

Incorporation of a Sustainable Design in the Integrated Engineering Project Design Model: The Capstone Course at UPRM

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Abstract

The Civil Engineering program at the University of Puerto Rico at Mayagüez is focusing its attention in providing the students the opportunity to address a real world problem with a real world engineering solution methodology. As part of this process, the students are developing a unique integrated engineering project design experience incorporating a sustainable design in the development of a community on 1,000 acres already selected by the planning board of the Municipality of Mayagüez to develop residential and commercial facilities. Over 50 students are working as 6 independent teams composed of students having preference working in each of the following areas: Construction management, structures, transportation, water resources, environmental, geotechnical. The University of Puerto Rico at Mayaguez, is aware that the island has only 3,515 square miles, but has 3.8 million of habitants, with its capital San Juan that has growth 4 times from 1935 to 1990 and as a result has limited space for development and handling waste material. For that reason it is our mission to incorporate in the design the present and future concerns that will affect our environment and promoting the use of recycling materials, avoiding the development of inappropriate sites reducing the environmental impact from the location of a building on a site, seek for alternative transportation reducing pollution and land development from automobile use, reduce the site disturbance, manage stormwater runoff, reduce heat island, limit the use of potable water for landscape irrigation, use of on-site renewable energy systems, provide the effective delivery and mixing of fresh air to support the safety, comfort and well-being of building occupants. The project is multidisciplinary in nature and is an open-ended type problem and will be concentrated in the development of a site with low income houses, intermediate income houses and high income houses bounded by commercial facilities and community services. After each team performs the feasibility analysis of the complete site, the selected alternate are being developed in further detail leading to the preparation of plans and specifications.

During the development of the project, several speakers from the industry and government as well as developers provide valuable support with their experiences and suggestions. Faculty and engineers from the industry and government have worked together directing students into this new learning experience. The major engineering design projects for CE students have proven to be successful in engineering education.

Keywords

Internships; research; engineering education

1. Introduction

The Civil Engineering program at the University of Puerto Rico at Mayagüez is focusing its attention in providing the students the opportunity to address a real world problem with a real world engineering solution methodology. As part of this process, the students are developing a unique integrated engineering project design experience incorporating a sustainable design in the development of a community on 1,000 acres already selected by the planning board of the Municipality of Mayagüez to develop residential and commercial facilities along with the necessary roadways, and community buildings.

2. Project Location

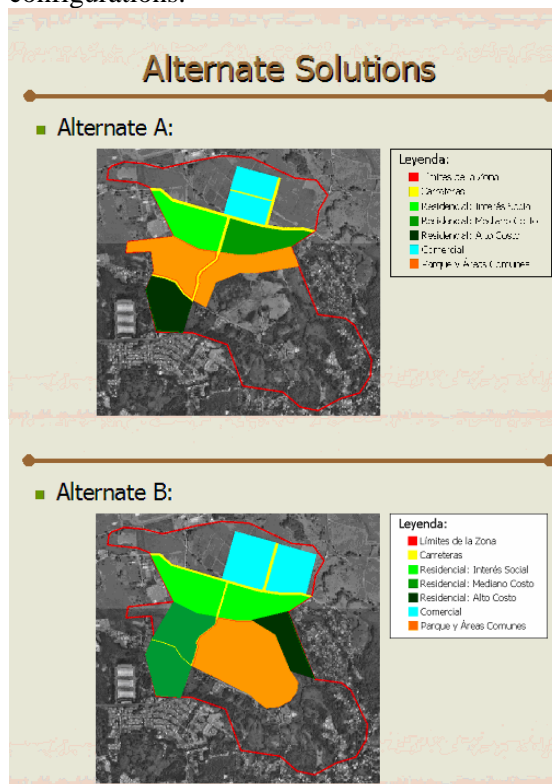
The site to be developed is located in Mayaguez between Miradero and Sabanera, at the north is located the Mani Airport, and at the south is located the waste fill land. The total area to be developed is 1006 acres and the topography of the site is flat at the North and the south area has hills. The area to be developed is marked in the Figure No 1.



