EERI Student Chapter University at Buffalo

Institute of Bridge Engineering

Reconnaissance of damaged structures after the 2016 Muisne-Ecuador Earthquake

Dept. of Civil, Structural and Environmental Engineering University at Buffalo, State University of New York: Jerome S. O'Connor, PE, F.ASCE, Executive Director Bridge Institute and Enrique Morales Moncayo, Ph.D candidate.

OUTLINE

Introduction

Part I: Seismic hazard-2016 Muisne Ecuador Earthquake

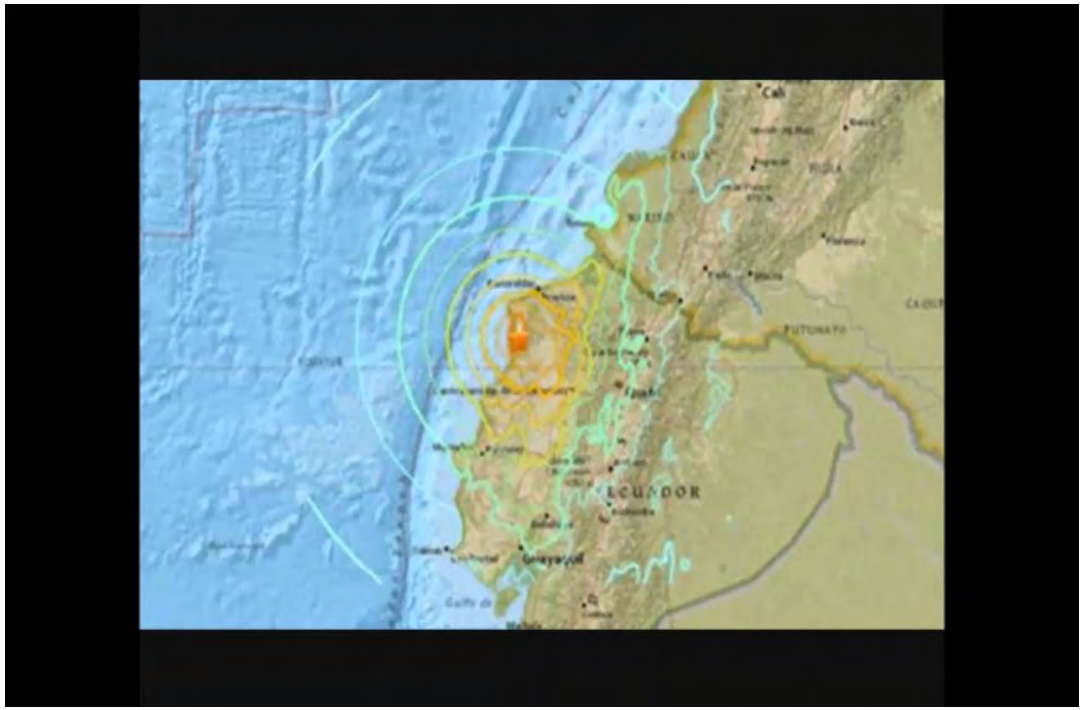
Part II: Structural reconnaissance-Damage

Part III: Nonstructural reconnaissance-Damage

Part IV:

