contribute to its bending strength. The Guadua species has a tensile strength of up to 40 kN/cm2, surpassing that of timber (5 kN/cm2) and some steel (36 kN/cm2) (Janssen 1995, 8). The bending strength of bamboo varies with the relative position of the nodes; however, in general and in comparison to other building materials, it is highly flexible and has a high bending strength. This physical characteristic in particular makes bamboo an ideal material for seismic-resistant construction. Bamboo's compressive strength is comparable to that of wood.

In addition to its strength characteristics, another advantage of bamboo is that it is plentiful, cheap, and locally sourced. Persons with access to materials, tools and basic skills can build and repair their own houses.

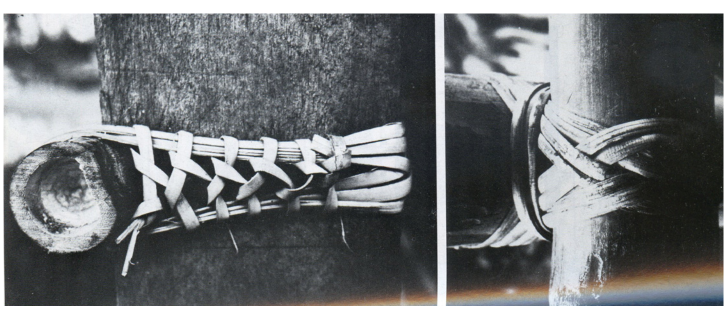


Map of El Salvador showing sub species, location, and elevation of Guadua bamboo in relation to San Vicente (Ximena 2001)

Challenges to construction with bamboo include deterioration by rot, fungi and insects, as well as vulnerability to fire. Within the culm, the middle and tip portions are less resistant than the bottom portions to destruction by insects and rot. Also, the Guadua angustifolia species of bamboo has been observed to resist rot and insect attack and remain 'serviceable' for over 40 years (Mohan and Narayanamurty 1972, 11-12). Additionally, joining bamboo elements can be difficult and may require skill, although despite the difficulty of standardization among elements, standardization at the joints is possible.

Joinery

Much of the original binding techniques stem from nomadic cultures like those who inhabit parts of China, Burma and Thailand. These inhabitants tend to remain in one place for 10 to 15 years, at which time they dismantle the framework of their bamboo houses, transport them to their new location, and re-erect them (Kries and von Vegesack, 2000, 109). These traditional joining strategies consist mainly of lashing and weaving, using bark strips of bamboo, rattan or lianas (Gass et al. 1985, 118).



Examples of joinery using natural materials for lashing
(Gass et al 1985, 119)

In modern joints rope has sometimes replaced the more traditional binding materials. Advances in materiality and technology have led to a number of new strategies for bamboo joinery, many of which involve pin and socket methods that take advantage of bamboo's hollow interior cavity. However, the cost of new joinery materials can be significant and often concentrates stresses there.

Examples of modern bamboo joinery
(Kries and von Vegesack 2000, 114)

Shelter After Disasters

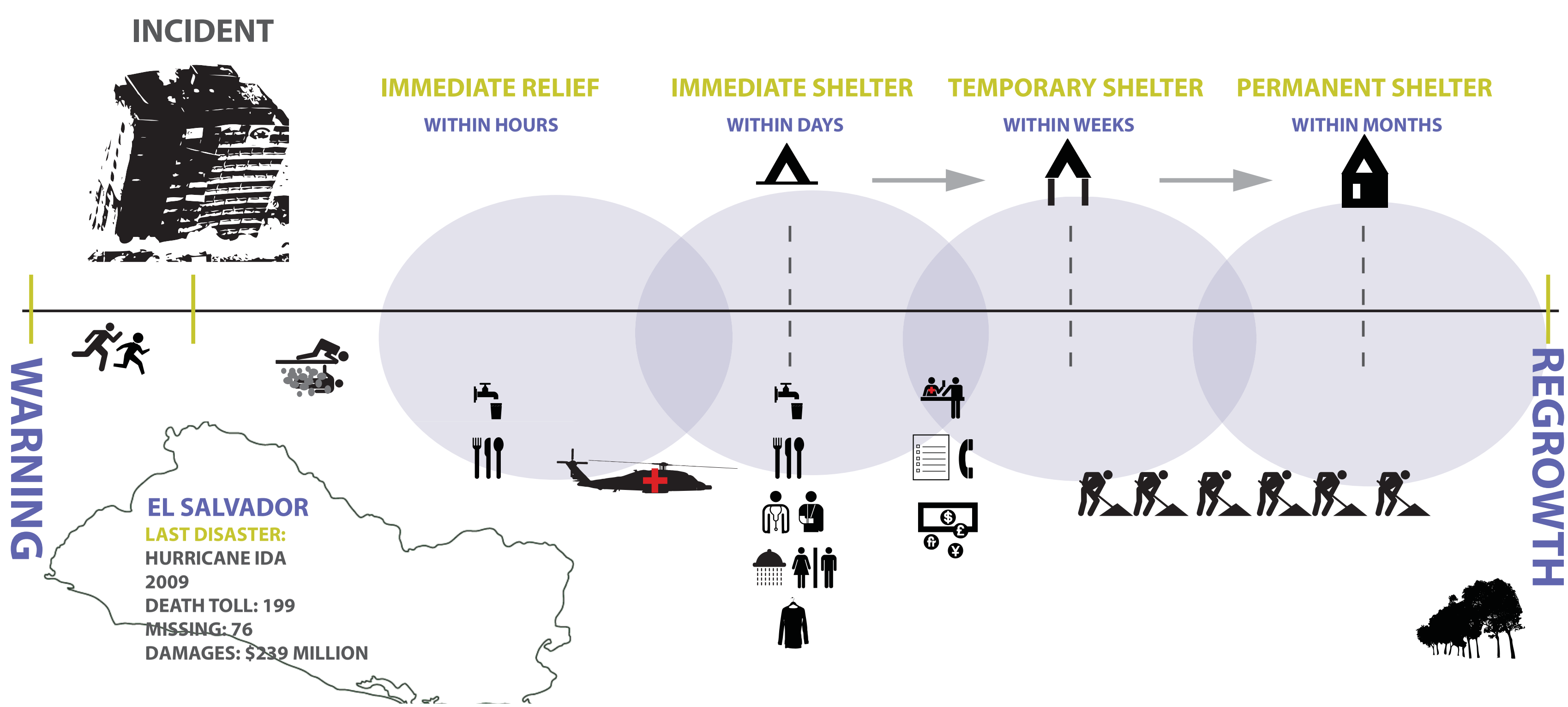
> Shelter must be seen as a process, not as an object. (Davis 1978, 33)

Traditional Response

When considering designing housing for those who have lost theirs due to disaster, there are many, and often seemingly conflicting, factors to consider, especially when also considering re-development in the context of the developing world. From an economic standpoint many organizations focus on how to house the most people for the least amount of money. While funding is an important and necessary consideration, it often leads to culturally and climatically insensitive projects with little consideration for future development and long-term inhabitation. An obvious strategy to enhance economic sustainability would be to use local materials and expertise to provide work and funds to the affected population, however, this raises the question: how can we plan to use materials and labor when availability of both cannot be relied upon following disaster?

For that matter, how do we prepare shelter that is climatically and culturally responsive when the location and time of disasters are not known and thus the culture and climate cannot be predetermined?

For these reasons, I believe that the emergency response phase of shelter after disaster is, and should be, considerably different than the subsequent phase(s) of shelter. My approach considers shelter after disaster as a second responder: that is, following the emergency phase when more long-term shelter solutions are required.



Disaster timeline

Shelters proposed by architects for aid programs are often characterized by unique design and careful use of materials but ignore completely any concept of place or culture (deGroot 2008, 8). While this may be appropriate in emergency response shelters, which, by the unpredictable nature of disasters do not allow for culture or place to be predetermined, such an approach is not desirable for longer-term housing solutions. Prefabricated emergency structures solve the immediate need for shelter and amenities but in time such solutions

> often create a host of other problems by using foreign materials and construction techniques without any local input or knowledge. Even the study of vernacular architecture aimed at creating more appropriate new construction tends to focus on simplistic explanations of the determinants of built form. (deGroot 2008, 8)

Also,

> Packaged housing is notoriously inflexible; it burns up a great deal more energy, and generally has a much shorter life than housing assembled by small builders from combinations of local and imported materials and components in response to local demands. (Turner 1976, 15)

Often housing provided is abandoned not because it cannot provide shelter or is culturally incompatible, but because it is inappropriately located. Relocation sites are frequently located far from the disaster site in an attempt to place people on safer land. While on the surface this seems prudent, locating people far from their original homes cuts them off from familiar means of support and often places them far from the income generating activities that originally drove them to reside there in the first place. Separation from livelihood activities as well as homes made from unfamiliar materials and construction techniques also create a population dependent on foreign aid (particularly when foreign materials and technologies prevent users from maintaining and upgrading their own shelters).

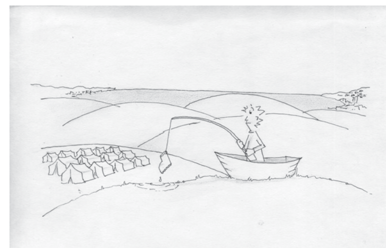
Additionally, housing supplied/proposed is most often a repetitive unit that lacks adaptability. It is not uncommon for identical units to provide shelter for a family of four as well as a family of ten.

Furthermore, relief settlements commonly lack community infrastructure and thus a sense of civic identity. While a community facility may not seem significant with so many people requiring shelter, a public space can provide those affected with a place of civic pride – somewhere to gather and resume normal activity.

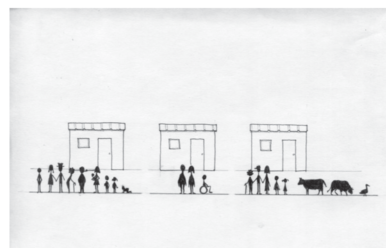
Despite the traditional breakdown of disaster housing response into phases involving immediate shelter, temporary housing and permanent reconstruction, these phases tend to overlap in reality. As observation of this process has shown, decisions made early on tend to influence long-term results:

> The houses start off with a very small structure of usually only one room, used as sleeping quarters for the entire family. Over a period of time, usually a long number of years, the house acquires more rooms and eventually becomes a formal home. The implications of this are that when any type of structure is introduced, be it an emergency shelter, a temporary structure or a long-term structure, it must from the very beginning be very strong because people will continue to use that house in its original form and incorporate it into the long term structure which evolves. (Davis 1978, 63-64)

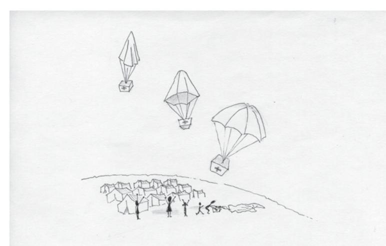
Homes lack cultural/climatic sensitivity



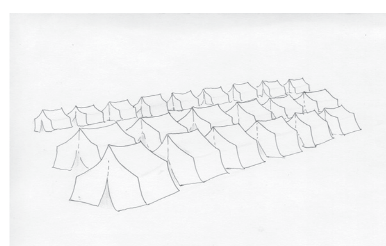
Homes inappropriately located



Repetitive units lack adaptability



Homes create dependence on foreign aid

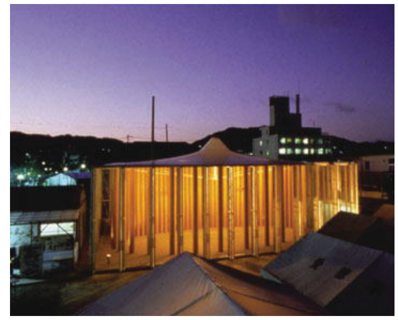


Settlement lacks community/ civic identity

Precedents

Ban

Shigeru Ban developed temporary housing using paper tubes in response to the earthquake in Japan in 1995. The walls of the house were made from 4 mm paper tubes, the foundation from plastic beer crates filled with sand bags, the roof from plastic sheeting with paper tube supports, and waterproof adhesive sponge tape for insulation. This is an example of a temporary solution that can be deployed quickly (requires 6 hours for assembly) with little material investment but also lacking long-term durability.



Church exterior, Japan, 1995
(Ban, 2004)

Church interior, Japan, 1995
(Ban, 2004)

In addition to the paper tube housing Ban also designed a community centre, the Paper Church, using paper tubes. It was built as a place of worship by 160 volunteers whose church was also destroyed in the 1995 earthquake in Japan. The Paper Church is significant because its elegance allowed for the adoption of paper tubes as a housing material in a climate biased toward newer more familiar materials.

What is particularly interesting about the paper tube project is how it was further developed for emergency shelter for refugees of the 1998 genocide in Rwanda as well as for temporary housing solutions in response to the 2000 earthquake in Turkey and the 2001 earthquake in India. The variations in design among the countries show adaptation for climate and culture.

The design for Turkey is similar in form to the Japan model, however, the paper tubes are insulated with shredded wastepaper. Fiberglass was added to the ceiling, and cardboard and plastic sheets were added for more insulation. These modifications make the structure more suitable to the colder Turkish climate. Also, the size of shelter was increased due to the larger average family size in Turkey as compared to Japan.

Japan, 1995
(Ban 2004)

In the Indian solution, the design was modified to incorporate cultural elements such as an overhanging roof with cultural adornment. Rubble from destroyed buildings coated with a traditional mud floor was used in the foundation instead of beer crates. Split bamboo was used in the roof vaults and the roof was made from clear plastic sheeting sandwiched between locally woven mats. These modifications make the structure more culturally appropriate.

Turkey, 2000
(Ban 2004)

The impact of the paper tubes in Rwanda is somewhat different in character than the previous examples. Ban introduced paper tubes to refugee camps in Rwanda as structural supports when it was discovered that refugees were selling the metal supports and replacing them with cut down trees in an area suffering from deforestation. While the paper tubes provide an environmental and shelter solution, the metal poles allowed refugees to participate in their own recovery, a point which is not trivial – the desire and ability of people to help themselves and participate in their own recovery is at the core of long-term acceptance of shelter solutions. The selling off of tent poles also highlights how, regardless of intended use, people will re-appropriate and transform what they are given to best suit their own needs.

India, 2001
(Ban 2004)

Rawanda, 1998
(Ban 2004)

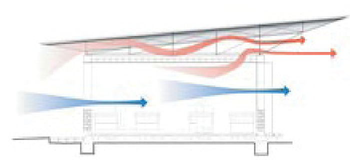
Kéré

The Gando Primary School in Burkina Faso, West Africa, by Diébédo Francis Kéré is of particular interest as a precedent because of the design approach. The project began at the request of the community for Kéré, a community member and foreign-educated architect, to save their only school, which was collapsing. He, along with classmates, started a non-profit group where he convinced classmates to buy symbolic bricks for the school. This inaugural project embodies the philosophies of his foundation and future works, which are: the use of local materials and labor, sustainability through design approach, and education to promote independence and self-sufficiency.


Gando Primary School
(Kéré 1999)


School extension, amphitheater
(Kéré 1999)

The project used mud-brick, a traditional building material and rebar cut with a handsaw and welded. The design allowed for the materials to be used in such a way that local builders, without the use of heavy equipment, could assemble them. The design took advantage of passive solar and ventilation properties with shading provided by the roof overhang and cooling provided by the double roof structure as well as the absorption and release of heat by the mud-brick mass.


Section showing ventilation
(Kéré 1999)

The use of locally available materials and local skilled labor in a thoughtful way to create an inspiring space empowered surrounding communities to adopt similar design and material use to build their own schools. In this way the building embodies Kéré's approach to design which aims to involve the whole community in an effort to educate and foster sustainability rather than dependence. This involves the development of a system that can be easily imitated because it employs simple and accessible technology.

San Vicente Project

On November 8, 2009 hurricane Ida hit El Salvador, causing massive destruction including landslides and flooding. The disaster left 14,000 people without shelter, many of whom were from the hard hit areas in and around the town of San Vicente. The housing response was divided into the typical three phases: first emergency tents were erected within days, followed by temporary housing on government donated land which has begun to be replaced by permanent housing.

This housing response exhibits some of the challenges of disaster relief housing. This includes extended stays in temporary housing (2+ years), location (new settlement location far from original community resulted in only a portion of those displaced participating in the resettlement), and a lack of coordination of resources across phases.

Emergency tents
(Google Earth 2009)

Temporary shelters: light metal frame, cardboard cladding, thin sheet metal roof, and dirt floor.

Community moving temporary house to make room for permanent construction

Permanent housing: hand poured concrete walls, tile floor, sheet metal roof.

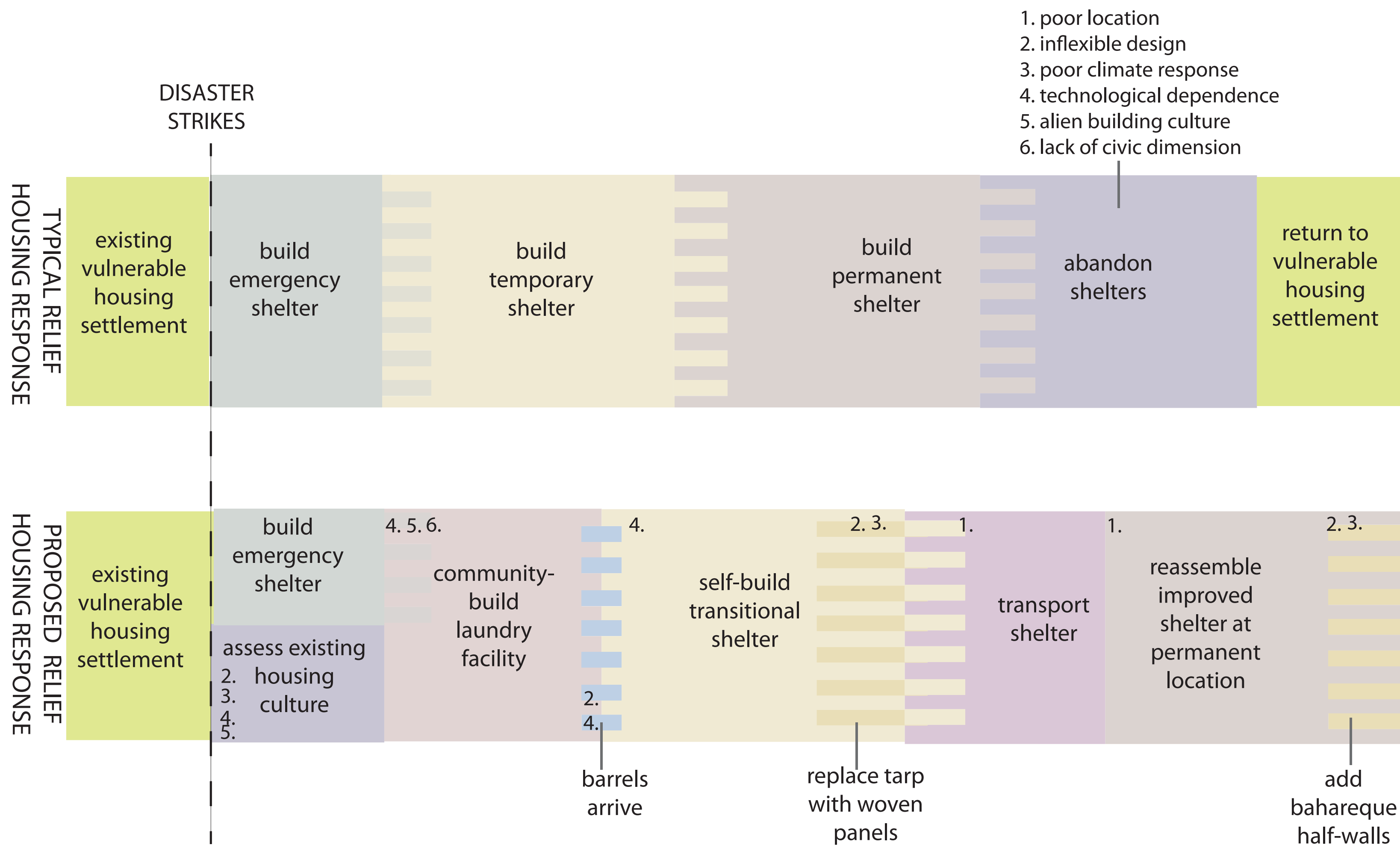
CHAPTER 2: DESIGN

Design Intentions

My design intentions are to work within existing political and social realities to create a transitional and transportable housing solution for disaster victims – in particular those vulnerable populations previously described. The reality is that land tenure and relocation sites are difficult to procure and are often inappropriately located far from the beneficiary population's source of income; consequently the process of relocation/ repopulation can take upwards of one to two years (the average stay in refugee camps in 1998 was 17 years) (Sinclair and Stohr 2006, 43). The consequence is that families are forced to stay in relief camps far longer than the temporary shelters they are provided were designed for. As a result, some families choose to return to their original housing sites, once again on disaster-prone land in substandard housing, perpetuating the cycle of vulnerability.