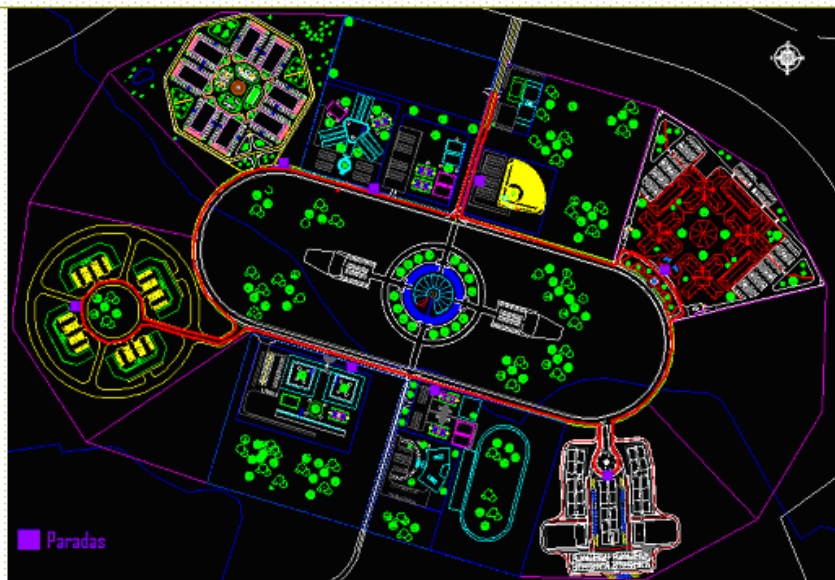
Figure No 1 Project Location

3. Feasibility Analysis

In order to develop the area a feasibility analysis was performed for different lay-out configurations.



ALTERNATE SOLUTION C



For each alternate several aspects were considered such as:

Economical Evaluation

Item	Proposed Area (S.F.)	Subtotal
Low Income Houses	211,500	14,370,000
Intermediate Income Houses	275,000	18,425,625
High Income Houses	338,090	21,392,700
Commercial Building	694,000	44,069,000
Office Building	140,000	25,575,000
Elementary School	80,000	7,450,000
High School	100,000	9,480,000
Roadways	1,870,000	12,000,000
Park	200,000	8,200,000
Shopping Center	15,000	8,650,000
Total =		169,612,325

Environmental Impact Evaluation

The site location has several aspects to be evaluated such as:

- The Caño La Boquilla Natural Reserve, which is located at the North East Area as shown in the project location map and is protected by the Natural Resources Department.
- There are many endangered species
- There are many wetlands that impact the project and action need to be taken
- The Waste landfill is located at the south part of the project.
- The noise level is 65 db from 7:00 a.m. to 10 p.m. and 50db from 10p.m. to 7 a.m.
- The impact of the development related to the possible land fill due to the requirements of hydrologic and hydraulic analysis requiring to increase the level of certain areas of the north site.
- The impact of the development in generation of waste

Social Impact assessment

- The area is partially rural and partially urban with low density and with a people living in that area, varying from low to high income.
- It is expected an high increase of employment generation due to the development of the area.
- According to the survey performed 95% of the population agree with the proposed development, 75% could go to public hearings and 93% could use a public transportation.
- The communities under mayor impact will be sabaneras and miradero.

Archeological Evaluation

- It was found remains of fossils of the Indian civilization.
- No historic construction was found in the area
- In the area was established the first catholic population
- It was part of the Old San German city.

Legal Aspects

Three types of zone areas were found:

- R-0 with low population density and uses for agricultural purposes or family houses.
- R-1 with low population density and row developed houses.
- IL-1 Industrial development categorized as “Industrial liviano”

Technical Evaluation

- The area is categorized as flow level category 2 in the north east area only
- The access road area is PR-342 that goes across the development from west to east and intersects with mayor roads such as the PR-108 and PR-2. The PR-342 has two lines, one for each direction and has the classification of R-7 according to the Highway Design Manual and the ADT is between 1,000 to 2,000 vehicles per day, with a service level D
- The PR-108 has the classification of R-6 with and ADT between 2,000 to 6,000 vehicles per day with a service level C, however the calculated ADT at the present time was 9,300 vehicles per day with traffic congestion between the Km 0.1 through Km. 4.3 which connects with the PR-342, where the calculated ADT was 12,300 vehicles per day
- The PR-2 will be affected from Km. 146.5 to Km. 150, this road is classified as U-7 according to the Highway design manual with and average ADT between 10,000 to 20,000 vehicles per day, however the calculated ADT was 55,600 vehicles per day in the area to be impacted.

Conclusions of the Feasibility Analysis

- The alternate C was selected for economical, environmental, social and sustainable design.
- The development will be surrounded by a trolley system
- A limited number of vehicles will allowed.
- The Green Building Rating System will be used
- A cycle via will be developed around the area and to provided access to the University of Puerto Rico
- The Commercial, Community Buildings, Schools, will be located at a walk able distance or may need only a trolley system.
- The surrounding environment will have a minor impact, and
- The population needs will be evaluated and measures will be taken to comply with their requirements.

