Water Catchment Design Applied to **Educational Centers**

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1. Introduction

The principal background of water catchment is found in "**Aljibe**", which was a deposit designed to save rain water in ancient structures found firstly in the Mayan Peninsula. Recently, this practice has been taken to design new water catchment systems adapted to neighborhood houses, receiving the rain water using the roofs as base and gutter to direct it to the main filter. Actually, they are used in houses of Campeche and Yucatan in Mexican Mayan Peninsula. This water is for human use in personal care activities, but this practice is not really appreciated in other places of Mexico or around the world.

The justification of the implementation of an integral product of water catchment is because it represents an alternative with sustainability vision, because it proposes for environment, to avoid that rain water ends in the drainage. By the way, it helps to decrease the deep wells exploitation and the same impact to groundwater. From society perspective, it represents a technically and economically viable alternative to resolve the water lack. Economically it reduces the cost assigned to water supply by private delivery.

That is why the general objective of this project is to analyze, from sustainable development perspective, the viability of the implementation of rain water catchment systems in educational centers by the coaching of a consultancy.

The procedure to develop this project consisted in design a prototype, with which the technical and financial feasibility were proven in an infrastructure project. A market analysis was realized before the business plan, with which we decided to establish a consultancy offering the product "**Water Catchment Design**" and products as: diagnostic, system design, construction project elaboration and implementation.

2. Problem Statement

Actually the lack of water is considered as one of the most important environment troubles in the world. In Mexico are seen long areas of eroded earth and most of the rivers or canalized to drainages (Sainz-Santamaría & Becerra-Pérez, 2009). In Oaxaca as the rest of the country, the high population concentration in urban zones because of the centralization of the public services, between them the educative services increases the lack factors. The educative services include the sanitary services for their educational population but actually in drought seasons they are forced to be closed.

In the literature review there is a background of rain water for human use (Nuñez, 2008) and in houses of Yucatan and Campeche in Mayan Peninsula of Mexico, they build deposits called "Chultunes" for rain water. This people drink the rain water after ebullition but generally it is used for personal cleaning. It is an ordinary practice, however, in Mexican urban zones, rain water is poured into the drainage with the sewage that at the same time ends in rivers because of the bad infrastructure planning for water in Mexican Cities.

As we said before, the infrastructure for rain water use in cities is not available in Mexico. A clear example is viewed in the metropolitan area of Mexico City, where the excess of rain water causes flooding in down areas. The lack of water and the flooding because of the excess of water should incorporate a paradox.

The mentioned evidences allowed us to integrate as research questions: What is the viability to implement a Rain Water Catchment System in Educational Centers? Which is the collaboration of a Rain Water Catchment System to attend the services of educational centers? How it contributes to environment protection?

Justification. The catchment and use of rain water, trough the construction of "Aljibes", have represented historically an alternative to provide water to communities, but it is not really a generalized practice. The lack of water, that is constant in all regions of Mexico and is showed evidently in the affectations to agricultural production. In the major cities, the lack of water in houses and public buildings include the educational centers. The benefit of sanitary service from schools, becomes a priority in hygiene and health aspects for school population, who stay in the educational center for until eight hours daily. In educational centers of all sizes it is seen that in drought seasons the restrooms are closed and sometimes with a sign announcing "Service not available". The lack of sanitary service becomes a source of infection and may cause collective health problems in schools.

The development of a prototype called “Rain Water Catchment Design” represents an alternative with sustainability vision, because it proposes to avoid that water ends in the drainage, to decrease the water extraction by deep wells and the impact to groundwater.

It is technically feasible and an economic option to store rain water in educational centers for sanitary services (restrooms), green areas irrigation and public areas cleaning in drought seasons. The benefit of having a “Rain Water Catchment System” in schools, besides of test its financial feasibility, it will benefit to students, teachers and educational workers having an uninterrupted sanitary service, green areas irrigation and public areas cleaning with treated rain water, and adding a “Soakaway” (absorption well) to contribute water filtration to groundwater.

3. General Description of Entrepreneur Project

3.1 Approach

The line of business that we claim to establish is called “Technical Consultancy for Environmentally Sustainable Projects” which has as objective to develop projects for implementation of systems environmentally sustainable. The consultancy will be established to offer the professional technical services, including diagnostic, design, coaching and tracing for “Rain Water Catchment System”

The Rain Water Catchment System is designed to be implemented in buildings with plane roofs or gable roofs that are conventional in educational buildings, so their implementation and operation will be based on the previously constructed.