While I acknowledge that the root causes of vulnerability are social, political and economic, my goal is to work within the discipline of architecture to overcome challenges and deficiencies presented by traditional housing responses. My hope is that the housing provided would decrease the vulnerability of the affected population to future disaster as well as enable them to further help themselves.

The proposal is to create housing that responds to the challenges identified in existing disaster relief strategies.



Process diagram showing typical disaster relief housing response (above) compared to proposed disaster relief housing response (below). Numbers on proposed timeline refer to numbered reasons for abandonment of shelters in typical response timeline and are placed on proposed timeline where corresponding solution occurs.

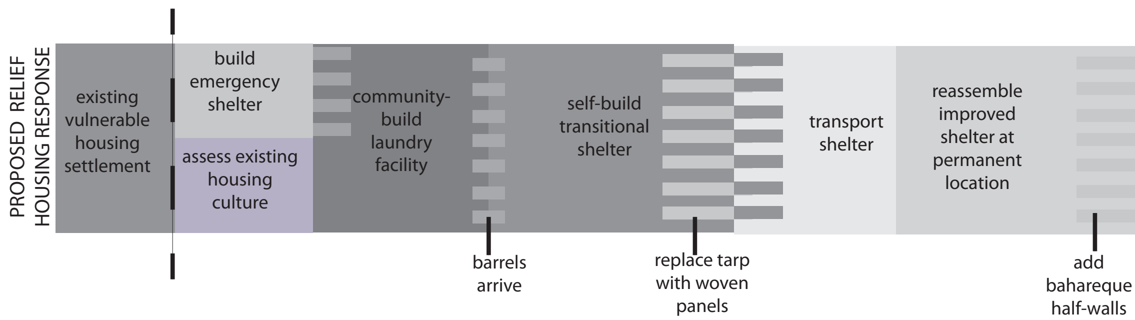
This requires a solution that is spatially adaptable in terms of family size, configuration, and community settlement. Because resettlement occurs both on newly provided sites and previously occupied sites, housing must also be transportable as well as adaptable to sloped site conditions. In order to achieve the desired adaptability, the housing proposed consists of smaller units that can be recombined in a variety of ways to accommodate different family and settlement patterns. The unit itself is designed to accommodate two people based on the United Nations recommendation of 3.5 square meters of sheltered space per person (size also closely relates to the minimum roof size required to capture enough water to meet the daily water needs of one person year round, based on annual normal rainfall in El Salvador). Materially the use of bamboo in construction responds in part to both the transportability challenge and dependence on foreign aid existing relief solutions sometimes foster. As a relatively lightweight material, a unit consisting of bamboo elements allows its components to be more easily transported between temporary and permanent settlement sites. Additionally, bamboo provides increased seismic safety in terms of both its mechanical properties and its lightweight roof framing and sheathing materials.

In addition to seismic safety, the proposal also addresses climate. The cladding strategy evolves with time to address ventilation and also reflects temporary and permanent site conditions. Water is an important part of the proposal and storage and harvesting are addressed and contribute to independence of occupants as well as to site drainage.

The implementation of the proposed housing relies on community cooperation, acceptance, and learning. This is achieved through design and building of a community laundry facility which serves as a teaching tool for building of the houses as it employs the combination of units used in the housing. Additionally, the community centre serves as inspiration for the adoption of the housing strategy / technology as well as providing a communal space whose function as a laundry and water collection facility ties together community and housing.

Proposed Relief Housing Strategy

Assess Existing Housing Culture



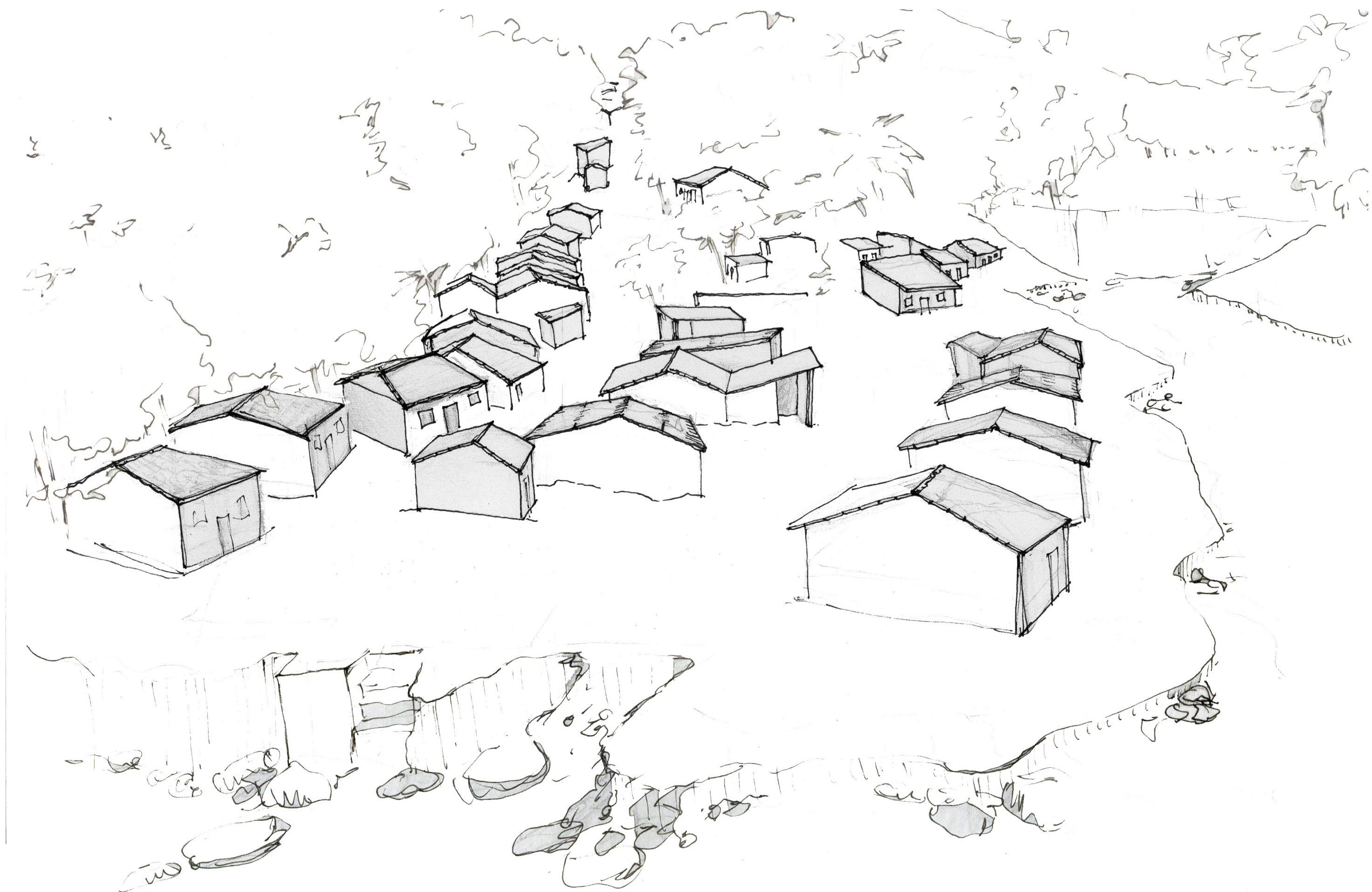
Process diagram key with color to highlight phase of process being discussed.

In order to prevent developing housing that is abandoned because it is not culturally suitable, an important first step in the proposed process is to assess the existing housing culture and to gather information about available skills and materials. As a second responder this can begin during the emergency phase of relief but could also be done before a disaster strikes as part of a pre-existing plan for disaster relief. The following builds on the information contained in Chapter 1, and is a more site specific assessment of housing culture for the proposed project in San Vicente, El Salvador.

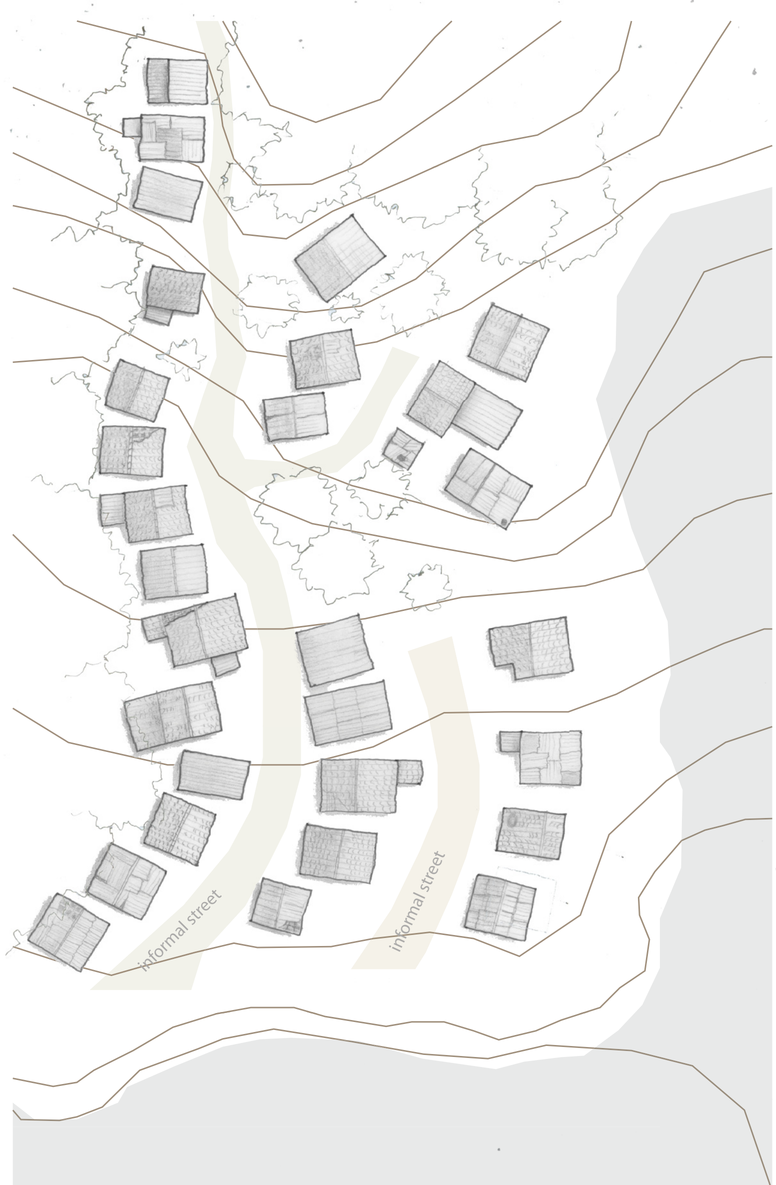
Site Information

San Vicente is a town in the department of San Vicente, El Salvador. It was founded by the Spanish in 1635. Main access to the town is via the Pan Am highway with the main entry into town via an elevated bridge crossing the Jiboa River, which bounds the city on the north side. Access by railway is also possible with entry on the northwestern side of town.

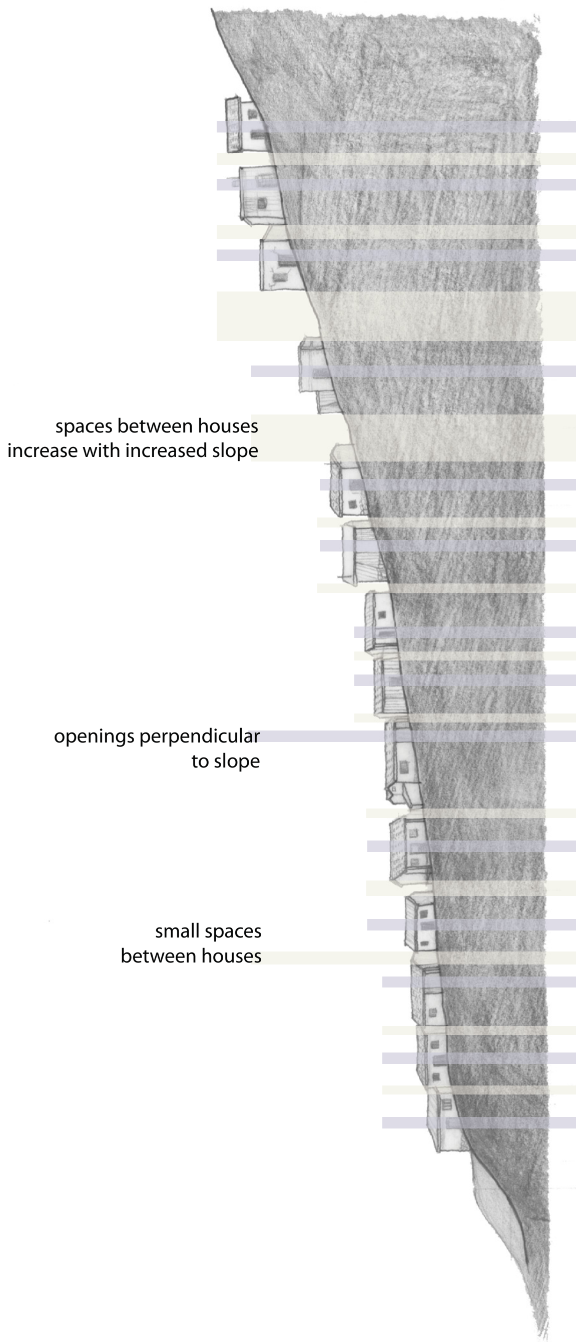
The town consists of both formal and informal settlements. The formal settlements recall their Spanish heritage with grids forming street blocks. The informal settlements occur on the fringes of the town and tend to develop and grow without a rigid organizational plan.



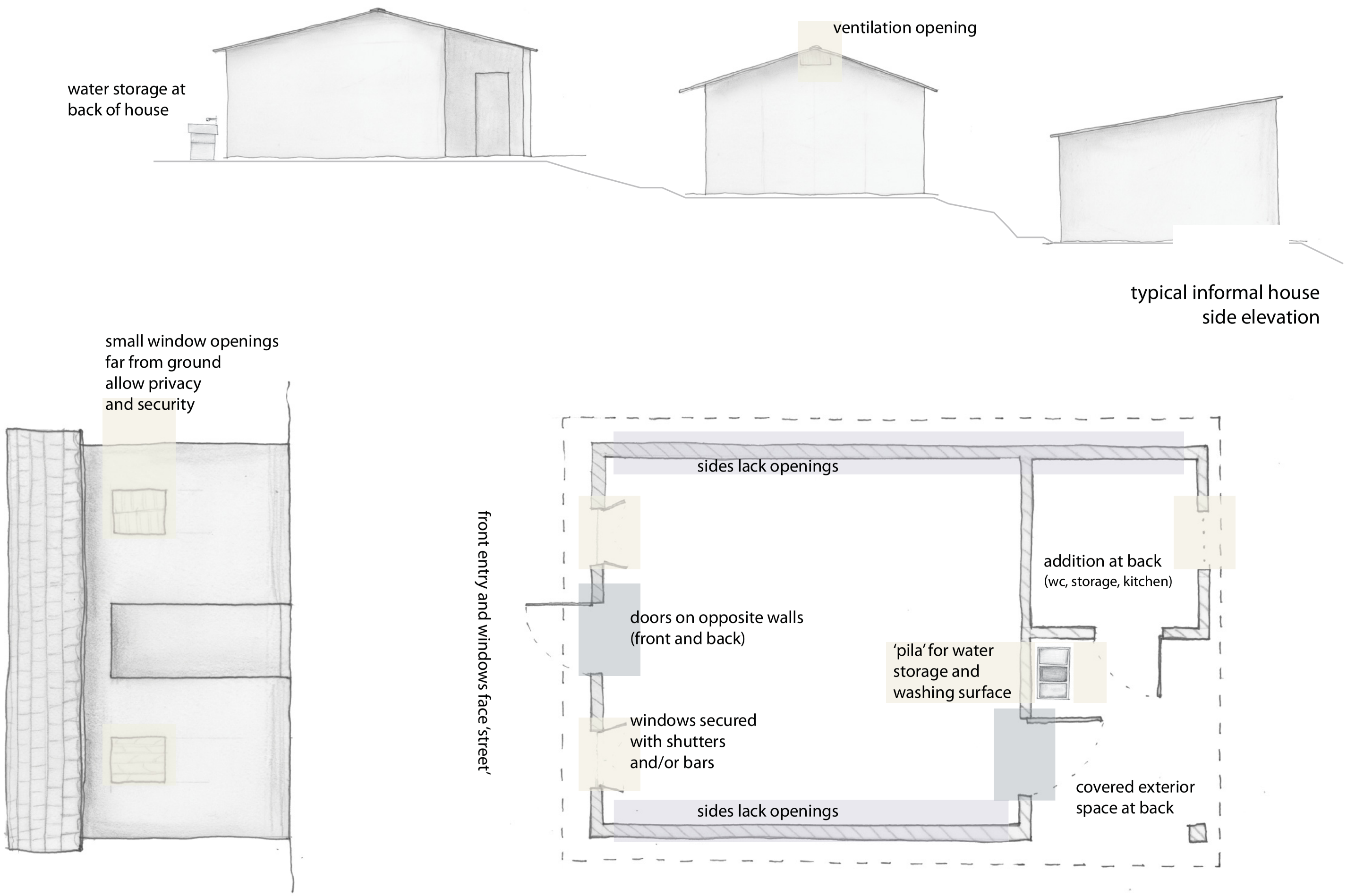
Sketch of informal settlement in San Vicente