4. Development of the Site

Each of the areas shown in Figure No 1 had been develop for each group of students working as a group for the development of each area. For the analysis and design of the common areas such as roadways and management of the water such as sewer and storm water, as well as for the hydrological and hydraulic analysis of the total area to be developed, all groups worked together.

In the development the groups had been also encouraged to the used of sustainable design, taking into account the project life cycle performance parameters such as:

- Physical and non-physical context capabilities and response
- Function and operability
- Form
- Life Cycle cost
- Time
- Risk
- Safety and Security
- Constructability
- Procurement
- Maintainability

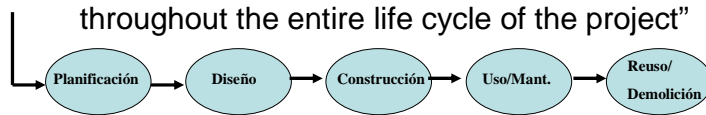
- Quality and Reliability
- Sustainability

Having this in mind, the students strived for:

Sustainable Design and Construction

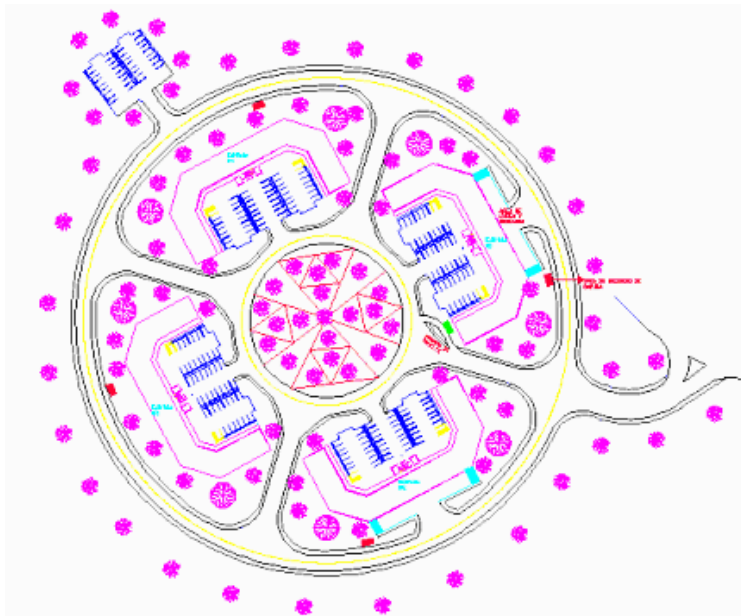
- “Design process that integrates the knowledge and the concerns of all present and future stakeholders”
- “Process that takes into consideration the economic, environmental, social, political and technical objectives simultaneously throughout the entire life cycle of the project”

Necesidad



5. Development of West Valley Plaza located at the South West Area

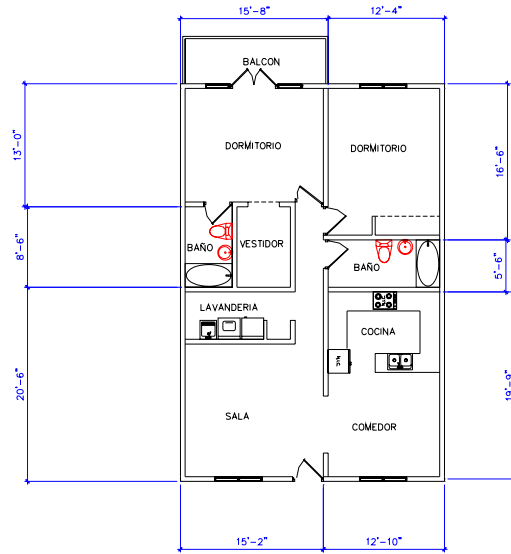
The south west area shown in Figure No 1 is called West Valley Plaza and is being located between the Sabaneras and Miradero Communities. Their location is at the south of PR-342 and to the east of PR-2. The development has 4 buildings with a foot print area of 23,000 sf per building. Two buildings (1 and 2) have commercial and offices areas on the first floor, on the second floor it will be located apartments of low and medium cost, and on the third and fourth level will be located apartments of medium to high cost. The other two buildings (2 and 3) have apartments of medium to high cost on all four levels.