Designing the prototype for rain water catchment in educational centers, the valuation of the average water liters was realized and how much is needed to give sanitary service to a school and workers population of 2,300, considering that they use them twice at work shift and each one uses five litters per download. The result was 23,600 litters, equivalent as 22 water tanks.

3.2 Hypothesis

Feel free to use colour images. It is advisable not to use very thin lines in graphs, but instead dots, dashes or coloured lines.

Formulation: Rain Water Catchment has an historic background in the world and particularly in Mexico there is evidence of its construction and of the use of rain water for human use. However, in Mexico it is located in the Mayan Peninsula Area and recently added to housing units.

Researches realized by Sainz-Santamaría and Becerra in 2009 and the experiments of Núñez in 2008, show evidence of the rain water use in agriculture and for human use as the benefits for environment, so we propose to test the feasibility of a “Rain Water Catchment System” to care the water needs in drought seasons for educational centers. **Hypothesis**: The implementation of a “Rain Water Catchment System” to care the water services in educational centers is feasible and contributes to decrease the environmental impact.

3.3 Project Objectives

Analyze the sustainable viability to implement “Rain Water Catchment Systems” in educational centers.

Specific Objectives

- To analyze the contribution of a “Rain Water Catchment System” in the sanitary services offered in educational centers.
- To analyze the cost.-benefit in the implementation of a “Rain Water Catchment System” in educational centers.
- To define the environmental sustainability characteristics of the implementation of “Rain Water Catchment System”.

4. Theoretical Framework

Water scarcity and sustainable development in Mexico. Population and economical growth have increased its pressure above the water reserves in Mexico, at the point that the volume demanded is higher than the supplied in some regions of the country. This reason forces the government to decide who will have access to this resource, causing problems of distribution. The competence for this resource is a cause of conflicts in different social intensities and it is represented not only between individuals of the same community, it still causes problems in different communities, municipalities, states and inclusively across frontiers.

According to Sainz-Santamaría & Becerra-Pérez (2009), there are at least three reasons in this context why the knowledge and analysis of conflicts related with water could be a critical decision factor for environmental policy in Mexico. First: Water lack problems in Mexico generate a higher pressure in the competence to get this resource, inside and outside the country. The design of prevention mechanisms and, if necessary, of coaching and conflicts resolution are needed to know deeply the way they arise and how they develop. Second: Some conflicts arise as movements of rejection against a public decision. Any policy proposed that may have elements typically unpopular (subsidies reduction, rates creation) will have a higher possibility of success if it has an analysis of political feasibility that may allow anticipating to the resistance grade that the practice may find. Third: The conflict is related to a set of causes that are different in each geographic region or social sector. In some zones, the determinant point of a movement could be a bad administrative management in combination with the social groups mobilizations, when in the other side; the constant drought is the principal point.

Systematizing the existent conflicts and variables related in each case, we established a preliminary public policy agenda and a first diagnostic of the conflict.

As seen in the research background of Sainz-Santamaría & Becerra-Pérez (2009), realizing the analysis of the problematic situation of water scarcity in Mexico and trying to explain what it causes, they mention a panorama, not interested in analyze and evaluate any alternatives to propose a solution, however, in the available literature are found some researches that are directed to analyze alternatives to resolve water scarcity and to document

them to share experiences. Nuñez in 2008 published the results of a water catchment project realized in communities of Central America. He describes it as implement constructions with local materials in little water dams to retain rain water. In his results he mentions the achievement of this project to verify that retain rain water allowed to improve the agriculture activities and provided a water alternative for the inhabitants.

Despite of the background and evidences that can be observed actually in the Mayan Peninsula, there are not examples of projects directed to rain water catchment in Mexico. That is why taking as base the "*Aljibes*" model, the construction of a prototype of rain water catchment was proposed. This prototype is proposed as an alternative to resolve the problems that scarcity causes in educational centers.

5. Planning description and development of the project.

The Rain Water Catchment System is an integral product. It integrates the assessment, diagnostic, design, elaboration, implementation (installation and operation) and after sale services. The materials needed for implementation of the Rain Water Catchment System, as the construction, plumbing and the bombing equipment, are available in stores of any community of Mexico. Defining the architectonical project, the costs and the quality of the materials will be evaluated.