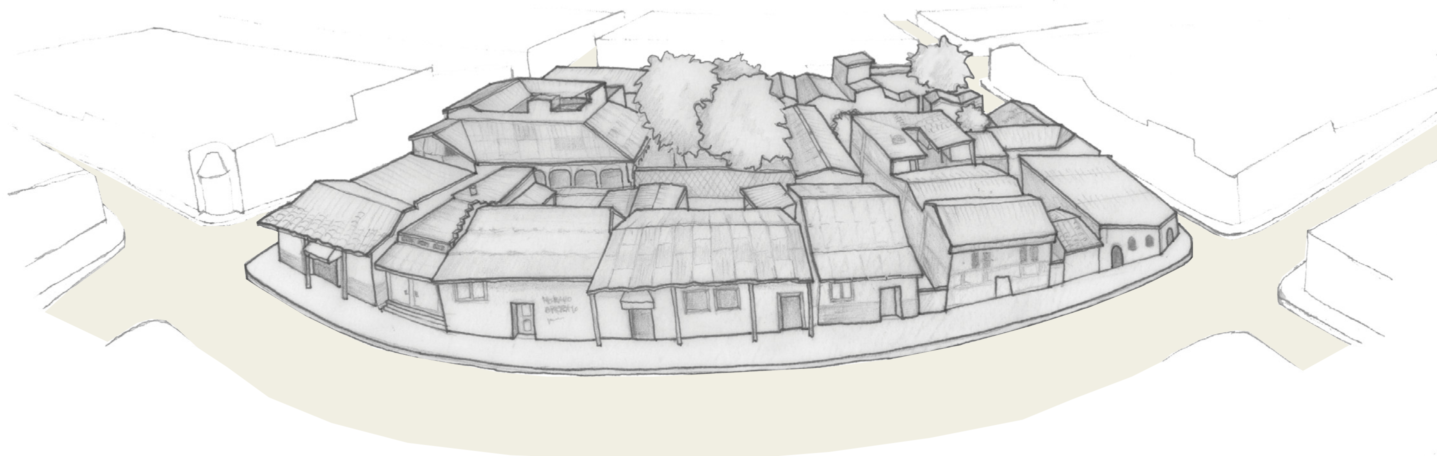
Plan of informal settlement in San Vicente



Section of informal settlement in San Vicente

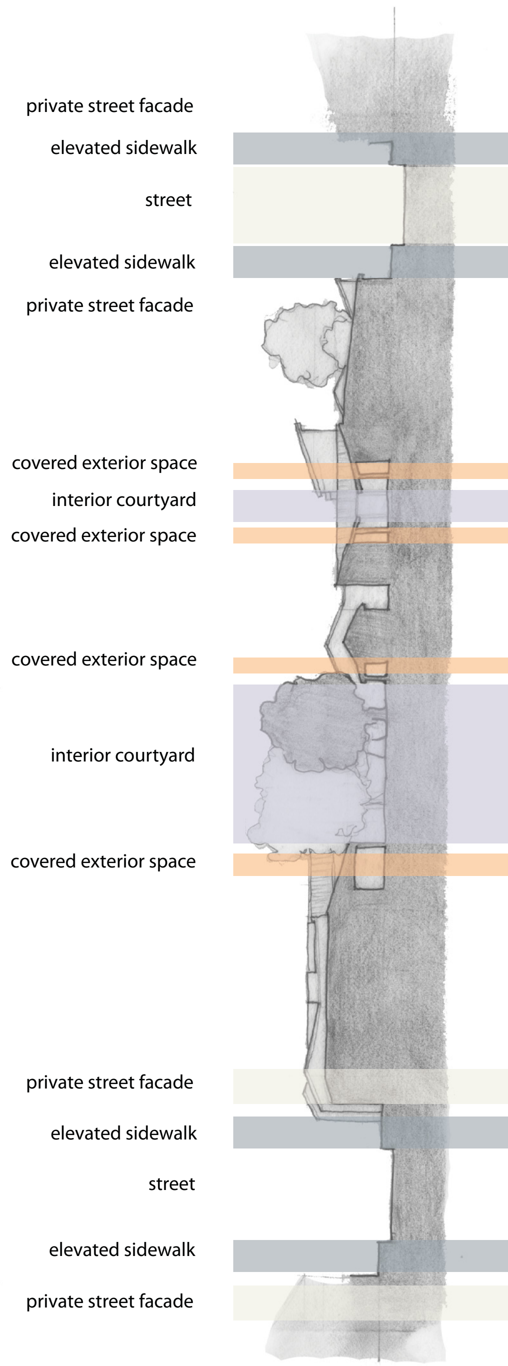


Typical house in informal settlements

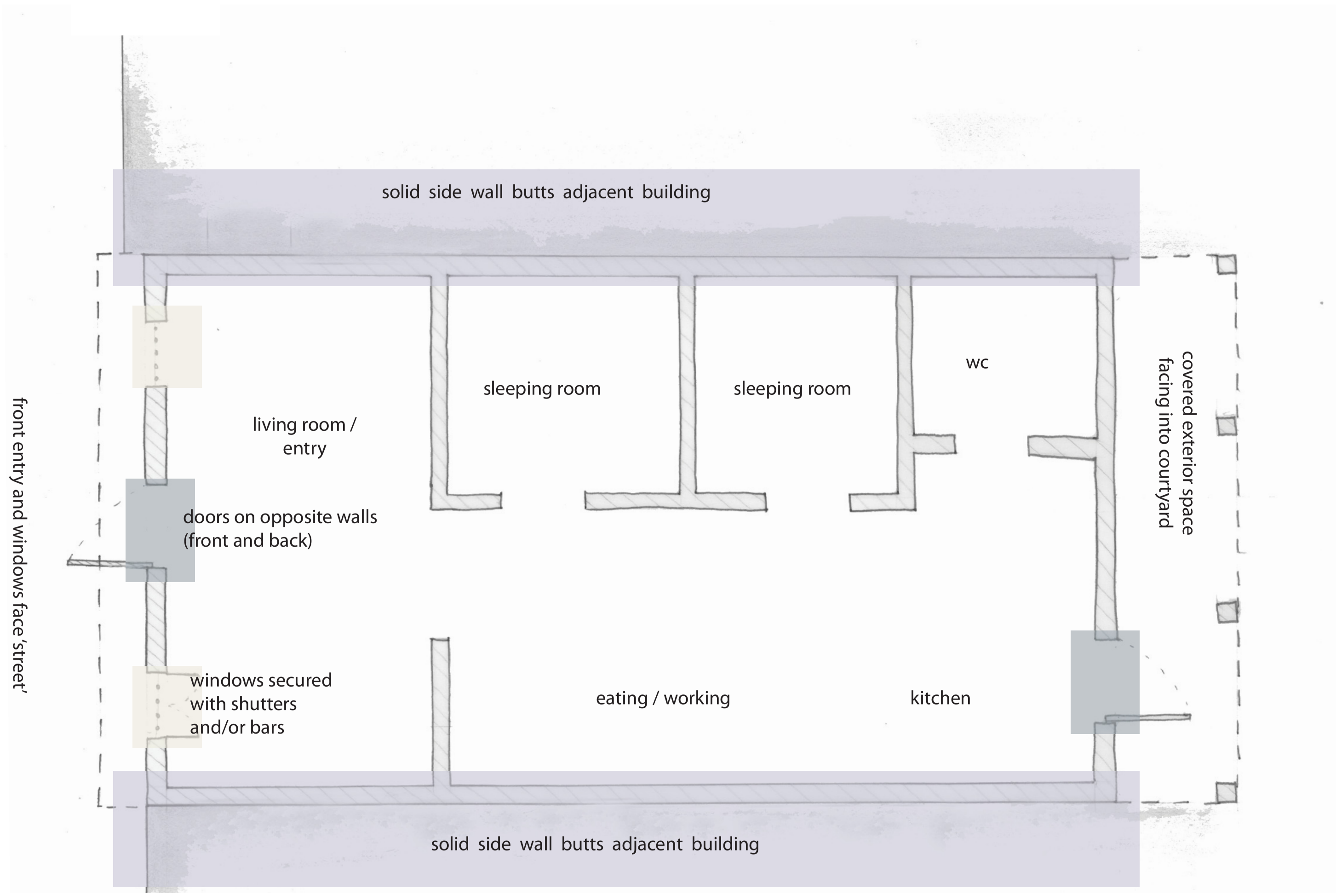


Sketch of formal settlement in San Vicente

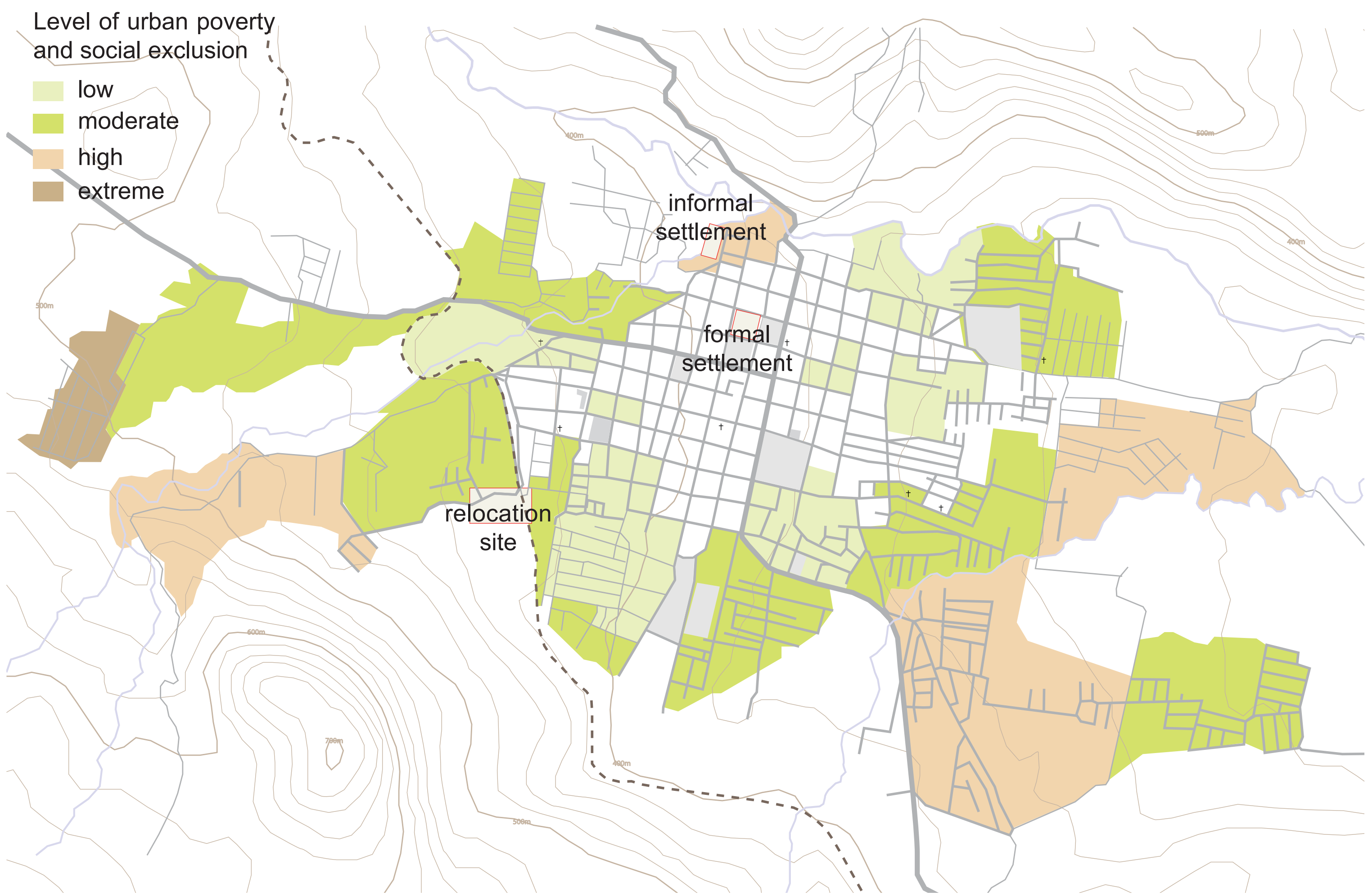
Plan of formal settlement in San Vicente



Section of formal settlement in San Vicente



Plan of typical formal home in San Vicente



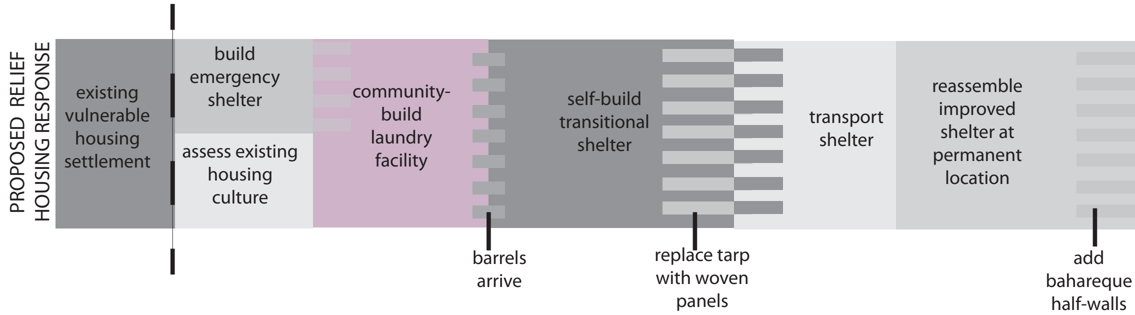
Map of the town of San Vicente, El Salvador showing site of formal and informal studies and proposed relocation site as well as areas of urban poverty and social exclusion (with respect to total country and according to predominance of precarious households).

Proposed Temporary Relocation Site

The temporary settlement is located on safe, flat, cleared land adjacent to an intersection of the railroad and a city street that attaches to a main access road (two main roads run perpendicular to one another and quarter the town). Also, the site is near settlements that have been identified as extremely, highly, and moderately vulnerable to disaster (based on a number of factors like those previously discussed, including poverty and social exclusion). Locating the temporary settlement in proximity to vulnerable sites means that those most likely to be affected by disaster will not be displaced significantly from familiar surroundings.

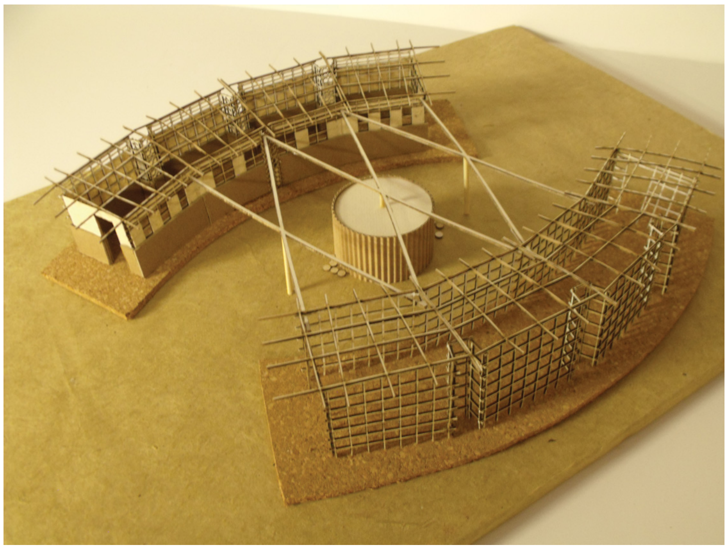
Temporary settlement showing plan of possible community layout and showing location of community laundry facility.

Community-Build Laundry Facility



Process diagram key with color to highlight phase of process being discussed.

Once the assessment of existing housing culture is done and a design for the housing has been established based on findings, the next step in the housing process is for the inhabitants of the relief settlement to build a community facility. For the proposed San Vicente project this is a community laundry facility that will also serve as a distribution centre at the temporary relocation site during relief efforts. Following community relocation, the facility will remain at the site and continue to be used for laundry and water collection and the distribution centre will become a community service space. There are several reasons the community facility is constructed before the next phase of housing; firstly, since the material and technology employed in the community building is the same as that for the housing, building of the facility by the displaced population serves to teach residents the skills needed to then build their own house with minimal supervision. The building itself consists of a combination of the same small units that are used to make up the housing units and in this way construction of the community laundry facility demonstrates the construction of the housing units while also teaching how units can be combined and altered by their tenants to adapt to particular family configurations. Furthermore, the community building also acts as an example showing how the temporary housing units will evolve to become permanent at their final location(s).

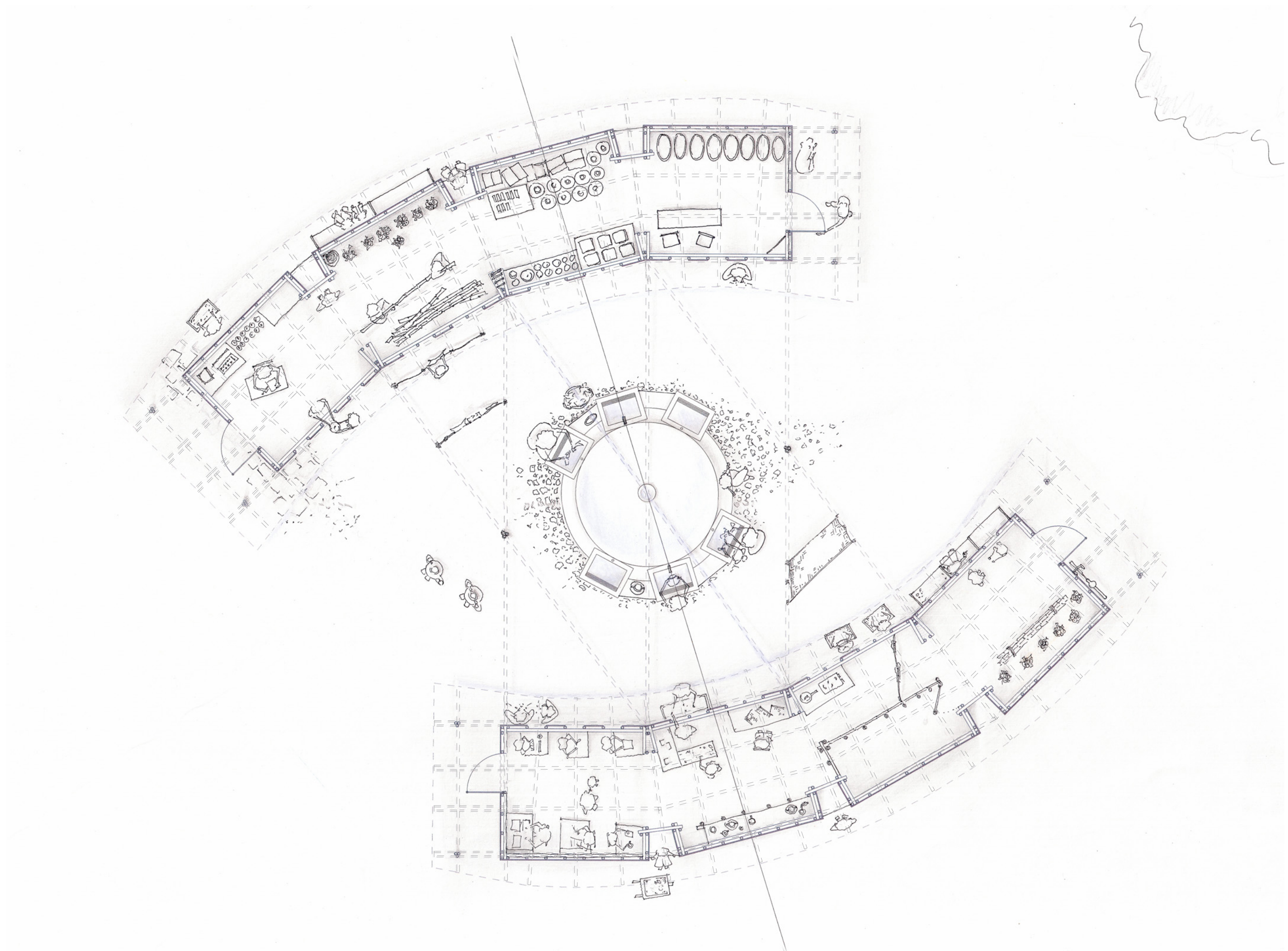


Photograph of model of community laundry facility with view of courtyard, cistern, framing, and wall cladding.