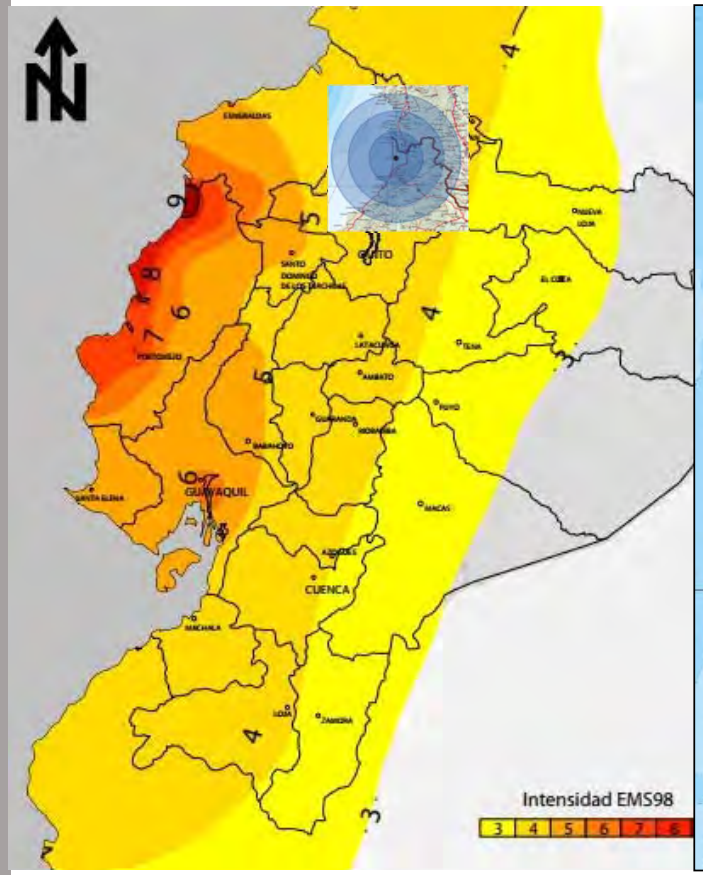
Part V: Conclusion

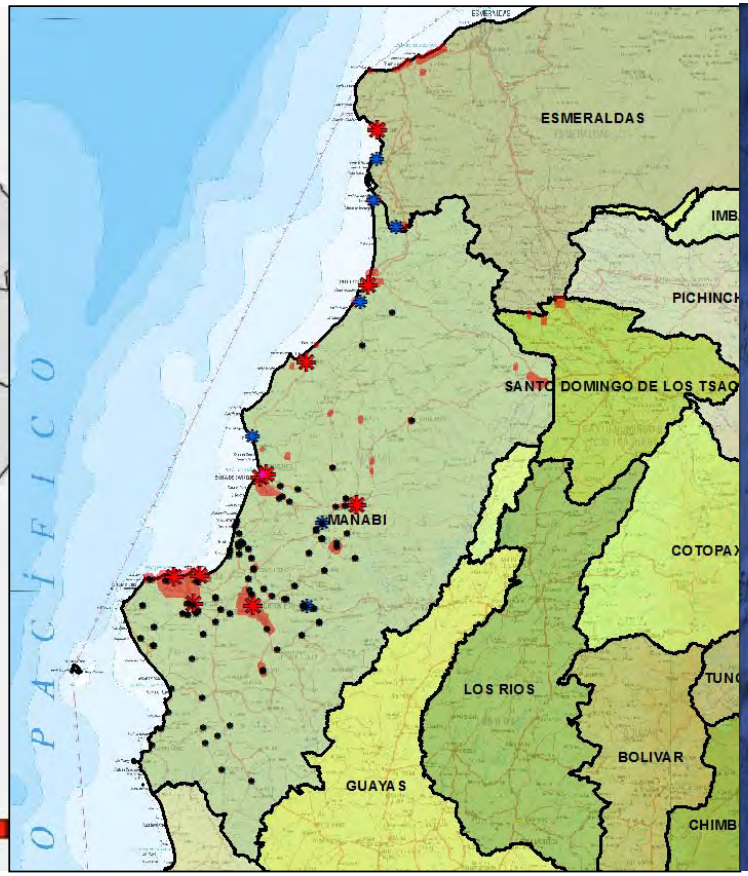
At 18:58:37 local time off-shore of the west coast of northern of Ecuador