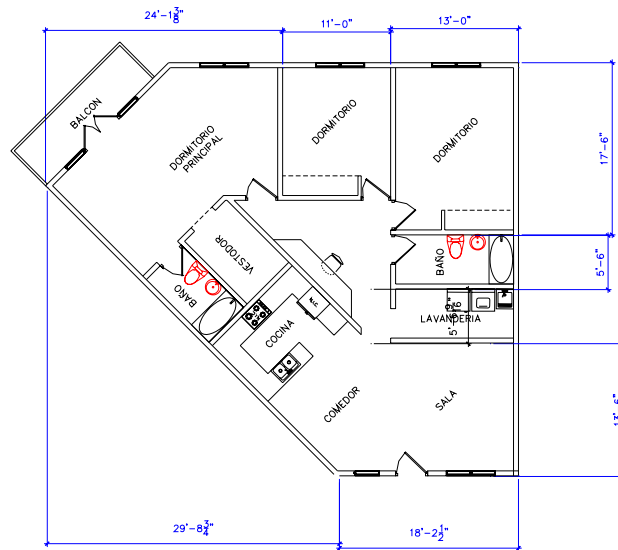
As shown in the Figure, the complex will have parking areas limited to one per apartment to promote public transportation, and will have also parking areas for visitors. The complex has also access to a trolley system and a multistory parking building to a walk in distance.

Architectural Layout

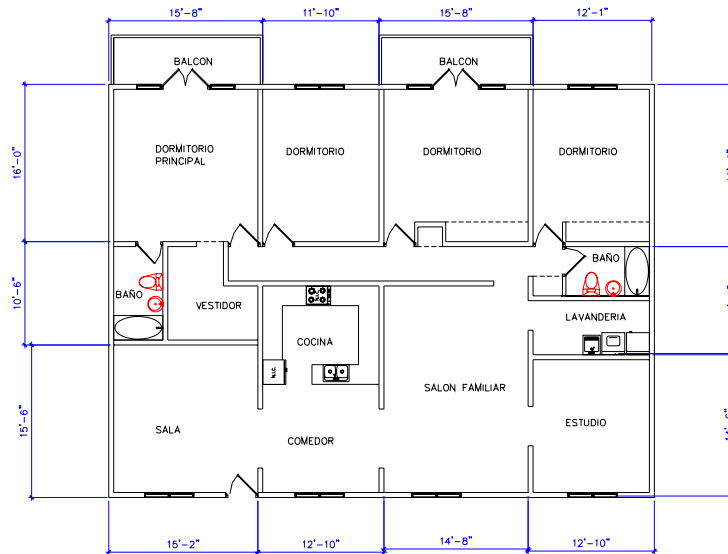
One architectural lay-out for the low, medium and high cost apartments were developed as shown in the following figures.