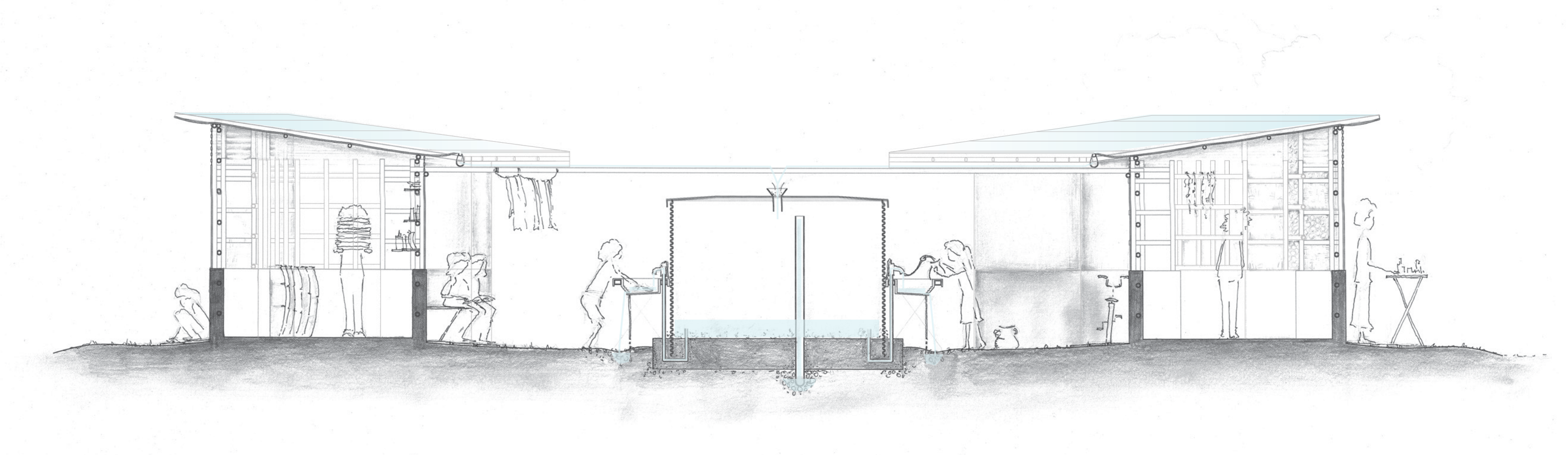
Secondly, there is a potential challenge presented by the introduction of a new building system. The housing and community laundry facility proposed for San Vicente use bamboo as the primary material for construction. Bamboo was chosen for construction because it is lightweight (which is helpful in terms of transportation of housing from temporary to permanent sites), it is available and accessible to populations at a variety of income levels (persons could literally grow their own house), and it performs well in earthquakes (due to its mechanical properties). The challenge presented by using bamboo as the primary material for construction is to encourage those who may see bamboo as a

Photograph of model of cladding panel made with off-cuts of bamboo. These panels provide ventilation and allow day lighting. They are located on inset walls for protection from weather.

Photograph of model of woven cladding panel. Lightweight panels are easy to transport, employ local skill from textile industry (the second largest industry in the country), and their fabrication recognizes the abundance of time and skilled workers available.



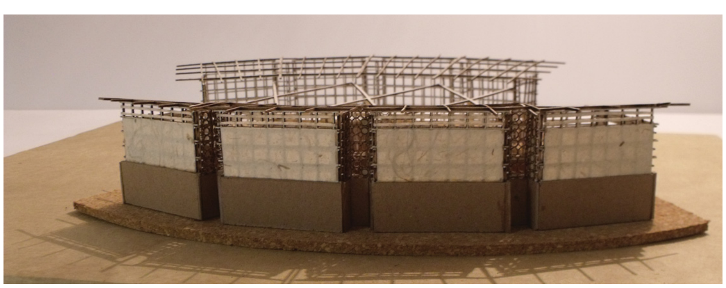
Plan of community laundry facility. North and south wings are made up of four smaller units with a central courtyard containing a cistern for water collection surrounded by sinks for water distribution.



Section through community laundry facility showing water in blue to highlight collection, flow and drainage.

material of the poor of its potential for use in all types of construction, not only for affordable housing but also for high-end construction (which in the present community of San Vicente consists mainly of stone, brick, cement block or concrete). The community laundry facility will serve to showcase bamboo construction in an elegant building. The success and quality of space demonstrated will help to combat stigma or preconception associated with use of bamboo in quality building.

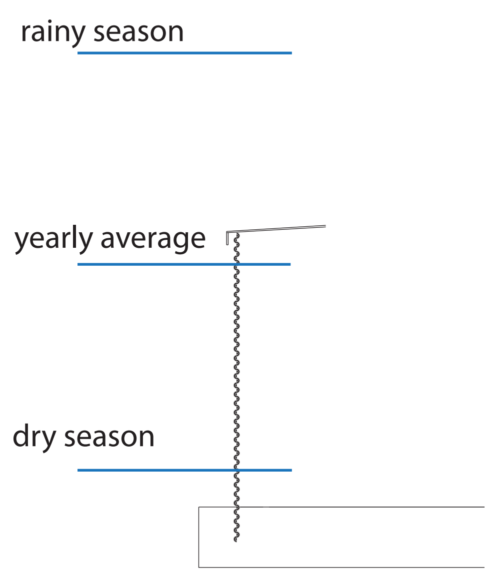
Photograph of model of community laundry facility showing interior space with roof unclad.



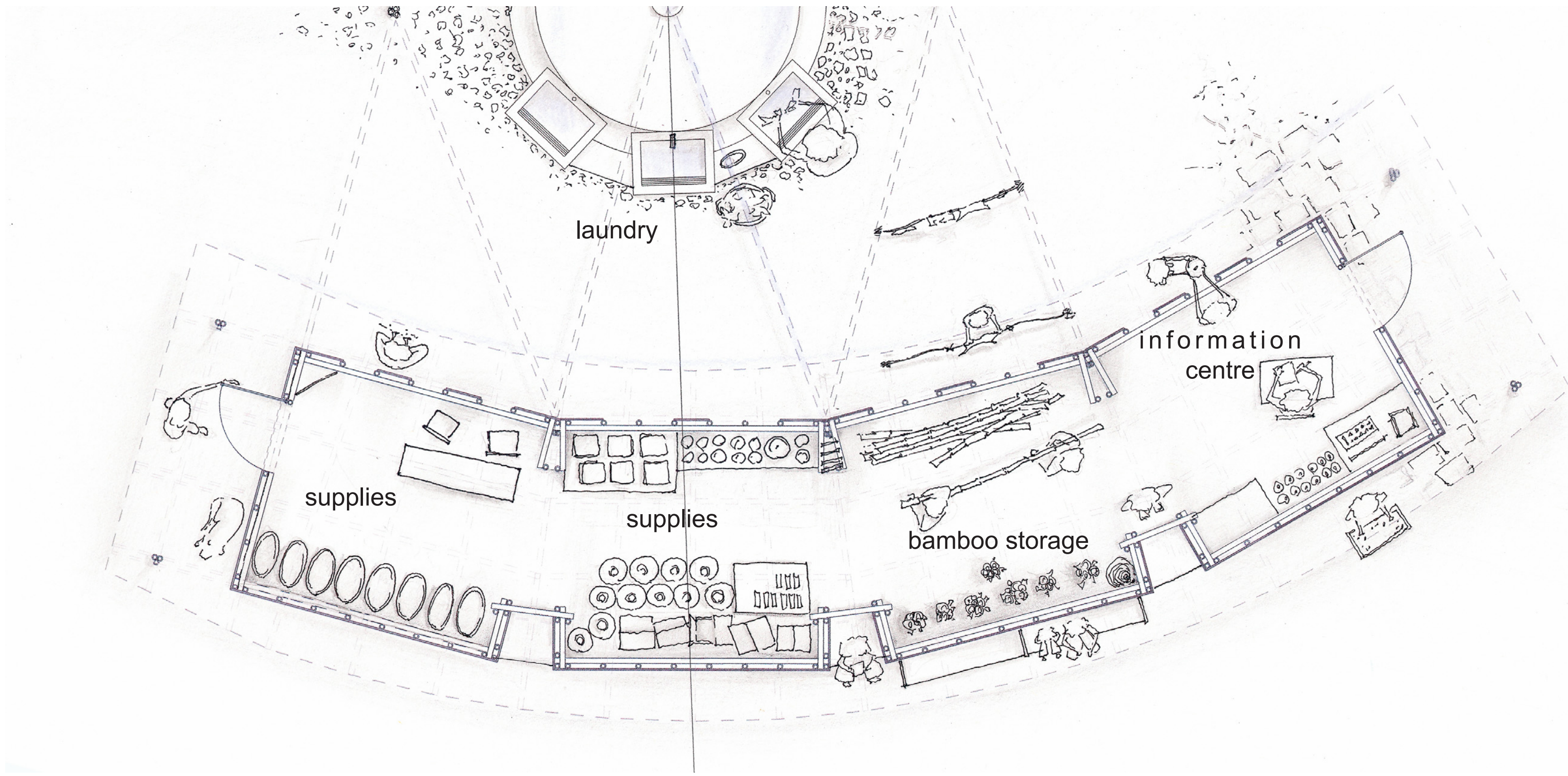
Photograph of model of community laundry facility showing exterior elevation.

Water and Community

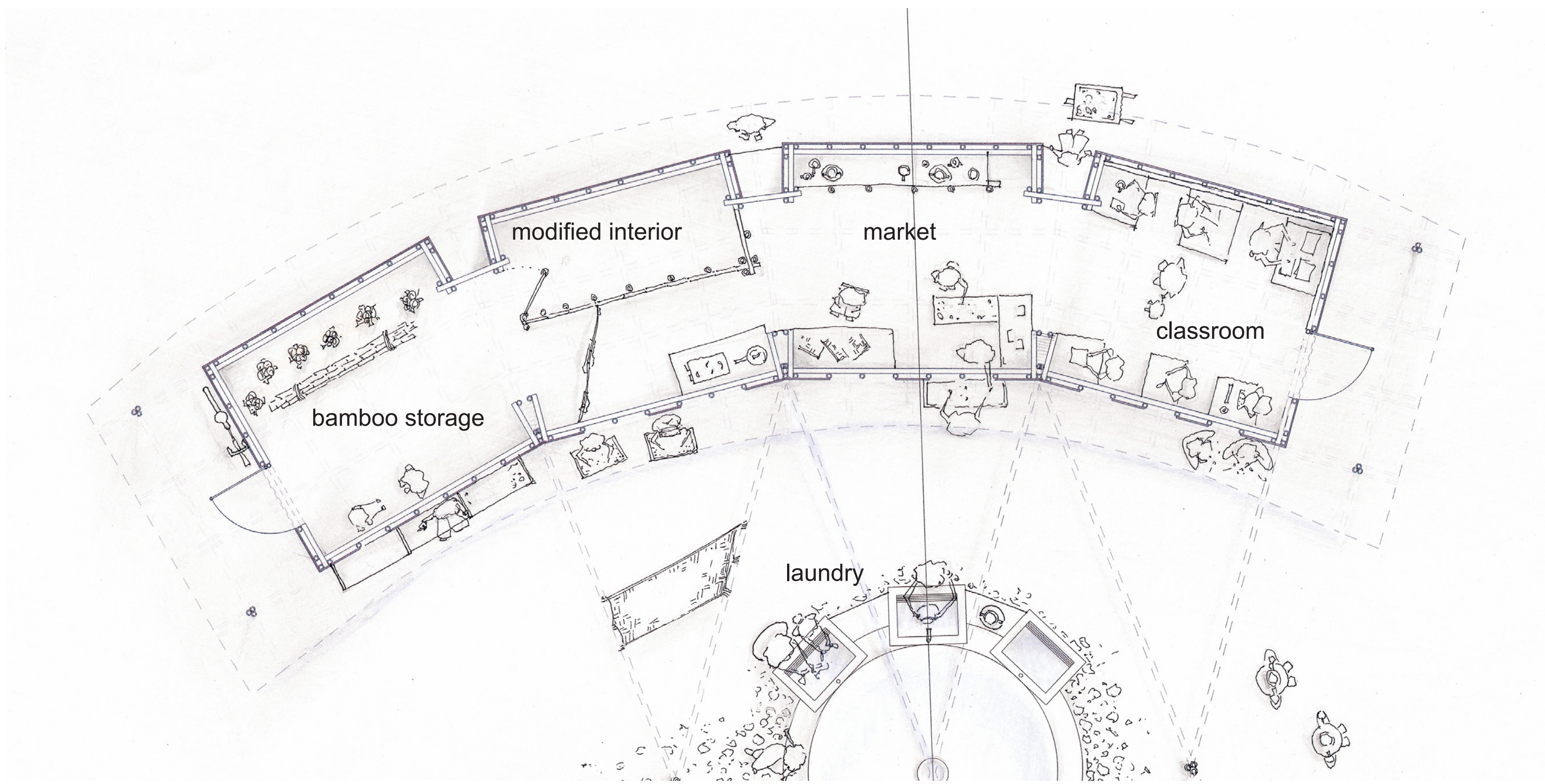
In addition to serving as a teaching tool and an exemplary building for bamboo construction, the community laundry facility also serves as a gathering place for the displaced population - a place of civic pride. Its program as a community laundry facility allows the displaced population to return to a normal activity (washing clothes) and helps to restore dignity and self-sufficiency in the face of loss. With water as such an important element for basic human survival in addition to its storage and access playing such a prevalent role in the everyday lives of Salvadorans, the incorporation of a cistern for water collection and storage is a key feature of the community facility. Also, because it remains a laundry facility even after the displaced population has moved on to a permanent relocation, this continuity helps the transition of the distribution centre to a community service space.



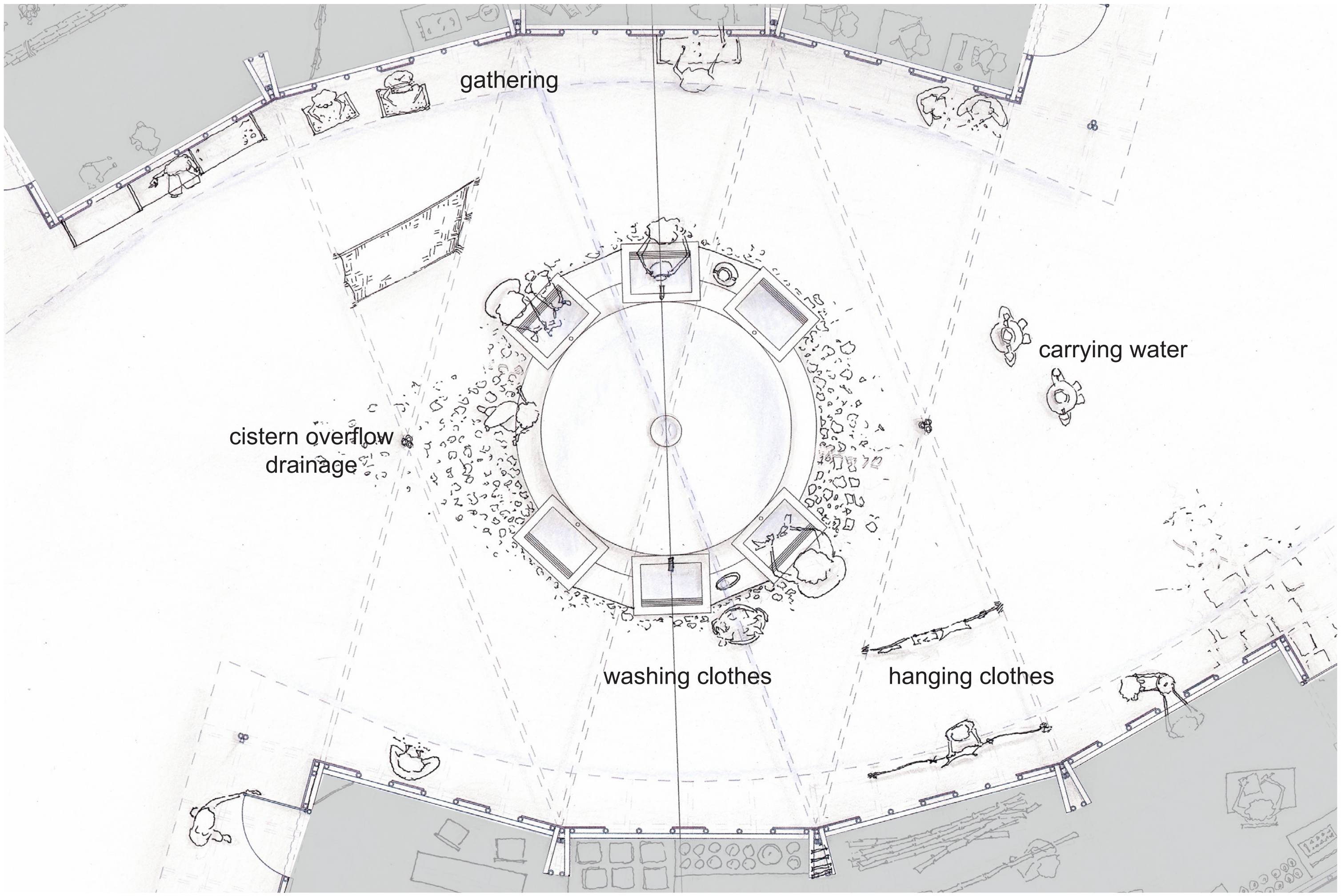
Drawing showing water level in cistern for monthly collection during dry season, rainy season and yearly average based on roof size of community laundry facility and normal rainfall for El Salvador.



Detailed view of south wing of community laundry facility showing program of space as distribution centre for disaster relief. Cistern and laundry remain constant.

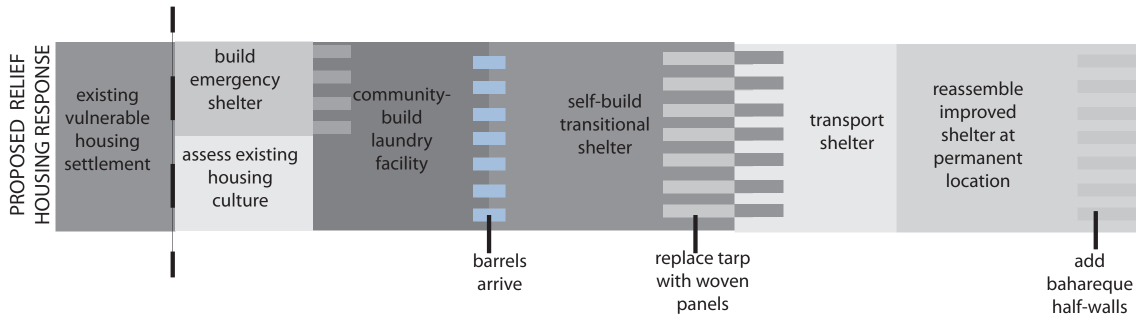


Detailed view of north wing of community laundry facility showing potential use of interior spaces once disaster relief distribution centre is no longer necessary. Cistern and laundry remain constant.