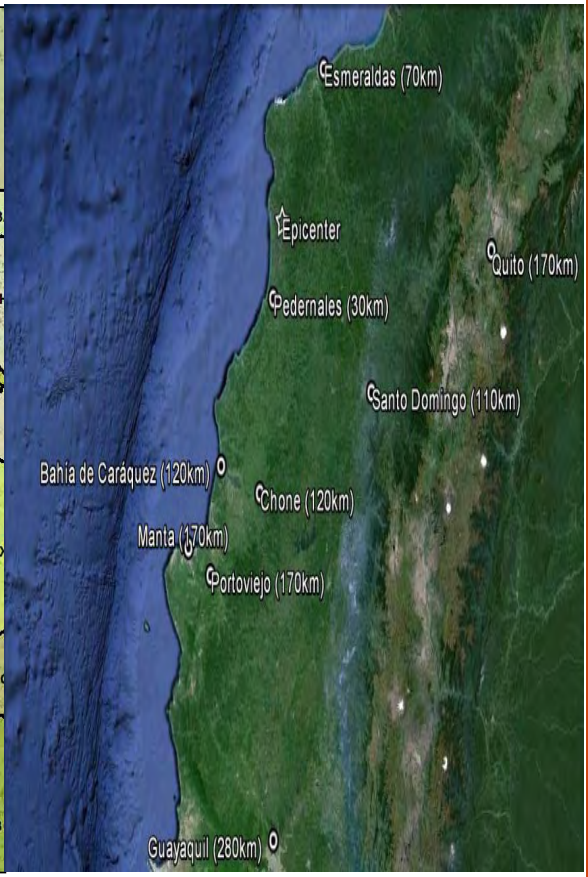


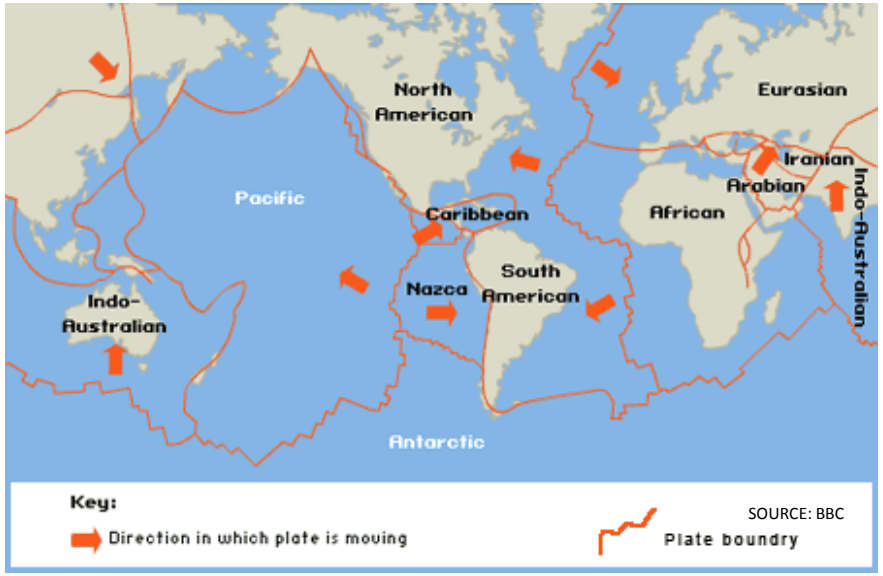
Source:emapsworld

Mw=7.8 on 16th April at 18:58,depth=19km