Low Cost Apartment Plan Lay-out



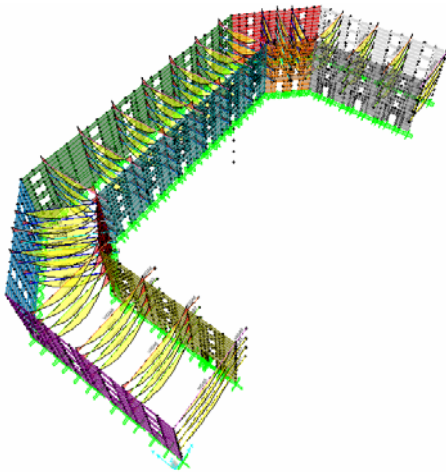
Medium Cost Apartment Plan Lay-out



High Cost Apartment Lay-out

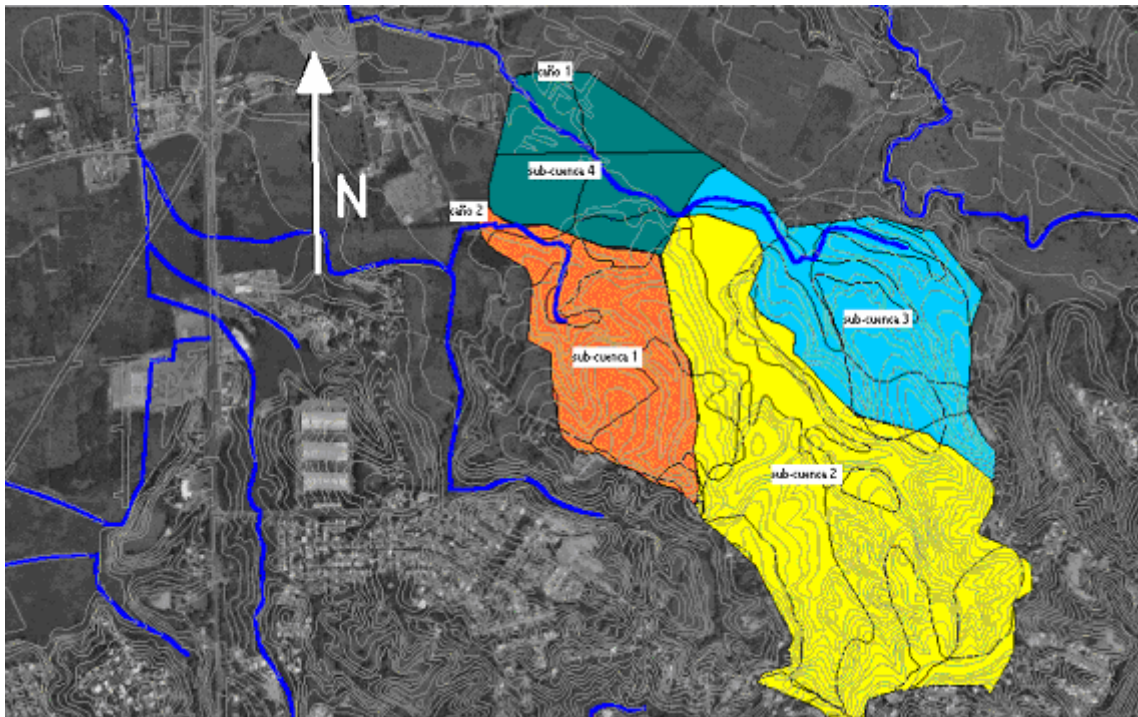
Structural Analysis

A three dimensional structural analysis was performed for gravity and lateral loads due to wind and earthquake. The structural model for this building showing the bending moment diagram is presented below



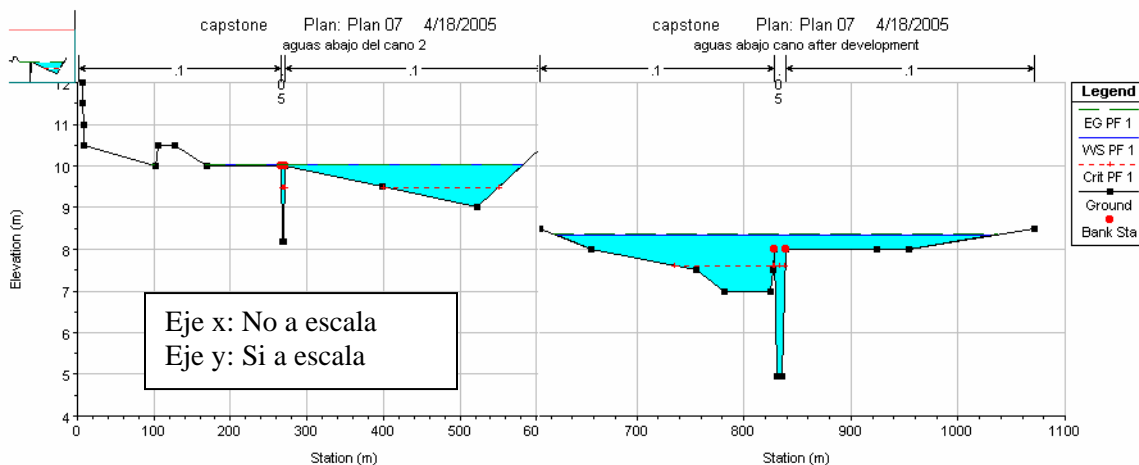
Hydrologic and Hydraulic Analysis

Due to the fact that the project has several “caños” and wetlands, and the impact of the new development it was necessary to perform a hydrologic and hydraulic analysis. For this study the software ArcGIS, HEC-RAS del USA Army Corps of Engineering y WinTR-55 del USDA were used. Using the Win TR-55, several “hidrogramas” were developed for a rainfall with a period of recurrence of 100 years. The basins contributed to the “escorrentías” every two years, and one of them runs across the project from southeast to northeast and the other one is at the southwest.



In this figure is shown the basin used for the HH study. The area marked on orange is the basin 1 which contributes to the caño 2 and the other 3 (green, blue and yellow) constitutes the basin 2 and contributes to the caño 1.