Detailed view of community laundry facility courtyard showing activity at cistern and under shaded overhangs.

Essential Materials Kit



Process diagram key with color to highlight phase of process being discussed.

The bulk of materials needed for construction of the community centre and housing can be sourced locally. This includes primarily bamboo which is used as the main structural elements in walls and roof. Additionally, readily available natural materials such as reed and rattan are used to make woven mats for cladding. Those critical elements that are not so easily procured are packed into a barrel to be shipped to the displaced population for use in construction of their housing. This occurs as soon as the barrels become available so that their contents can be accessed as early as possible. For the proposed housing project the contents might include cord for attaching bamboo elements, the barrel itself for water storage, a shovel to dig foundations, tools for cutting and splitting bamboo, a lightweight fibreglass sink for washing and hygiene, a tarp for cladding, blankets, and a hand pump for water delivery to prevent contamination of stored water. While the contents of the barrel are intended for a specific purpose, they are also versatile and open to local appropriation.

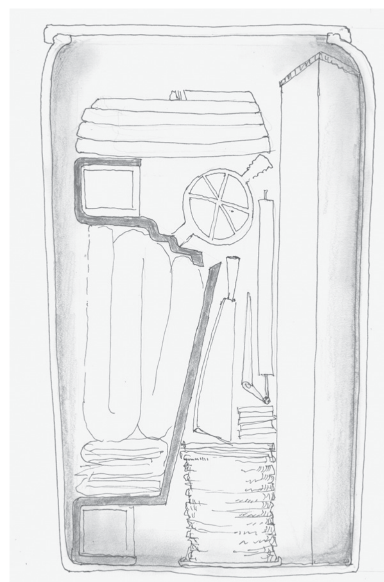
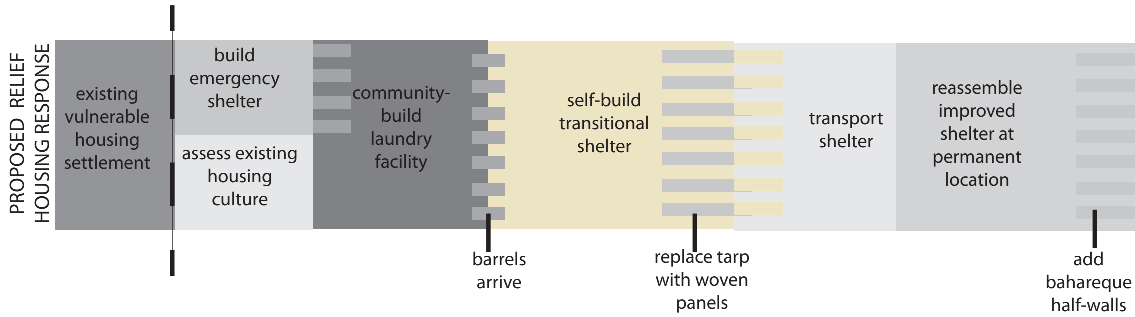


Diagram of barrel to be sent to San Vicente for disaster relief (500 x 750 x 900 mm)

Photograph of model of sink with example of possible stand.

Self-build Transitional Shelter



Process diagram key with color to highlight phase of process being discussed.

Once the community laundry facility has been constructed, the displaced population can then use the skills acquired to begin construction of their own homes. This process is meant to take place at the temporary relocation site under minimal supervision until a suitable permanent relocation site is established (which often takes upwards of two years due to political and legal delays). However, from this stage forward it is acknowledged that the population now have the skills, materials and knowledge to relocate where and when they see fit (although there is some site preparation that should be done before establishing a permanent house on any land and on sloped sites in particular).

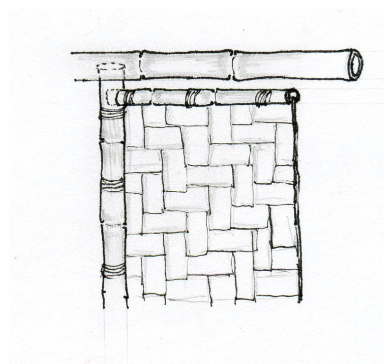
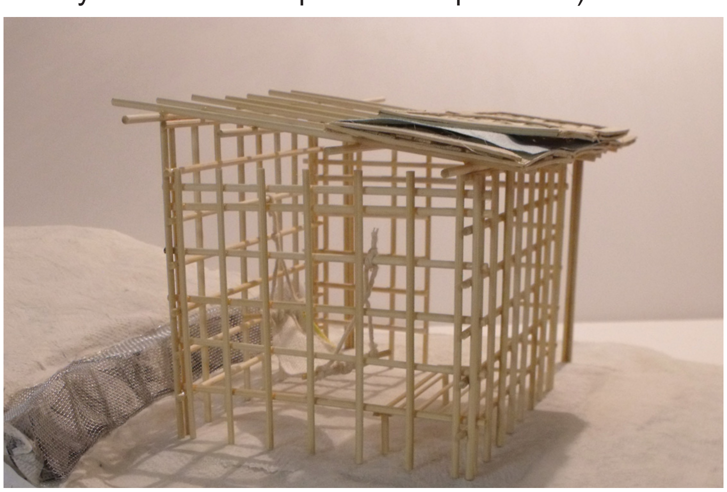
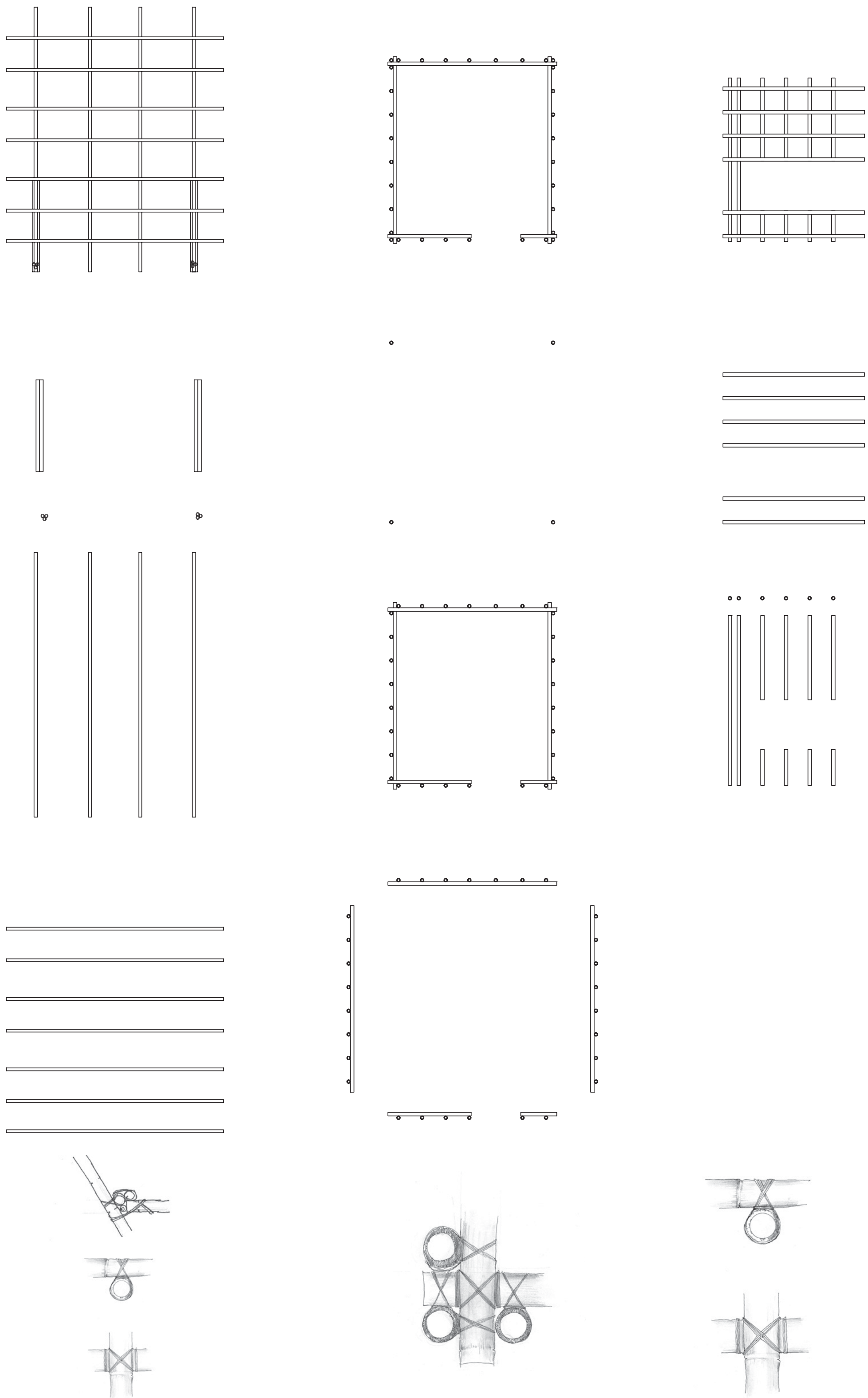


Diagram showing door or window detail.



Photograph of model of basic housing unit.

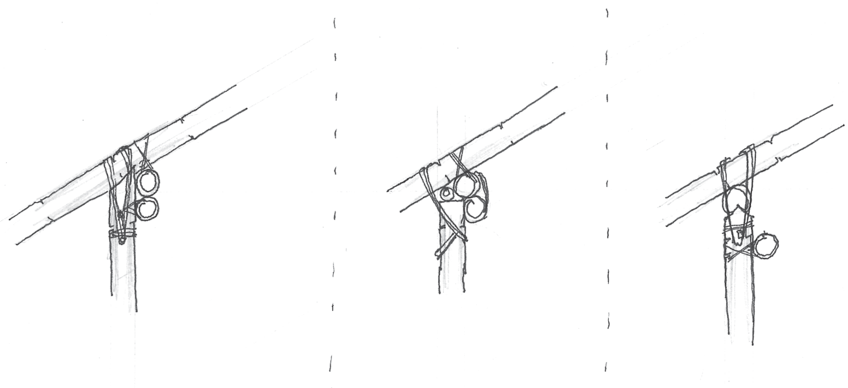


3. assembling roof members

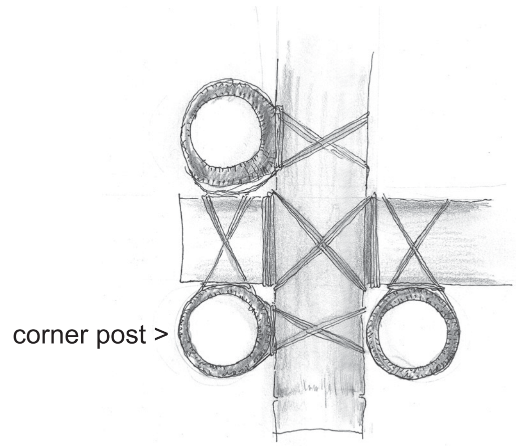
2. assembling walls and corner posts

1. assembling horizontal and vertical members

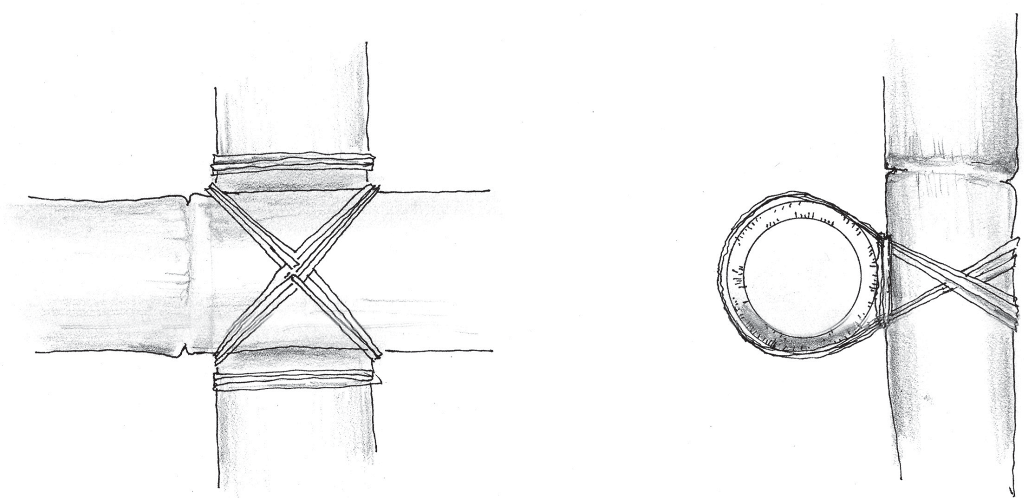
Construction sequence showing assembly of basic unit with bamboo connection details shown.



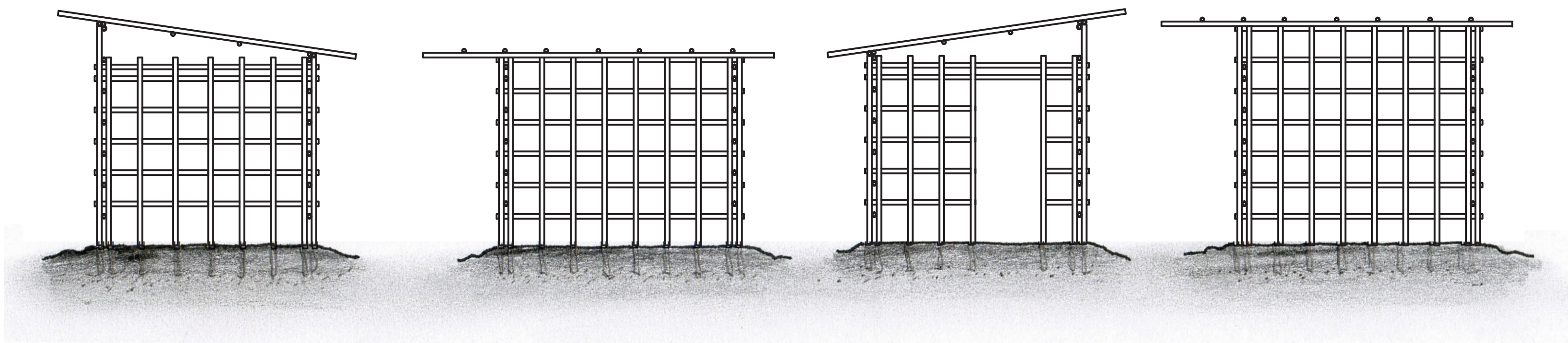
Sketch showing three potential roof wall connection details. The first and third require the vertical posts to be specially cut at the top and a peg inserted into the bamboo. The second sketch shows the roof wall connection with no special cuts or pegs.



Sketch showing in plan the connection of wall units to each other and to the corner post.



Sketch showing the connection detail (front and side views) for connections between horizontal and vertical members.



Framing elevations of basic unit.

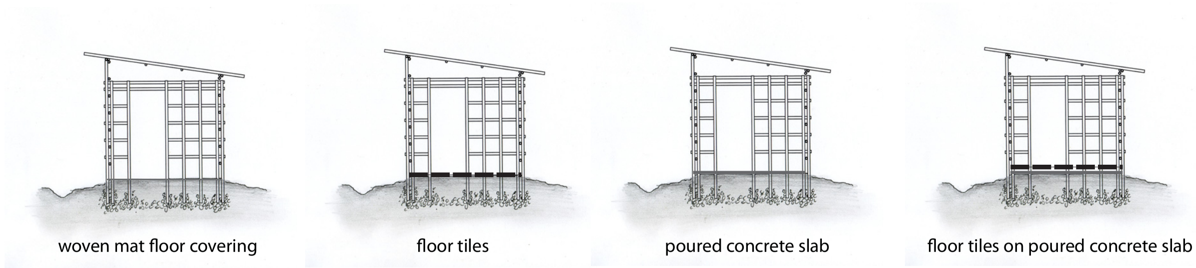


DIAGRAM SHOWING HOUSING UNIT WITH VARIOUS FLOORING OPTIONS / EVOLUTIONS

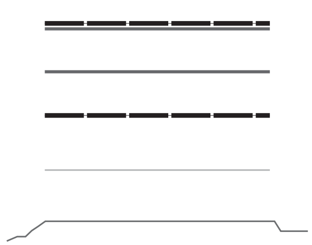
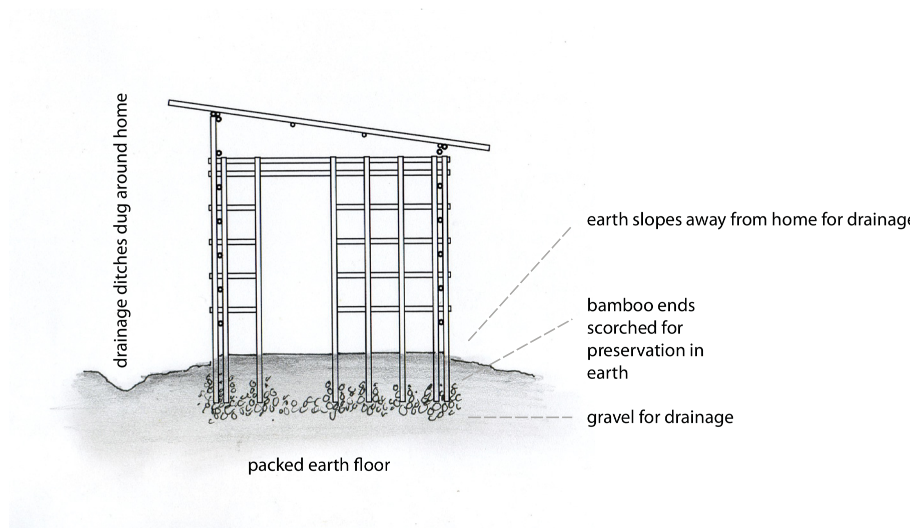
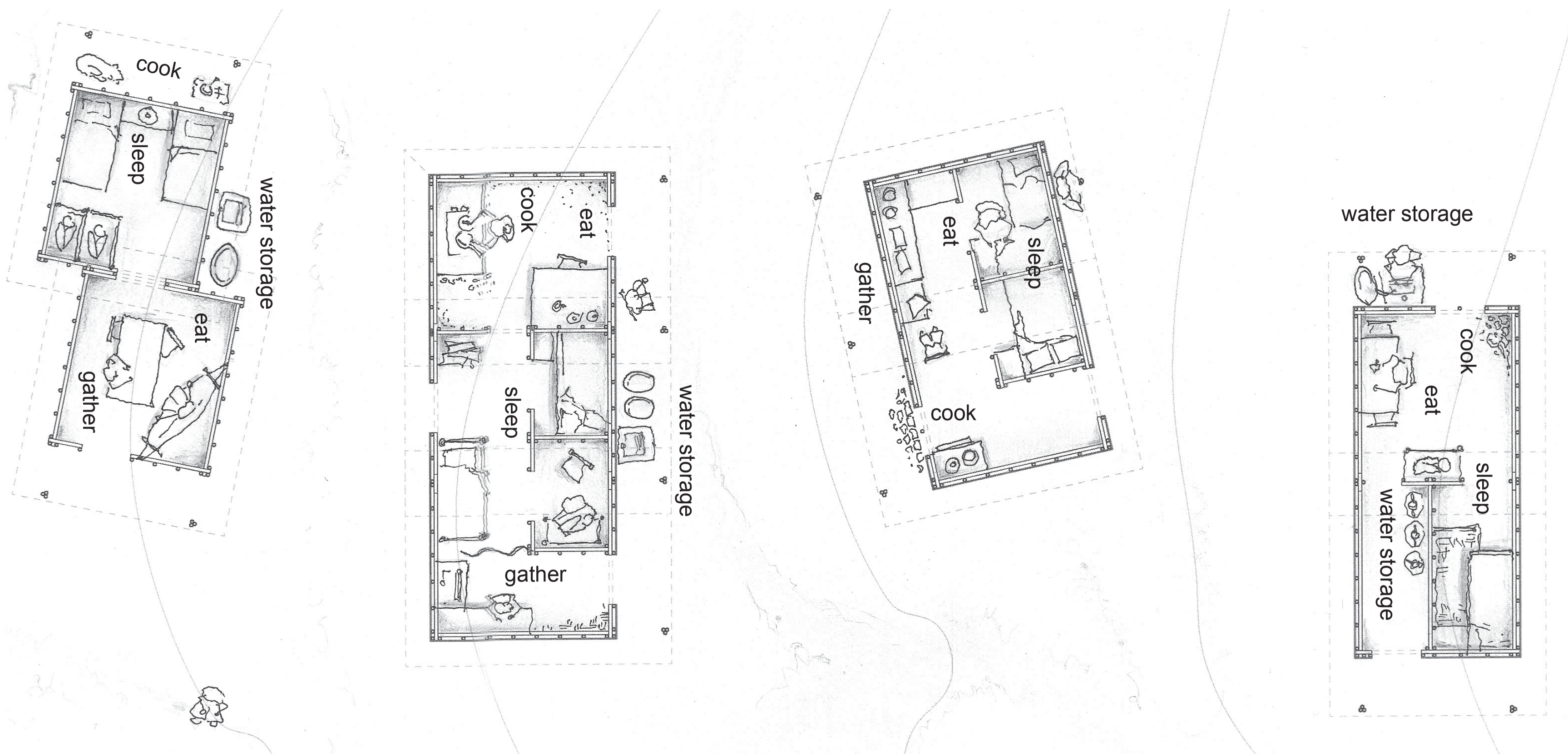