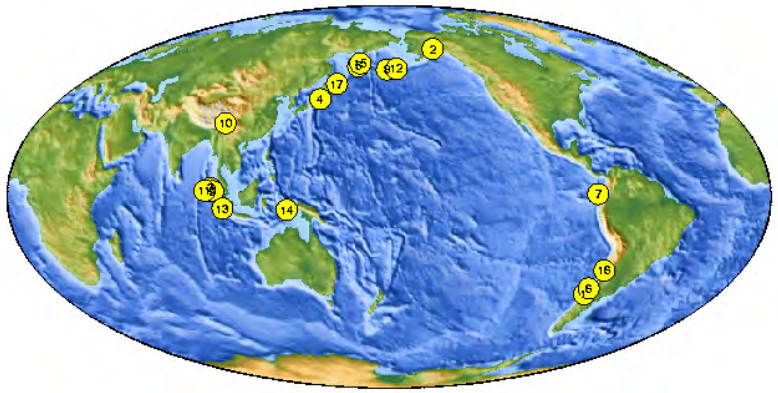






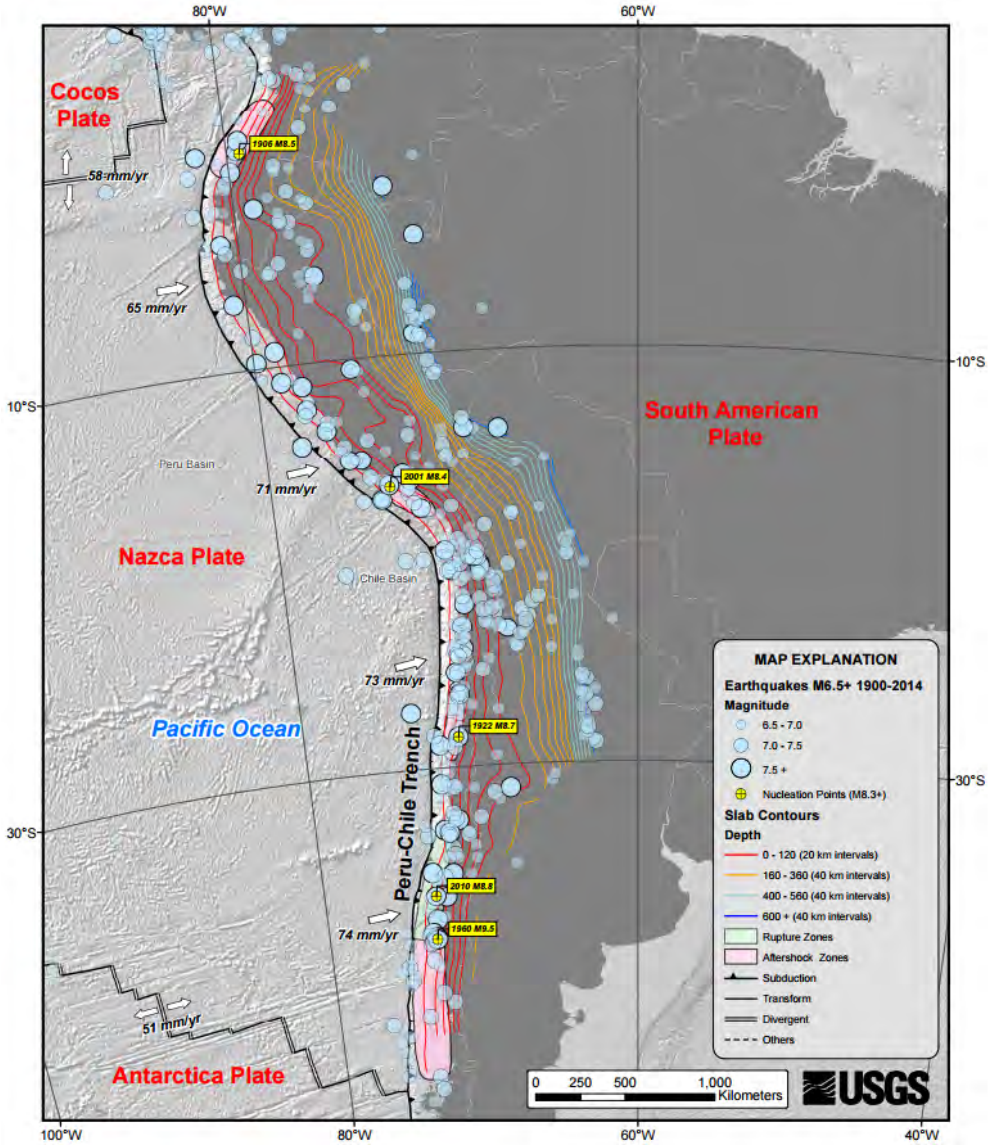
SOURCE: BBC

Largest Eartquakes (1906)# 7 Off the Coast of Ecuador(USGS).