According to human resources, the sales of the "Integral Product" will be realized by a "Technical Consultancy for Environmentally Responsible Projects". This will count with a staff of consultants, who will be trained for customer service and about system specifications. Besides, it will work with a professional technician's catalog offering they professional services to the consultancy for the implementation stage.

6. Analysis Situation

General conditions: In the initial stage of operation of the consultancy, it will be directed to a market composed by educational centers in Mexico southeast, having contemplate the extension to housing adaptation, with a future impact in national and international markets.

The situation of water need for human use is incrementing dramatically in drought periods, but the scarcity is permanent in many regions and urban areas. To analyze the acceptance of this system as an alternative to supply with rain water, an interview was applied to 100 students and 100 teachers in different public schools of Oaxaca City in Southwestern Mexico. The results indicated that the 100% is conscious about the water scarcity, the 85% expressed to know that rain water ends in the drainage. The 95% expressed that would use rain water in schools with the optimums treatment. 95% would be interested in helping to recollect rain water in Schools.

Neutral conditions: Historically, the service by municipality water supplies has been used and sometimes resorted to move water from remote places by trucks (causing perforation of deep wells and groundwater abatement). However, these practices have resulted insufficient and harmful for environment. That is why other alternatives are needed as our consultancy offers.

Competence Conditions: The competence is established as potential shape, because there are not businesses with the specific characteristics of this project in Southwestern Mexico but they may appear as constructor enterprises or in the same material suppliers. However, the competitive advantage will be observed in the consultancy shape offering integrated products-services.

Enterprise Conditions: The consultancy will be characterized by being entrepreneur in the environmentally sustainable products market and the integration of products and services. It will be helped by a consultant's staff, which will be selected between the outcomes of technical graduates in the localities and integrating a professional technicians catalog to have an index of who offer they professional services for the consultancy in the implementation stage.

Operations Plan

Consultancy service process for the implementation of Rain Water Catchment System: 1. - Diagnostic development, 2. - System Design, 3. - Elaboration of the architectonic project, 4. - Implementation (installation and operation) of the system.

The essential materials for the implementation of the Rain Water Catchment System, as the construction, plumbing and bombing equipment are available in material stores in any population of Mexico.

Service Characteristics: The consultancy process, system implementation and technical assistance is composed in a set of activities: The diagnostic to meet the situation of the construction available to install the system. **The design of the system**: According to the data previously provided from the diagnostic (building characteristics, ground soil and roof type). **Project elaboration**: Based on architectonic specifications to respect the structure and integrity of the buildings, as well as consider the advisable materials, equipment and employees for implementation. **The implementation:** To realize the plumbing, electricity and civil works for the construction of the system facilities.

The process includes a diagnostic in the first stage. The diagnostic requires about one week for its development, if there is construction data (construction planes). With the results of the diagnosis we realize the design and develop the construction project.

Catchment: Conformed by the roof of the educational centers with slope directed to the rain gutters. Recollection - Could be made of PVC or any other material that not alter the physic-chemical composition of the collected water. The minimum of width in the rain gutters will be 75 mm and 150 as maximum. **Natural filter system**: Three step filter (Gravel, sand and Activated Coal) this will be designed for a filtration velocity less than 0,2 m/hour. **Storage**: The volume of the storage tank will be designed by the demand of water and if it is made of plastic could be underground; it will need a sanitary lid of 0.60 x 0.60 to facilitate the cleaning and maintenance. The interior of the tank should be impermeable and this water should not have any contact with outside environment to guarantee the water quality.

The alternatives of construction and materials were evaluated and presented to the customer the one that offers more technical and economic feasibility and environmental viability. In the last stage the Rain Water Catchment System is implemented. The product offers guarantee, technical assessment for its operation and maintenance, and if needed, services after sale. Graphic3. SWOT Analysis.

SWOT ANALYSIS		STRONGS	OPPORTUNITIES
		Technical Feasibility Environmentally Sustainable Economic. Social benefit.	Open Market. Other sustainable products. Demand on the environmentalist segment
WEAKNESSES	User attitudes Unfair competence from water providers by trucks Actions from the government		
THREATS	Climate Change Drought Conditions		

The outcome influences, also called critic factors that the business may deal are: The irregularity of rain and drought periods caused by the climate change. The characteristics of the building where need this system.