DIAGRAM SHOWING POTENTIAL FLOORING
OPTIONS ON TOP OF PACKED EARTH FLOOR

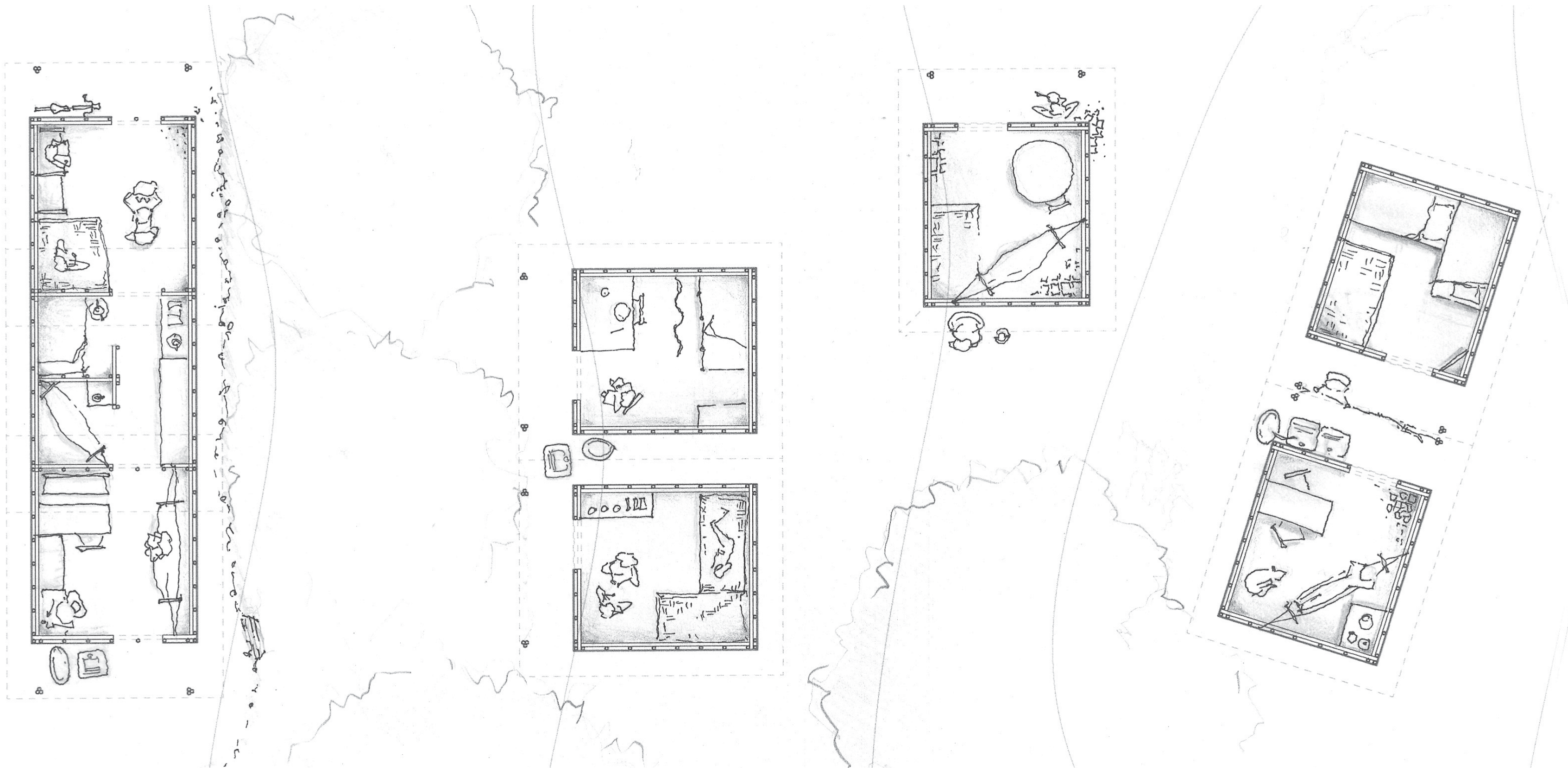


SECTION SHOWING GROUND CONNECTION AND DETAILS

Diagram showing foundation and flooring.



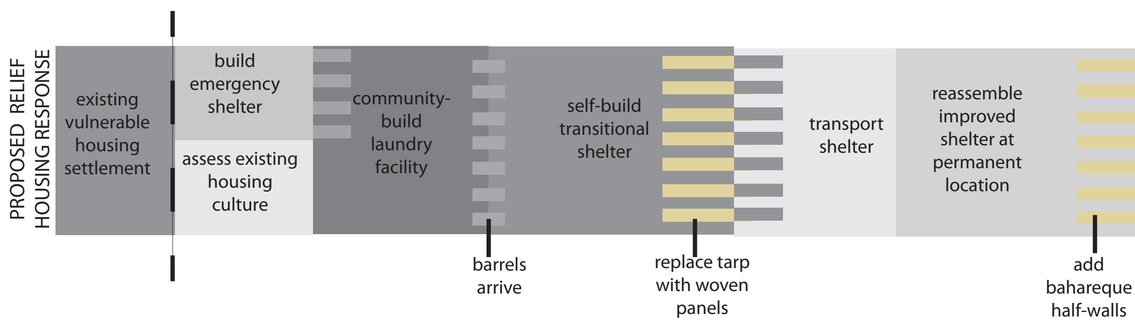
Detailed view of potential housing configurations (left side) with units expanded so that narrow span follows contours on sloped site.



Detailed view of potential housing configurations (right side) with units expanded so that narrow span follows contours on sloped site.

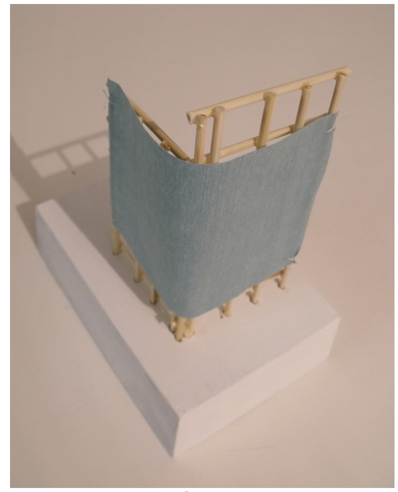
The basic unit designed and used in construction of the community laundry facility is meant to accommodate two people based on the United Nations recommendation of 3.5 square meters of sheltered space per person. The grid system employed in the wall and roof construction allows for easy adaptations in space planning with occupants as builders. Several units can be combined and divided into various room sizes and wall units can easily be cut and reassembled creating infinite possibilities and the ability of the proposed housing to accommodate different family structures and sizes.

Cladding

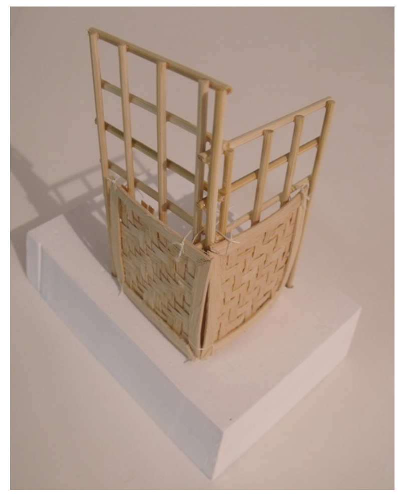


Process diagram key with color to highlight phase of process being discussed.

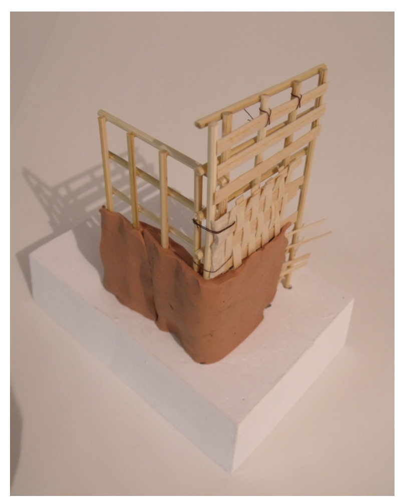
Once the house frame has been constructed by its occupants and community members, cladding must be applied. First, a tarp is attached to the frame with ties to provide immediate protection from the elements (the corner detail allows for continuous cladding around corner). This can be sourced from emergency shelters as well as from the barrels provided. Subsequently, woven panels of natural material are fabricated by community members (weaving is a skill familiar to the population as the textile industry is the second largest industry in the country and much of the fabric is made by hand on wooden looms, also local craft includes the weaving of natural fibres into baskets). These panels can also be attached with ties and are easy to transport. Different weaving techniques provide variations in ventilation and day lighting by the panels. Additionally, woven panels that are replaced by bahareque half-walls in the final stage of cladding can be re-used as flooring and any panels that are damaged can be relatively easily replaced by owners. As mentioned, the final stage of cladding involves the addition of bahareque half-walls once the house is in its permanent location. This serves a number of purposes: firstly it gives occupants a sense of permanence as well as security. Also, it relates the new housing to established housing culture where bahareque wall construction is the third most common wall material in homes (after adobe and concrete) (Konagai et al. 2002).



Photograph of cladding model: tarp



Photograph of cladding model: woven panels



Photograph of cladding model: bahareque half-wall, woven panels, split bamboo slats.

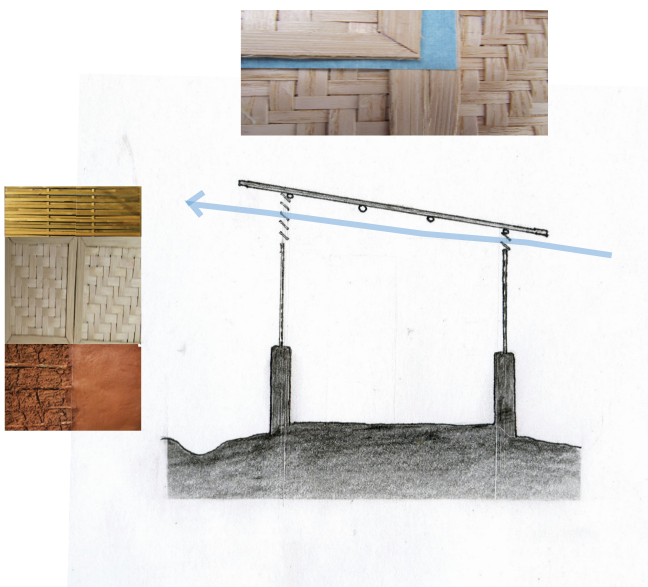


Diagram showing cladding in relation to ventilation.

The cladding of the community laundry facility serves both to teach the displaced population the skills required to clad their own homes and to demonstrate a cladding strategy for a house in its permanent location. The cladding strategy aims to provide inhabitants with improved natural ventilation and day lighting compared to typical disaster relief housing responses and some of the existing housing practices.

Photograph of model showing roof cladding: a layering of woven panel - tarp - woven panel. This creates a roof that is lightweight in comparison to traditional tiled roofs providing increased seismic safety. Also, this does not trap heat in the same way sheet metal roofs do (another common roofing material).

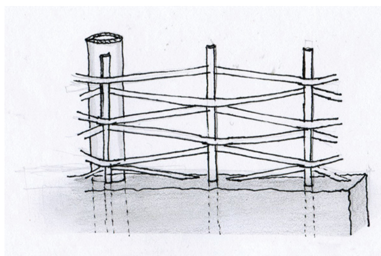
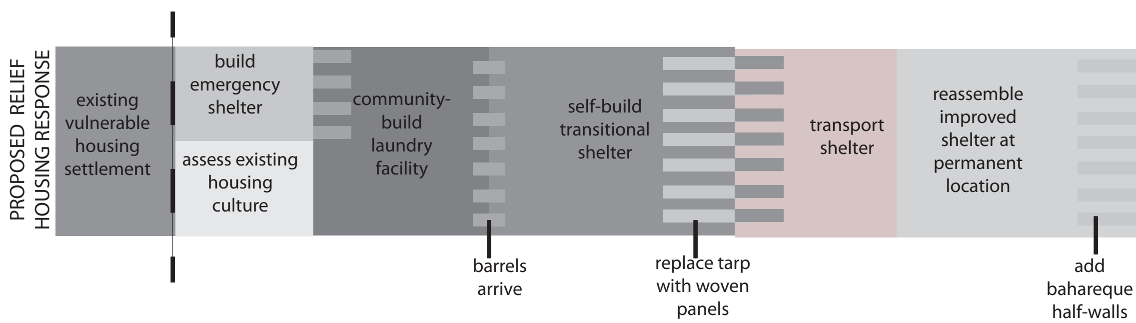


Diagram showing bahareque wall addition.

Transport Shelter



Process diagram key with color to highlight phase of process being discussed.

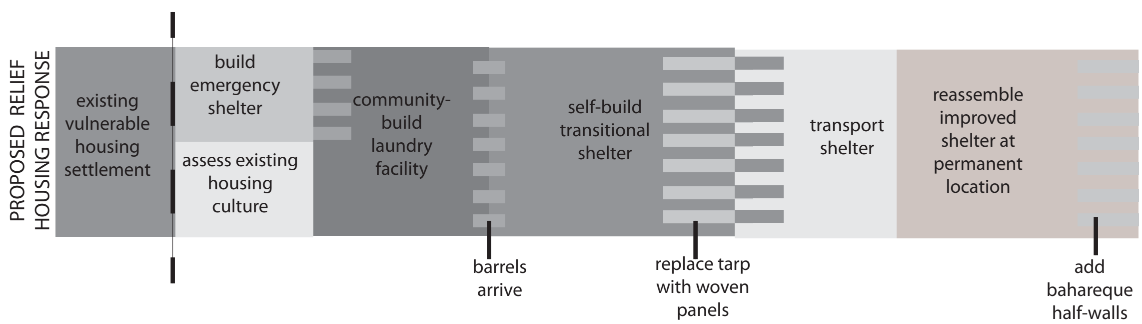
Once a permanent location has been established, the houses are disassembled into smaller units for transportation. The wall units embody a considerable amount of labour with the lashing of vertical and horizontal members so these will likely remain intact for transport. Because bamboo is hollow these wall units are not significantly heavy and warrant the effort to transport them intact.

Photograph of community members in San Vicente moving a temporary shelter to a new location.

In terms of transportability, by creating housing designed to enable relocation beneficiaries are not bound by political timelines. Conventional housing solutions fail to keep or attract occupants because they are either temporary shelters that have deteriorated because they were not designed to last the extended stay political and legal tie-ups can cause, or are inappropriately located. A transportable unit allows its users more freedom and control in terms of when and where to relocate.

Additionally, a portable unit has the advantage of low site impact during deployment. Although it exists in a temporary location, temporary does not mean disposable; rather, like architecture designed for a permanent site, the portable unit too is designed as a specific response to specific problems for a specific population, not as "the expedient provision of loose-fit, low-cost, projects with minimal satisfaction thresholds." (Kronenburg 2003, 53)

Transition from Temporary to Permanent



Process diagram key with color to highlight phase of process being discussed.

Before the house can be established on its permanent site this site must be properly prepared. Given that a permanent relocation site is not determined by those providing the housing but rather by the occupants themselves or a government agency, the house must be able to adapt to a variety of site conditions. Much of the disaster prone land in El Salvador can be found on slopes, at the base of a slope, or at the edges of rivers and the ocean. While the proposal addresses adaptation to sloped sites, it is important to note that return to vulnerable land is not encouraged; rather, it is acknowledged as a real possibility/probability that refugees will return to the site of their original dwelling which often is a sloped site for reasons previously described. The way in which the proposal addresses the slope is through a combination of smaller units with a narrow span that can combine linearly to follow the contours. In terms of sloped site preparation, a flat pad needs to be established with enough space around it for drainage ditches. This likely will involve some manipulation of the slope and the addition of a gabion wall to prevent erosion.