In order to take into account the conditions after the development of the area, which will affect the basin No 2, it was determined and increment in the “escorrentía of 56 cfs. After that it was performed an analysis with the software HEC-RAS to determine the level of inundation and the results are shown above.



In order to avoid overflow of the caño 1 upstream, it was proposed to construct a trapezoidal channel 15 feet wide at the bottom with a slope of 1:1 and with a depth of 10 ft with a natural cover.

Design of the Aqueduct System:

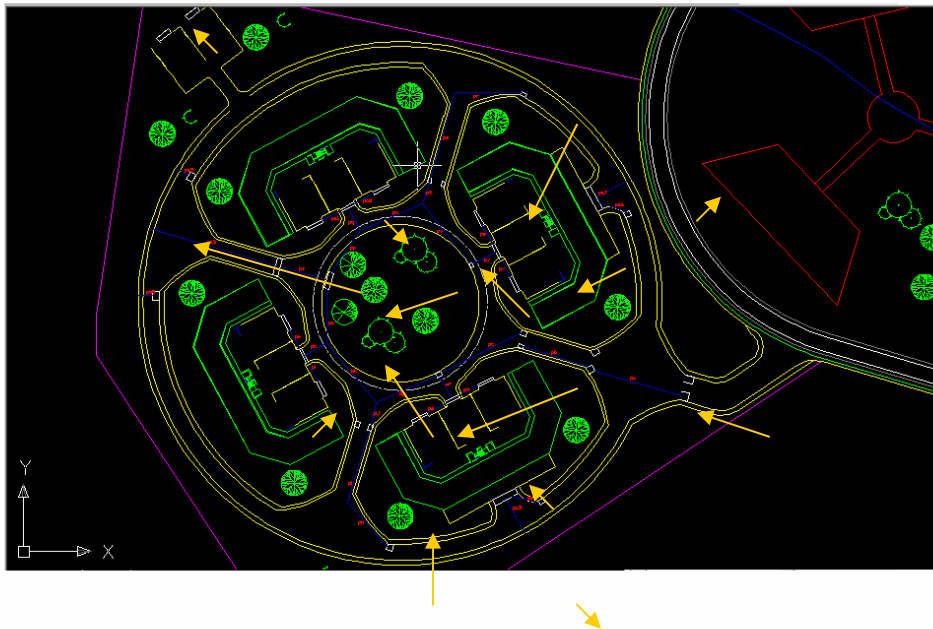
The project will have an internal net of pipes to supply the demand of 77,500 gal/day of West Valley Plaza. The system consists of 1900 lineal feet of PVC pipe of 6 inches in diameter. The pipe runs along the interior “rotonda” of the complex with nodes near each building.

Design of the Sanitary Water System:

For the West Valley Plaza it was estimated an average discharge of 66,333 gal/day. The sanitary system consist of 1,350 linear feet of 8 inches in diameter piping system with 9 meters. This pipe is then connected to the main sanitary pipe system of 10 inches in diameter with goes into a manhole and then is connected to the Regional Water Treatment Plant.

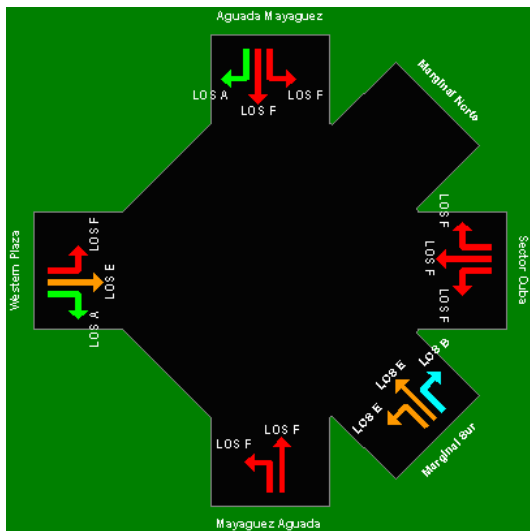
Design of the Storm Sewer System:

The system will be composed of inlets and piping system to transport the water outside of the project and then will be directed to the “caño” The following figure shows the way the storm sewer water is collected and taken outside of the project.