Marketing Plan.

Product.

The Rain Water Catchment System is an integral product. It integrates the factors of assessment, diagnostic, design, architectonical project, implementation (installation and operation) and services after sale.

Table Number 1. Product-Service Description for a Rain Water Catchment System for 100000 litters capacity.

Brand	Technical Consultancy for Environmentally Sustainable Projects
Product	Rain Water Catchment System
Structure	Assessment and installation of Rain Water Catchment Systems
Process	Assessment for diagnostic-design-project-i system implementation
Human Resources	Professionals and Consultants
Technology	Local and actualized
Image	Social-Economical-Environmental
Providers	Catalog

Cost.

The Rain Water Catchment System cost is designed based on the water volume required the building characteristics where it will be established, changes in costs of the materials and labor costs. As seen in the next table, it also depends of the material type that the client prefers for the cistern or rain water deposit underground.

Table Number 2. Approximate cost of a Rain Water Catchment System for 100,000 liters of rain water catchment in an educational center.

Cost with concrete cistern	$ 363, 000.00. + 10% per consultancy services.
Cost with plastic cistern	$ 200, 000.00. + 10% per consultancy services.

*Costs expressed in Mexican Pesos/100. Reference: Own elaboration.

Plaza.

In the initial operation stage of the consultancy, it will be directed to a market composed by educational centers in Southwestern Mexico. Then is contemplated an expansion to housing segment, with national and international implications by consultancy. The demand situation for water and human use increases dramatically in drought periods, but the lack is permanent in many regions and urban areas.

Promotion.

To promote the service and the product, one web page will be used www.ctpasustentable.net Visitations to campuses and with the support of a presentation we will present the Rain Water Catchment System and average budgets. Cards and pamphlets with system data and consultancy services will be distributed.

Innovation Description.

The water catchment has been realized as traditional form and with artisan elements, from the “Aljibes” structure to the procedure to direct the water from roofs to deposits, which are artisan too. In agriculture**,** mud tubs have been used to retain water taking advantage of the slopes shapes.

This prototype innovate the traditional form of water catchment because it includes actual materials and technologies and will be available in the market by consultancy services, oriented to educational centers where the number of users is evident. There is no background in use for educational centers, but we have expected a new offer for house installations.

Description of feasibility grade (Technical & Financial)

The Technical Feasibility of the Rain Water Catchment System is proven by the easiness of implementing it in educational centers, because it only needs the water deposits and to adequate the gutters by the roofs designed to water catchment. The evidences of business feasibility from the consultancy could be proven by the next indicators: materials, equipment and human resources availability, which are found in construction stores and job boards.

As a prototype, its operation and cost benefit have been proved as positive. This provides information to determine the financial feasibility. The financial feasibility is observed clearly with the results of the comparison between the economic inversion and the cost of other supply forms. As seen in Table 3, the egress by payments of private water services (brought by truck), the concept for two months is equivalent to the needed inversion to implement the Rain Water Catchment System for 100 000 liters in any educational center.

Table 3. Inversion for a Rain Water Catchment System in educational centers.

ALTERNATIVES	SPEND/INVERSION	OBSERVATIONS
Two Water Trucks Supply Daily	$ 28,800.00	Permanent Spending of $ 345,600.00 annually
Concrete Cistern Includes expenses and materials	333,985.70	
Plastic Cistern Includes 10 cisterns, materials, expenses and consultancy services	174,900.00	50 years warranty quality

Note: As seen in the table, the implementation of the Rain Water Catchment System proofs its technical and financial feasibility. Source: Own Elaboration

The economic benefit for the customer could be observed in savings, not having to pay for any water supply service, the same that sometimes represents an important money outcome in the financial reports. It could generate savings in electricity by reducing the bombing spending.