As previously discussed, evidence shows that initial interventions influence permanent settlements, thus transitional housing allows the process toward a permanent housing solution to begin in the early stages of relief. It avoids the need for temporary housing, which has been criticized for using resources that could be put toward permanent housing. The proposed transitional housing is something that evolves to become rooted in site giving its owners a sense of permanence and recovery. As Christian Norberg-Schulz writes,

> We could also say that the house is the place where daily life takes place. Daily life represents what is continuous in our existence, and therefore supports us like a familiar ground. (Norberg-Schulz 1985, 89)

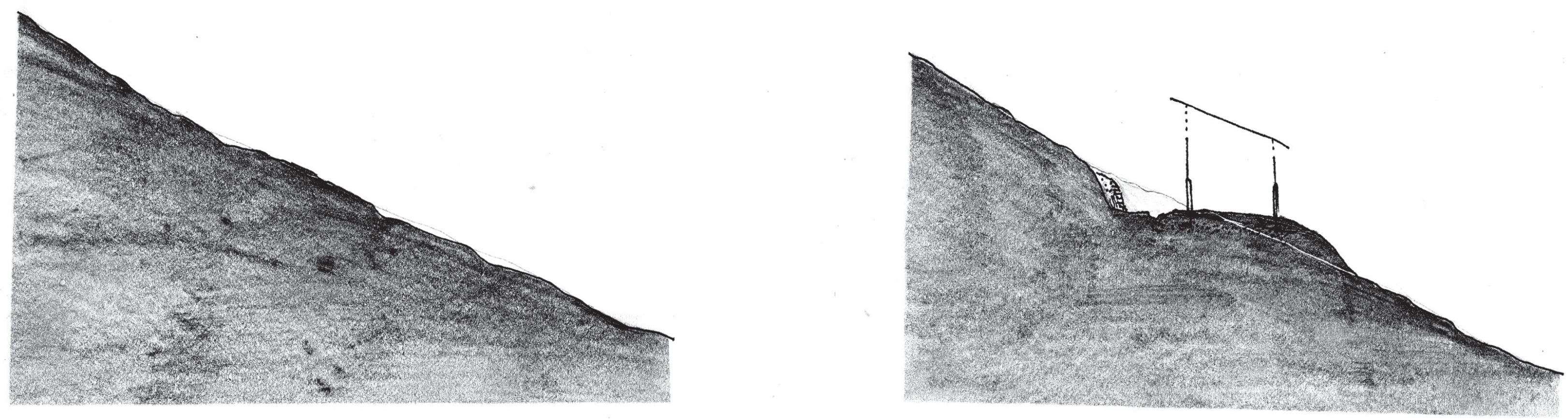
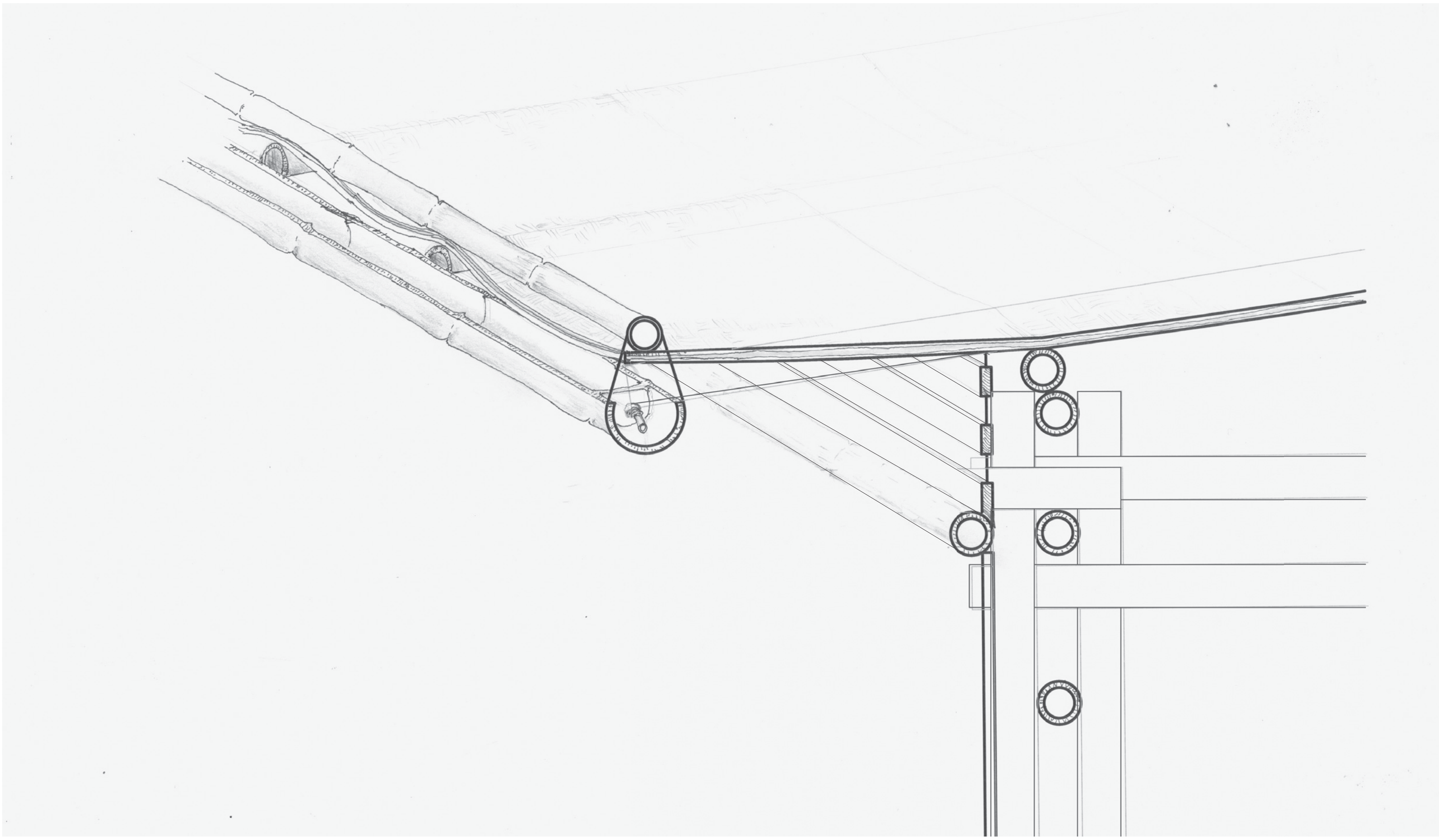


Diagram showing a sloped site before and after site preparation.

Potential permanent housing settlement on sloped site; plans and framing elevations

Water Collection

The portable sink/water-collection unit provided to each household via the barrels gives occupants a means to increased independence by providing them with a way to procure their own water needs – water being a basic survival need and something whose access is often jeopardized in the wake of disaster. As previously discussed, water storage and access is of concern to the people of El Salvador. While the barrels and sink are not adequate to meet a household's water needs during the dry season, it nonetheless provides increased relief and independence. With the experience of the community building of the laundry facility, which itself captures water in a cistern, there is the possibility of establishment of a cistern and collective water storage and collection at a relocation site given that this is a learned process.

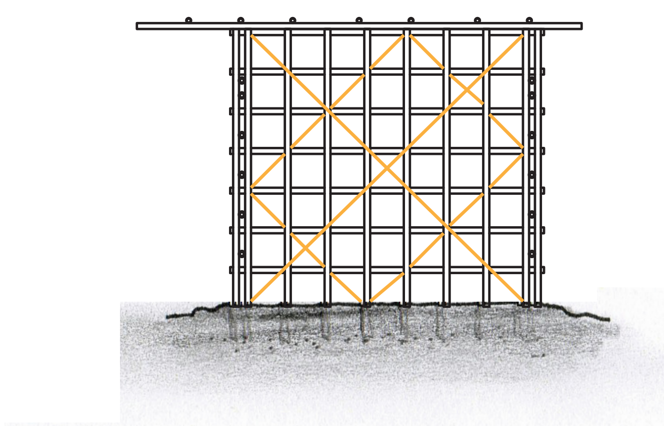


Drawing showing gutter detail on community laundry facility. Water is collected from roof and channeled into cistern via gutters and hoses that run along the courtyard’s overhead beams

Seismic Features

Construction System

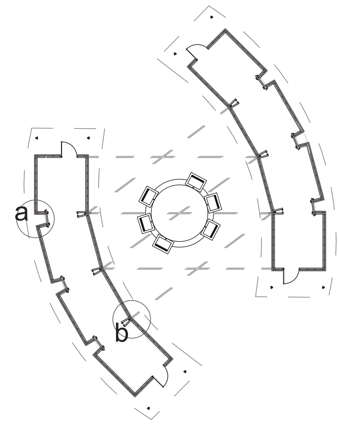
The grid system employed in construction of wall (and roof) frames contributes to the seismic safety of the homes by distributing the lateral forces experienced in an earthquake throughout the system. Additionally, the lashed joints allow for flexibility in the wall contributing to the seismic resistance of the system, however, diagonal cords were added after a scale model revealed that the grid alone was a bit too flexible. The mechanical properties of bamboo itself contribute to seismic resistance of the system, with its strong longitudinal fibers, arrangement of nodes, and hollow core. The lightweight roof system also relieves stress on the walls, particularly compared to the commonly used heavy clay roofing tiles.



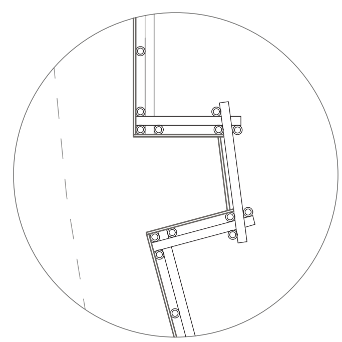
Drawing showing grid frame with diagonal cords in orange.

Community Laundry Facility

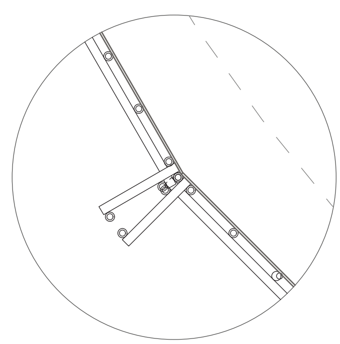
In addition to the seismic features described in the construction system, the design of the community laundry facility also contributes to the seismic safety of that building. The convex exterior walls feature insets and the concave interior walls (which face the courtyard) feature shear walls, both of which help manage lateral forces experienced during earthquakes. In addition to contributing to seismic safety, the design features mentioned also provide additional opportunities for teaching construction of the building system to the community population.



Plan of laundry facility showing detail locations



a) detail of inset in exterior wall



b) detail of shear walls in interior wall

CHAPTER 3: CONCLUSION

The investigation began with the intent of developing disaster-relief-housing for the vulnerable populations of San Vicente, El Salvador that both responds to the challenges identified by typical disaster relief housing and is mindful of existing political and social structures.

It became clear through this process that, while the ultimate “product” offered is a house and community building, the social, cultural and economic impacts of the project are tied to its organizational approach and implementation procedure as much as to its architectural expression. This then raises the question of what exactly is the responsibility of an architect in the development of disaster-relief-housing? It became evident that the role of an architect here needs to be expanded beyond building design to design of a housing process. Additionally, a proposal for implementation of the project/process needs to address several stakeholder groups including local and national government officials, local and national aid agencies, and the affected population itself.

The challenges associated with implementing the proposed project reflect many of the criticisms identified with typical approaches to disaster-relief-housing, which are related to the long-term impacts of the offered solutions. It is difficult to convince stakeholders to think long-term with the immediacy of relief efforts required. Nonetheless, decisions made early on influence long-term housing and so a process which allows careful consideration of this affords those involved the opportunity to not only supply shelter, but also to provide improved living conditions that will ultimately increase inhabitants' ability to cope with future disasters and therefore lessen the burden of government and relief agencies in the face of future disasters.

Ultimately, applying the proposed housing strategy to vulnerable populations prior to disaster would be ideal to prevent loss. This could be done as a means to test the proposal and would allow for preparation of supplies and procedures for efficient response to future disasters. Testing would also allow for evaluation of the project and improvements to be applied.

APPENDIX A: CASE STUDIES

Index of Case Studies

Central America:

- Honduras 1998
- Peru 2007
- Peru 2007
- Peru 2007
- El Salvador 2009

Africa:

- Japan 1995
- Rawanda 1998
- Turkey 2000
- India 2001

Others of Particular Interest:

- Sri Lanka 2005
- Sri Lanka 2005
- Iran 1995
- Rubble House 1999
- Extreme Housing 1999

PROJECT and DURATION	SHELTER SIZE and OCCUPANCY	MATERIAL	OTHER INFRASTRUCTURE ASSOCIATED WITH PROJECT	LAND TENURE and BUILDING METHOD	DESIGN	NOTES
SOUTH AND CENTRAL AMERICA						
Honduras 1998 Hurricane destroys 33 000 homes, damages 55 000 transitional housing (5 month project)	11.1 m² 3.05m x 3.65m 4-5 persons / shelter 2.2 - 2.8 m² / person	• wood frame • woven plastic sheeting • galvanized roof sheets • timber frame (reused from destroyed homes where possible) • 1 door, 2 windows and netting	none	families own lot near their destroyed homes or if land unsafe relocated to temporary sites local builders and self-help		• used disel to protect wood from termites? • poor camp layout • no sanitation or water supply
Peru 2007 Earthquake and tsunami transitional housing (24 day project)	9 m² material allowed for variable plan may be supplemented by beneficiaries to increase shelter size	• bamboo mats (sheathing) • plastic sheets • round poles (3" diameter, 3m length) • nails and hinges	none	Housing located on previously owned land self-build with flexible package of materials and manual		• bulk purchase of local materials caused prices to raise and scarcity of materials • materials distributed from neighbourhood public kitchens • established NGO aided implementation
Peru 2007 Earthquake and tsunami transitional housing (3 month project)	18 m² 5 persons / shelter 3.6 m² / person	• timber poles • soil and cement mix floors • plastic sheeting • woven reed mats	• water • sanitation • small business grants • transitional classrooms • paid local labour	No legal land rights so shelters required to be easily dismantled self-build, supervised by expert (final year engineering student volunteer)		• design arrived at by vetting and modifying designs of 3 local carpenters • paid workers to clear debris into streets • paid locals for construction

Table showing case studies from South and Central America

PROJECT and DURATION	SHELTER SIZE and OCCUPANCY	MATERIAL	OTHER INFRASTRUCTURE ASSOCIATED WITH PROJECT	LAND TENURE and BUILDING METHOD	DESIGN	NOTES
SOUTH AND CENTRAL AMERICA						
Peru 2007 Earthquake and tsunami semi-permanent transitional housing (9 month project)	18 m² 3m x 6m 1900 families sheltered	• wood frame • shed-roofed • tongue and groove wall covering • 1 door 1 window	?	Built on previous house site or temporary locations pre-fabricated in local 'factories', material to be reused in later building phase		• beneficiaries responsible for floor slab and rubble clearance
El Salvador 2009 Hurricane and mudslide temporary housing (9 month project)	20 m² 4m x 5m 4-8 persons / shelter 2.5-5 m² / person	• concrete and rebar exterior walls • drywall and metal frame interior walls • 2 doors 4 windows • corrugated metal roofing	• electricity and plumbing planned • community centre planned • school planned	built on land cleared and donated by government Habitat for Humanity, national volunteers, self-help		• 183 homes built using 2 sets of concrete frames and imited time alloted by governement officials • other infrastructure planned but as not yet implemented
AFRICA						
Rawanda 2008 Forced repatriation from Tanzania permanent housing (14 month phased project)	48 m² 6m x 8m 220 shelters / 469 families	• cement • foundation stones • sand • wood • doors and windows • roof sheeting • clay bricks	• rainwater catchment, water access boreholes • sanitation • community multi-purpose centre • day-care centre	Relocated into existing communities; new infrastructure shared between old and new community members hired mason, local assistant, beneficiary labor		• termites attcked untreated wood • new infrastructure shared between old and new inhabitants eased settlement • took up to 2 years to implement project

Table showing case studies from South and Central America and Africa

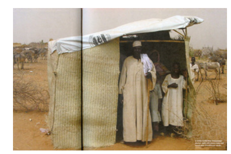
PROJECT and DURATION	SHELTER SIZE and OCCUPANCY	MATERIAL	OTHER INFRASTRUCTURE ASSOCIATED WITH PROJECT	LAND TENURE and BUILDING METHOD	DESIGN	NOTES
AFRICA						
D. R. Congo 2002 Volcano erruption transitional shelters (10 month project)	24 m^2 5m x 4.8m 5-6 persons / shelter 4-4.8 m^2 / person	• corrugated zinc sheet roof • plastic sheeting wall covering • timber frame and lathes • rock and earth foundations (encouraged)	none	Self-selection of land for shelter; either bought, rented, or donated by relatives self-build with technical support		• plastic walls lack PRIVACY and SECURITY • example shelters built as models and to teach construction • paid labour and sourcing of local materials
Sudan 2004 Displaced population from Darfur transitional shelters (3 month project)	6.25 m^2 4-5 persons / shelter 1.25-1.5 m^2 / person	• bamboo frames • woven grass mats for cladding • cord recycled from rubber tires (assembly).	• Cultivation and livestock access programs • micro-credit • psycho-social support • community infrastructure programs • employed locals to weave mats	Located on temporary site with the intention that materials can be reused and relocated self-build under supervision of CHF who began initiative		• cost per unit $90 • created a balance between prevention of permanent settlement and income generation • woven mats improved vetilation compared to plastic sheeting
Liberia 2007 Refugees returning post-war permanent housing (6 month project)	25 m^2 5m x 5m 3.6 persons / shelter 7 m^2 / person	• zinc roofing sheets • roofing felt • central pole • poles for rafters and frame • bamboo rope	• water • sanitation • education programs	land allocated by NGO with government and distributed by the community itself self-build shelters		• used local design and community input • suited to rural vs. urban context

Table showing case studies from Africa

PROJECT and DURATION	SHELTER SIZE and OCCUPANCY	MATERIAL	OTHER INFRASTRUCTURE ASSOCIATED WITH PROJECT	LAND TENURE and BUILDING METHOD	DESIGN	NOTES
OTHERS OF PARTICULAR INTEREST						
Sri Lanka 2005 Tsunami transitional shelters (3 month project)	m² 1 family / shelter m² / person	• wood • corrugated roof sheeting • cement blocks	• latrines (three of which were permanent to be used by the community once the shelters were relocated).	Temporarily located in a children's playground in the middle of the village engineer and site supervisor employed, beneficiary families contributed paid labor		• designed to be dismantled after a year • floors made of concrete tiles vs. poured concrete • wood joints bolted vs nailed or skrewed
Sri Lanka 2005 Safe[R] House Tsunami permanent housing	37 m² 5.5m x 6.7m (approx) 4 persons / shelter 9.25 m² / person (less bathroom & open kitchen/living space)	• 4 c-shaped concrete structures • local porus material (bamboo/woven mats) • raised platform	• community buildings	relocated to lots outside the restricted 100-200 yard coastline zone Prajnopaya Foundation builds with local labour		• flexibility of configuration • natural ventilation and shading • increased resistance to water
Iran 1995 Super Adobe War refugees from Iraq temporary housing (6-11 days per unit)	14.6 m² 2.43m diameter 1 family / shelter	• brabed wire • sandbags/earth tubes • sand • fire	• none	temporary site, homes destroyed after use built by refugees under the supervision and instruction of a local architect		• if no plaster or waterproofing added, shelter can be bulldozed at the end of project • lack of interior partitioning

Table showing case studies of particular interest

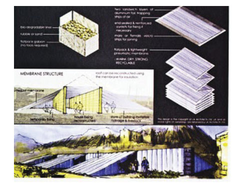
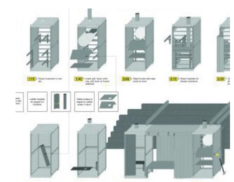
PROJECT and DURATION	SHELTER SIZE and OCCUPANCY	MATERIAL	OTHER INFRASTRUCTURE ASSOCIATED WITH PROJECT	LAND TENURE and BUILDING METHOD	DESIGN	NOTES
OTHERS OF PARTICULAR INTEREST						
Rubble house 1999 Kosovo Refugees temporary housing (same-day construction)	variable size	• packed flat • wire gabions • aluminum roof membrane • nylon-reinforced aluminum foil roof cladding • velcroe connectors	• none	variable sites built by users with detailed directions		• snaps together requiring no tools for assembly
Extreme Housing 1999 variable sites transitional housing components	variable size core units 2.25 m^2 1 family / shelter	• synthetic core • variable cladding: bamboo cardboard thin Al sheeting • beams (to connect cores)	• none	variable sites cores pre-fabricted, local materials and labour sourced for housing...		• structure can become core of housing or attach to semi-destroyed home or moved to permanent site

Table showing case studies of particular interest

APPENDIX B: HOUSING STATISTICS FOR EL SALVADOR

	According to the wall material				According to the roof material					Total
Department	Concrete	Bahareque	Adobe	Others	Slab	Tile	Asbestos sheet	Metallic sheet	Others	
Ahuachapán	14,892	6,192	20,492	9,540	0	33,616	3,912	10,520	3,068	51,116
Santa Ana	43,333	6,201	48,796	3,413	125	66,983	18,163	16,061	411	101,743
Sonsonate	33,702	9,727	17,262	13,700	137	20,139	18,632	33,976	1,507	74,391
Chalatenango	9,330	954	30,024	324	162	38,388	642	1,440	0	40,632
La Libertad	61,492	17,286	26,526	7,667	307	42,228	36,616	33,104	716	112,971
San Salvador	302,340	28,260	23,352	20,496	16,476	66,786	201,972	88,050	1,338	374,622
Cuscatlán	8,116	5,768	18,386	922	112	25,010	3,174	4,734	162	33,192
La Paz	17,330	7,354	21,462	3,696	366	41,584	4,036	3,096	836	49,918
Cabañas	6,525	2,780	14,011	1,115	49	21,704	1,774	598	152	24,277
San Vicente	8,051	5,308	15,536	2,527	0	26,686	1,714	2,728	154	31,282
Usulután	25,183	8,530	22,838	6,099	124	44,757	9,195	7,854	859	62,789
San Miguel	44,905	11,715	17,315	7,492	780	56,165	18,040	5,965	595	81,545
Morazán	5,302	5,087	14,291	7,370	0	27,307	1,071	2,407	1,283	32,068
La Unión	17,322	7,872	23,327	4,665	188	47,863	1,967	392	2,925	53,335
Total	**597,823**	**123,034**	**313,618**	**89,026**	**18,826**	**559,216**	**320,908**	**210,925**	**14,006**	**1,123,881**
Percentage	**53.2%**	**11%**	**27.9%**	**7.9%**	**1.7%**	**49.8%**	**28.6%**	**18.8%**	**1.3%**	**100%**

Source: Crystal InfoCenter webpage based on the data by the Vice-ministry of Housing and Urban Development

(Crystal Infocenter Web page, http://www.guate.net/crystal/.)