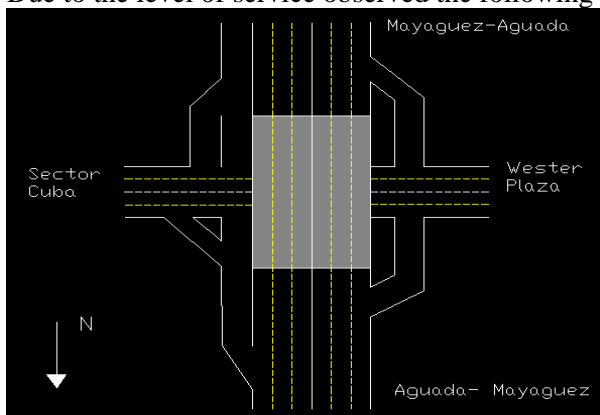


Traffic Análisis of Intersection with PR-2

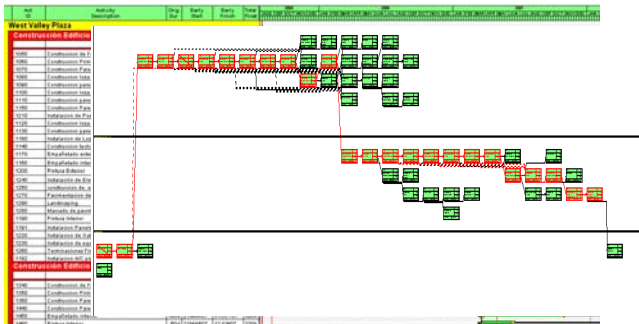
Alter performing several analysis for the existing and new condition, it was obtained the following



Due to the level of service observed the following solution was proposed:



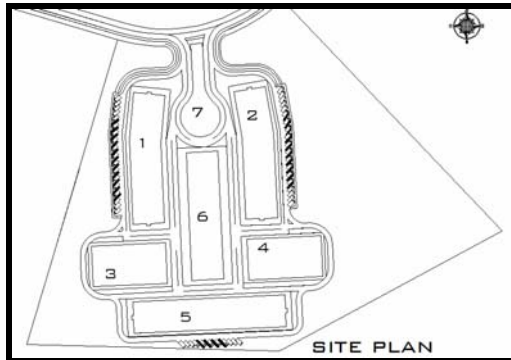
Program of Activities (Construction Phase)



Duración – 760 días laborables , 3 años Calendario

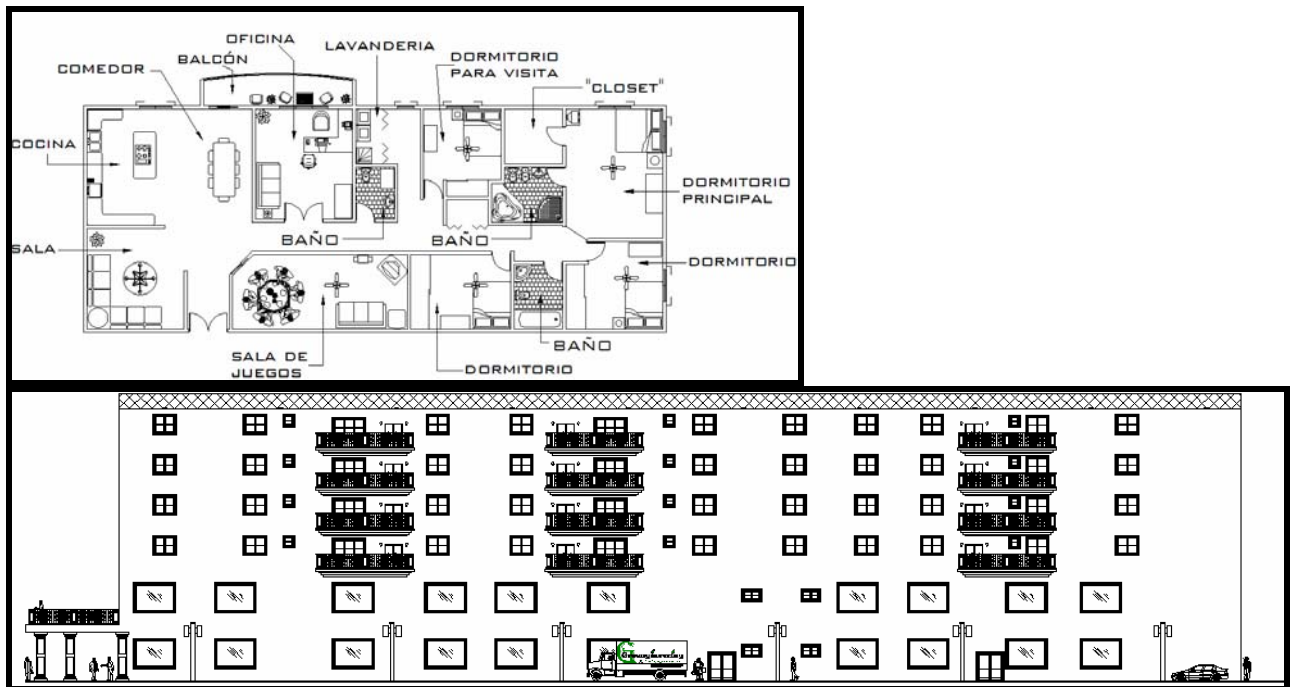
6. Development of Valle Encantado located at the South East Area