Social/Technological Impact – Sustainable Development Description

The principal base of the sustainable development arise the integration of three spheres where the man is involved, as part of the society, with economic determinants but with a coexistence with the environment. Under sustainable development base are included the three parts of the essential analysis of the entrepreneur project "Technical Consultancy for Environmentally Sustainable Projects". **The social impact** that the consultancy and the implementation of the Rain Water Catchment System may provide will be expressed in the number of users benefited with the rain water supply for sanitary services and green areas irrigation. Providing jobs in the man force participation for project elaboration, promoting an environmentally sustainable worldview, then in the attitude for environment care and rain water use. **Technological impact:** is oriented to reactivate a traditional practice in an integrated system for rain water catchment with the incorporation of materials, equipment and technical knowledge, all of them actualized. **Environmental impact:** Rain water is generally directed to drainages in major cities; Mexico in fact, is characterized by being the country where the rivers are polluted and drained and where rain water is directed to the rivers, mixing it with the drainage.

By other side, water is taken from deep wells to supply the urban centers. A Rain Water Catchment System allows using the rain water environmentally and avoiding that it deposits in the drainage as another pollution element. With the rain water catchment, the groundwater exploitation, deep wells perforations, rain water ending in drainage and possible flooding could be reduced.

Results Analysis

The results from a perspective based on the sustainable development show that the implementation of rain water catchment systems represents a feasible alternative to resolve the water supply in educational centers. As proven in this project according to the advantage of a system projected according to the building characteristics and of the expected water demand in schools may cover the water needs for sanitary services, green areas irrigation and general cleaning in educational spaces. During the rain period, the system is able to cover all the volume needed and up to 70% in drought periods. The cost-benefit analysis provides the evidence of the economic attractive for the authorities of the educational centers to decide for inversion in the project. It is adequate according to the available structure of the buildings; the evidences that are observed with the actual ending of the rain water and the environmental impact that deep wells perforation causes to attend water demand, allow us to proof the contribution that the environmentally sustainable systems may provide taking advantage of the water before it arrives to the drainage and reducing the water supply from remote areas by transportation.

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Conclusions

As showed in the results, the implementation of a Rain Water Catchment System in an educational center proofs its technical & financial feasibility, as well as offers to reduce the environmental impact taking advantage of the rain water that use to end in the drainages or polluted rivers.

The Rain Water Catchment System represents an environmentally responsible alternative and orients the bases of sustainable development to the customer, because it can contribute to generate positive attitudes for environment. The behavior could be observed in the activities for maintenance of the system. This alternative could represent social benefits for the user because it improves the organizational climate.

The Rain Water Catchment System is a product-service with which The Technical Consultancy for Environmentally Sustainable Projects begins its operations, taking on mind other sustainable projects with the same characteristics of product-service.

Annex 1. - Diagnosis Data.

1. Determine the monthly precipitation quantity. These data could be obtained from the national institutes of meteorology.
2. The research reach should cover the last 10 years to determine the precipitation factors.
3. The total of catchment area should be measured, so the roofs areas are measured to calculate the water volume that will be recollected.
4. It is important to considerate the loss factor. The quantity of rain water may full up the tanks. There is an alternative for absorption wells (soakaways).
5. It is necessary to determinate the demand of water in the services requested by an educational institution.
6. This can be simply determined by counting the number of people that are going to use the water and highlighting which average of liquid is used daily for the different purposes.
7. Design tanks for the rain water storage. The quantities of rain water and of the demand of water could be used to determine the appropriated design and size of the tank(s).
8. In some areas where the rain is equally distributed, it will be enough having a permanent tank that has the adequate size to store the water supply for one month or more.
9. In zones where there are rain and drought seasons, characterized by periods with less or none rain during about three months, the size of the tank could increase to store water for the drought season.
10. The cost establishes an essential factor in this case, because of the tanks, which should have an appropriated size to cover the need of the educational centers.

Annex 1. – Model Images

Fig. 1 Rain Water Catchment System Model for Educational Centers

Fig. 1 Rain Water Catchment System Detailed

References

11. **FAO** for Latin America. (2000).” Manual de Captación y Aprovechamiento de agua de lluvia, manual para América Latina” FAO, Santiago de Chile.
12. **Núñez**, Miguel Ángel (2008). Producción y cosecha de Agua Dulce. En el Libro Desarrollo Rural Sustentable de Venezuela. Editorial Gobierno de Venezuela.
13. **Sainz-Santamaría** Jaime y **Becerra** Pérez Mariana (2009). “Los conflictos por agua en México”. Dirección General de Investigaciones de agua. CNA. México.