Table showing the spatial distribution by department of dwellings according to the material of their walls and roof cover in El Salvador in 1994

(Konagai et al 2001)

Description	1994	1995	1996	1997	1998	1999
Number of existing dwellings	1,123,881	1,137,305	1,209,319	1,245,795	1,296,635	1,347,970
Housing growing rate	7.1%	1.2%	6.3%	3.0%	4.1%	4.0%
Qualitative housing deficit	549,852	543,173	549,724	534,511	514,637	511,507
Quantitative housing deficit	40,440	35,898	27,654	20,716	45,067	42,817
Total Housing deficit	590,292	579,071	577,378	555,227	559,704	554,324

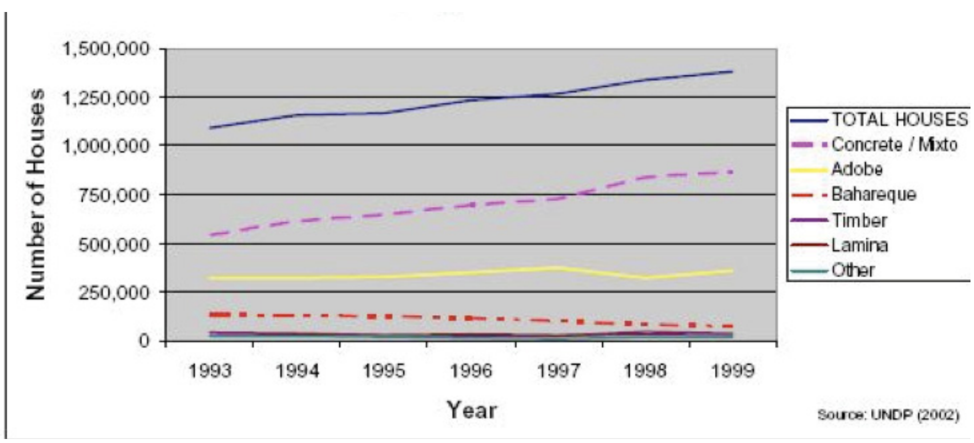
Source: Plan Salvadoreño de Vivienda y Territorio, Viceministerio de Vivienda y Desarrollo Urbano, Oficina de Planeamiento Urbano.

Table showing the housing indexes from the years 1994 to 1999 for El Salvador

(Konagai et al 2001)

Type of Dwelling	Number of Units		
	Urban	Rural	Total
Total	860,082	523,063	1,383,145
Mixto or concrete	685,464	178,476	863,940
Bahareque	27,625	45,633	73,258
Adobe	118,622	241,347	359,969
Timber	5,924	30,933	36,857
Lámina	17,116	11,740	28,856
Other	5,331	14,934	20,265

Table showing the distribution of housing units in El Salvador by type of construction in 1999
(Lopez et al 2004)



Graph showing the number of housing units in El Salvador by type of construction from 1993 to 1999
(Lopez et al 2004)

APPENDIX C: ROOF AND CISTERN SIZING CALCULATIONS

88, 150

survive on.

5 gal/person/day × 365 days = 1 825 gal/yr. = 6.90837 m3/yr. ⇒ 6908.37 L/yr.

N.A water conscious.

10 gal/person/day × 365 days = 3 650 gal/yr. = 13.8167 m3/yr ⇒ 13816.7 L/yr

45/person/day × 365 days = 16 425 gal/yr. = 62.1753 m3/yr 62175.3 L/yr

average % for laundry use.

100/person/day × 365 days = 36 500 gal/yr. − 20% (−7 300) = 29 200 = 110.534 m3

Avg. N.A.

↳ 138.167 m3/yr. ⇒ 138167 L/yr

↓ 27.6335 m3

Avrg. percipitation =

31	Jan	7
28	Feb	7
31	Mar	13
30	Apr	53
31	May	179
30	Jun	315
31	Jul	312
31	Aug	307
31	Sept.	317
31	Oct.	230
30	Nov.	40
30	Dec.	12

1 792 / 6 = 149 mm

monthly rainy avg: (May–Oct) (184–185 day) 1660 / 6 = 276.66 mm.

monthly dry avg: (Nov–Apr) (180–181 days) 132 / 6 = 22 mm

Normal percp

Average percipitation × 0.80 = 'normal' percipitation

			L/m²
total	149 × 0.80 =	119.5 mm	119.5 L/m²
rainy	276.67 × 0.80 =	221.3 mm	221.3 L/m²
dry	22 × 0.80 =	17.6 mm	17.6 L/m²

1 mm of rain on 1 m² of roof area produces ≈ 1 L of water.

(1" of rain on 1 ft² of roof area produces ≈ 0.52–0.62 gallons of water).

varies depending on roofing material & catchment system.

			month. avg. (L)
@ 5 gal/pers/day	6908.37 L/yr	÷12	575.7
@ 45 gal/pers/day	~~[illegible]~~ 62 175 L/yr.		5181.25
@ 100 gal/pers/day	138 167 L/yr		11 513.9

5 gal/pers/day

$575.7\,L \times \frac{1\,m^2}{119.5\,L} = 4.82\,m^2$

$575.7\,L \times \frac{1\,m^2}{221.3\,L} = 2.601\,m^2$

$575.7\,L \times \frac{1\,m^2}{17.6\,L} = 32.7\,m^2$

45 gal/pers/day

$5181.25 \times \frac{1\,m^2}{119.5\,L} = 43.36\,m^2$

$5181.25 \times \frac{1\,m^2}{221.3\,L} = 23.41\,m^2$

$5181.25 \times \frac{1\,m^2}{17.6\,L} = 294.39\,m^2$

100 gal/pers/day

$11513.9 \times \frac{1\,m^2}{119.5\,L} = 96.35\,m^2$

$11513.9\,L \times \frac{1\,m^2}{221.3\,L} = 52.03\,m^2$

$11513.9\,L \times \frac{1\,m^2}{17.6\,L} = 654.20\,m^2$

- Square meter size required for a roof to capture enough rain to meet the monthly needs at 5, 45, and 100 gallons of water per person per day for yearly, rainy season, and dry season average monthly normal rainfall (respectively).

CISTERN SIZING:

5gal/person/day.

$2.601\,m^2 * 17.6\,\frac{L}{m^2} = 45.78\,L/\text{month} * 6\text{ months} = $ **274.666 L** ① amount of H_2O collected in 6 months from a roof with min area required to supply monthly needs in rainy season. (@ 5gal/pers/day).

$575.7\,\frac{L}{\text{month}} * 6\text{ mnth} = 3\,454.2\,L - 274.666\,L = $ **3 179.534 L** ② amount of water needed to cover the difference...

+3.18 m^3 of tank space.

45 gal/pers/day

$23.41\,m^2 * 17.6\,\frac{L}{m^2} = 412.016\,\frac{L}{\text{mnth}} * 6\text{ mnth} = $ **2472.1 L** ①

$5181.25\,\frac{L}{\text{mnth}} * 6\text{ mnth} = 31\,087.5\,L - 2472.1 = $ **28 615.4 L** ②

+28.6 m^3 tankspace.

100 gal/pers/day

$52.03\,m^2 \times 17.6\,\frac{L}{m^2} = 915.728\,\frac{L}{\text{mnth}} * 6\text{ mnth} - $ **5 494.368 L** ①

$11\,513.9\,\frac{L}{\text{mnt}} \times 6\text{ mnth} = 69\,083.4\,L - 5\,494.368\,L = $ **63 589.032 L** ②

+ 63.6 m^3 tank space.

inc in roof size required to catch additional water needed during dry season... ≈ double. (92%).

5gal: $\frac{3179.534\,L}{6\text{ mnth}} = 529.9\,\frac{L}{\text{mnth}} \Rightarrow 575.7 - 529.9 = 45.8\,L$ $\quad \frac{529.9}{575.5} \times 100 = (92\%)$

45gal: $\frac{28\,615.4\,L}{6\text{ mnt}} = 4\,769.23\,L/\text{mnth}$ $\quad 5181.25 - 4769.23 = 412.02\,L$ (92%)

100gal: $\frac{63\,589.032\,L}{6\text{ mnth}} = 10\,598.172\,L/\text{mnt}$ $\quad 11\,513.9 - 10598.172 = 915.7\,L$ (92%)

$0.92(2.601) = 2.4\,m^2 * \left(17.6\,\frac{L}{m^2} \Rightarrow 42.11\,\frac{L}{\text{mnth}} * 6\text{ mnt} = \quad\right)$ ... etc.

$0.92(23.41) = 21.5\,m^2$

$0.92(52.03) = 47.8\,m^2$

5gal:	~~dry~~ wet:	1.61 m → 0.805	(2.601 m²)	3.755 m³ ⇒ 1.55 m
	avg:	2.195 → 1.0975	(4.82 m²)	**4.99 m² (2.23 → 1.12)**
	~~wet~~ dry:	5.72 → 2.86	(32.7 m²)	
15gal:	~~dry~~ wet:	2.78 → 1.39	(7.7 m²)	11.1 m³ ⇒ 2.23 m
	avg:	3.78 → 1.89	(14.26 m²)	**14.8 m² (3.85 → 1.925)**
	dry ~~wet~~:	9.84 → 4.92	(96.8~~7~~5 m²)	
100gal:	~~dry~~ wet:	7.21 → 3.605	(52.03 m²)	
	avg:	9.81 → 4.905	(96.35 m²)	75.1 m³ ⇒ 4.22 m
	dry ~~wet~~:	25.58 → 12.79	(654.2 m²)	**100 m² (10 → 5)**

roof size required to fill cistern to meet all the yearly water needs of one person.

5: 2.601 m² + .92(2.601)
2.6 m² + 2.39 m²
4.99 m² ≈ 5

$\sqrt{4.99}$ = 2.23 → 1.12

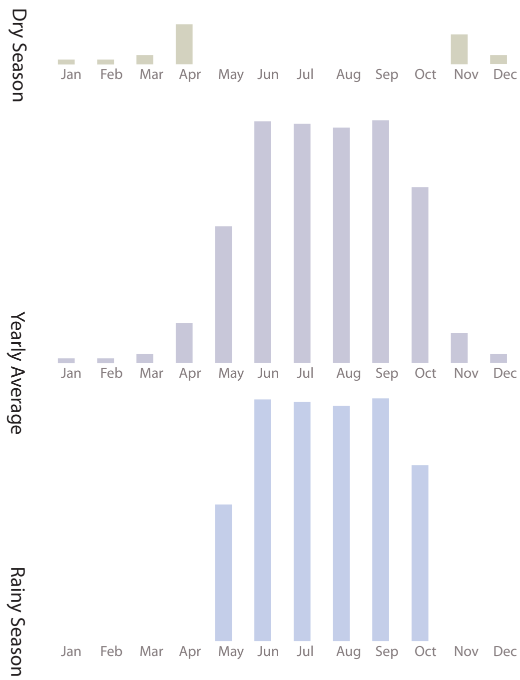
15: 7.7 m² + (.92)(7.7)
7.7 + 7.08
14.8 m²

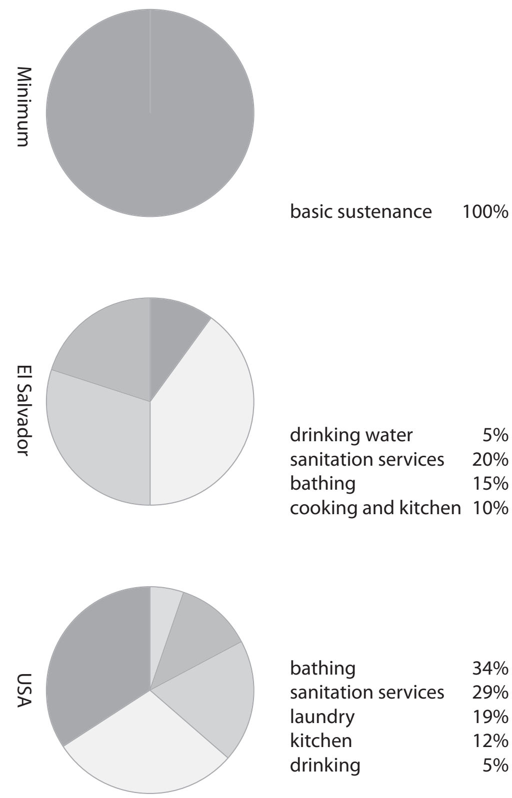
$\sqrt{14.8}$ = 3.85 → 1.925

100: 52.03 + .92(52.03)
52.03 + 47.8
99.9 m² ≈ 100 m²

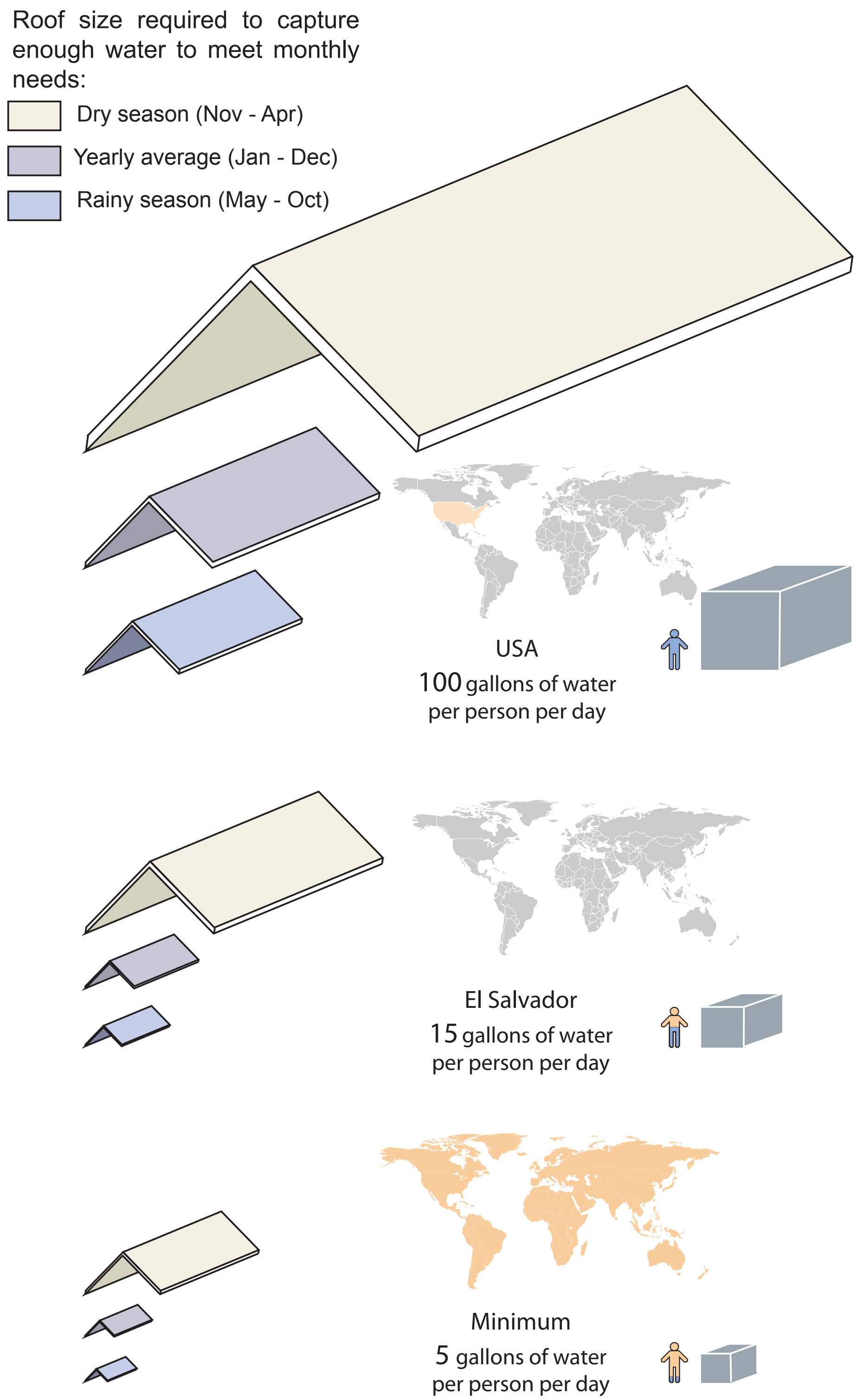
$\sqrt{100}$ = 10 → 5

APPENDIX D: WATER AND RAINFALL STATISTICS





Graphs show average rainfall in El Salvador during the dry season, the yearly average, and the rainy season. Pie charts relate water use in El Salvador to the USA and to minimum survival needs.



Drawing relating normal rainfall (in dry season, wet season, and yearly average) in El Salvador to roof size (m^2) required to meet the monthly average needs of one person (based on minimum water needs for subsistance, average water use in El Salvador based on per capita water use, and USA average). Green volume shows cistern size required to meet monthly needs year round with minimal roof surface in relation to the size of an average person.

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