The south east area shown in Figure No 1 is called Valle Encantado and is being located between the Sabaneras and Miradero Communities. Their location is at the south of PR-342 and to the east of PR-2. The development has 4 buildings with a foot print area of 13,000 sf per building. Two buildings will have 6 floors and the other two 5 floors. The first level will have a commercial area and the second level restaurants and fast food services, together with a convention center and the other floor will be used for high cost apartments.



Architectural Lay-out

A typical architectural lay-out along a facade is presented in the following figures, further details will be presented in a separate article.



Trolley Design

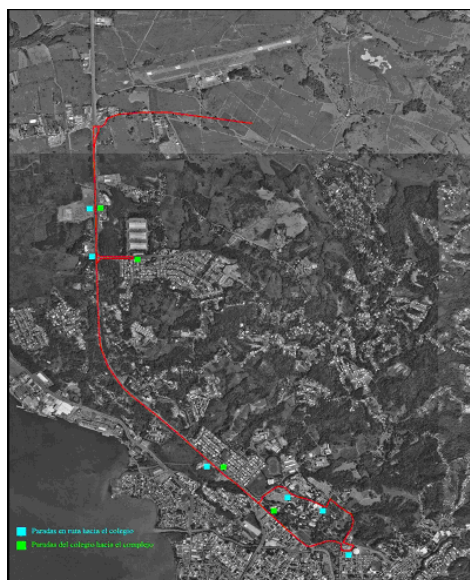
The complex will have an exclusive lane for the use of trolley. The lane used will be the right side with 12 feet wide. This will help to reduce delays for interior traffic in the interior side of the complex and eliminates the need of roadways in the “paradas”, because the trolley can stop to allow the passengers to get into the trolley.

The trolley will use biodiesel which is sustainable, increases the life cycle of the engine, non-toxic and control the emissions.

The following figures shows the internal y external circulation of the trolley.



Internal Circulation of Trolley and External Circulation

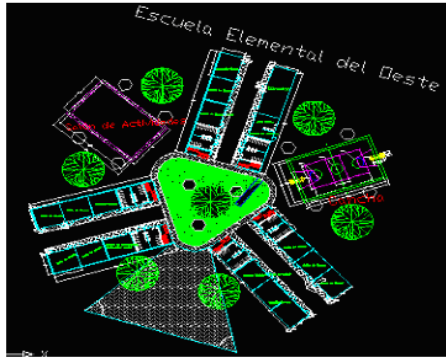


6. Development of Ecovillas at the Noreast

The north east area shown in Figure No 1 is called Ecovillas and is being located between the Sabaneras and Miradero Communities.



7. Development of Community Services

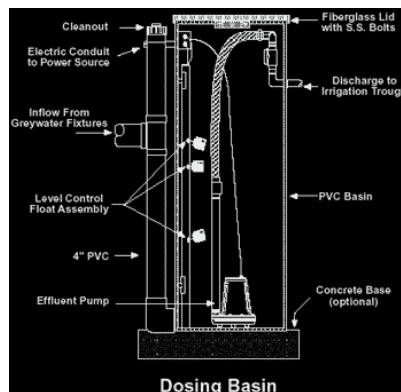


PLAN LAY-OUT OF SCHOOL BUILDING

Several building were designed such as schools, government agencies, museums, etc.

8. Some Sustainable features

Gray water had been implemented, however the permitting process is still underway.



Collection of rain water is also used.



Other features such as trees, solar generated poles, use of recycling materials, the use of a road for bicycles and trolley system are only a few examples included in this work

9. Conclusions

This is only a part of the effort the students put to develop the project which includes a complete set of drawings and specifications.

10. References

American with Disabilities Act
AASHTO LRFD Bridge Design Specifications
AASHTO Highway Design Guide
AASHTO Green Book
AASHTO Pavement Design Guide
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