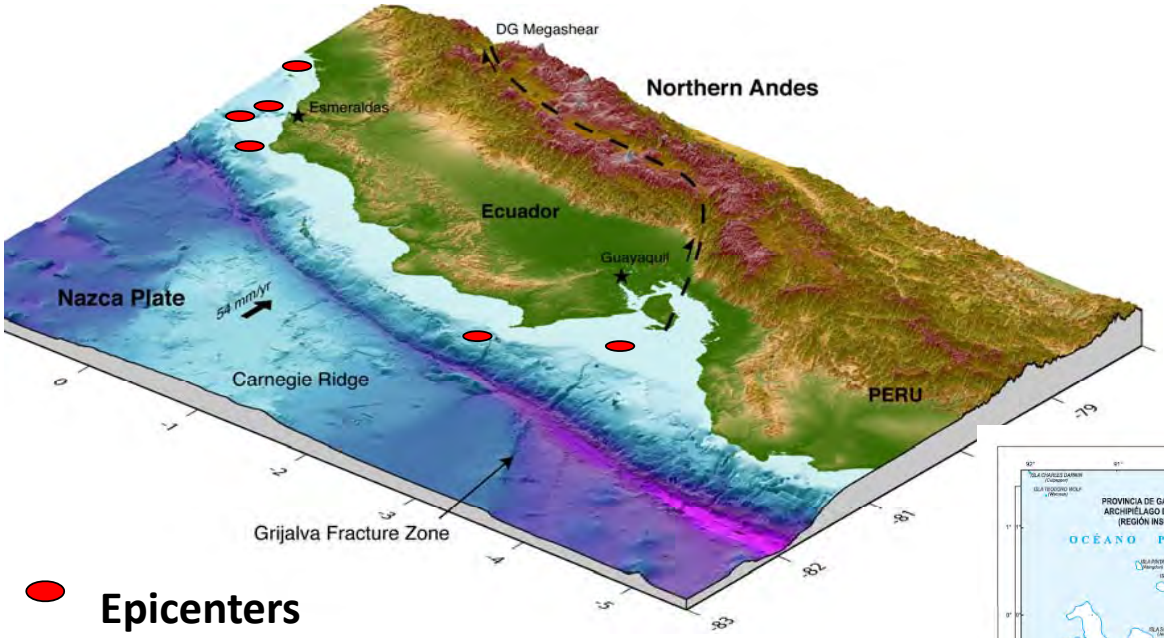


SOURCE: USGS

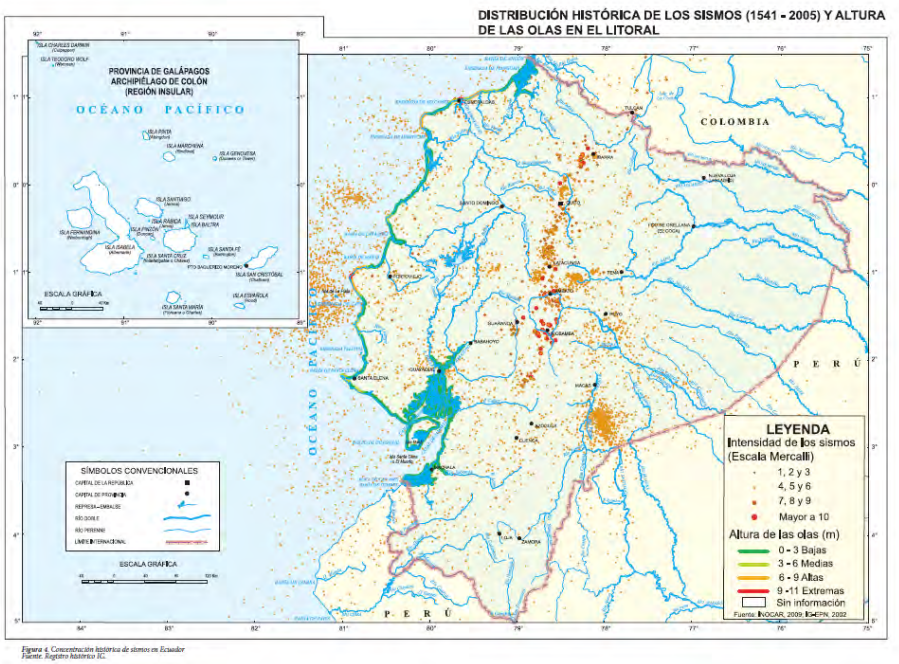
Map of Tectonic Summary Region



The event occurred near the boundary zone between the Nazca and the South American plates(Toulkeridis, 2013)



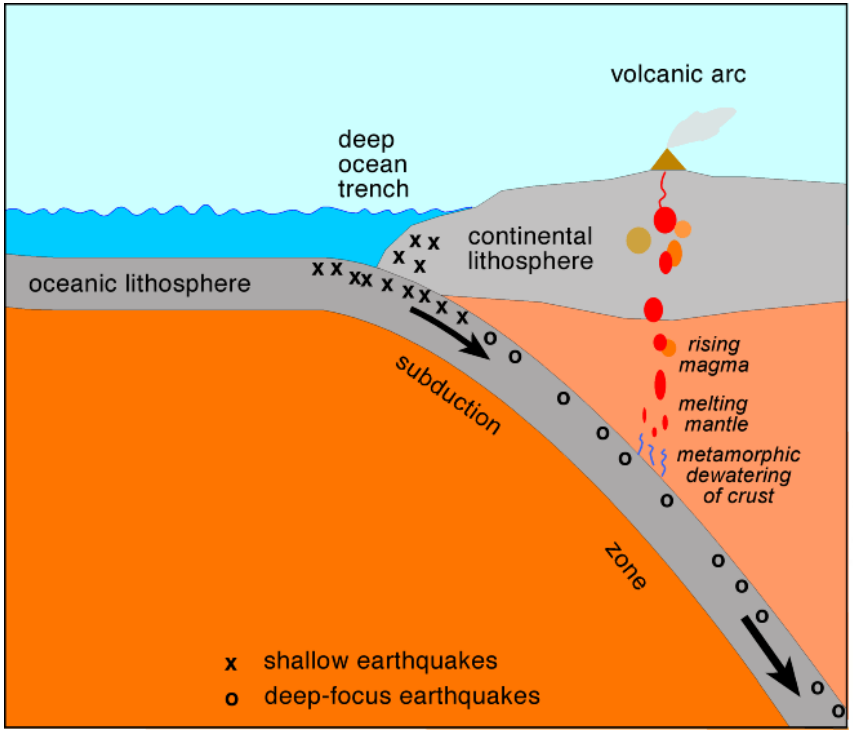
- **Epicenters**

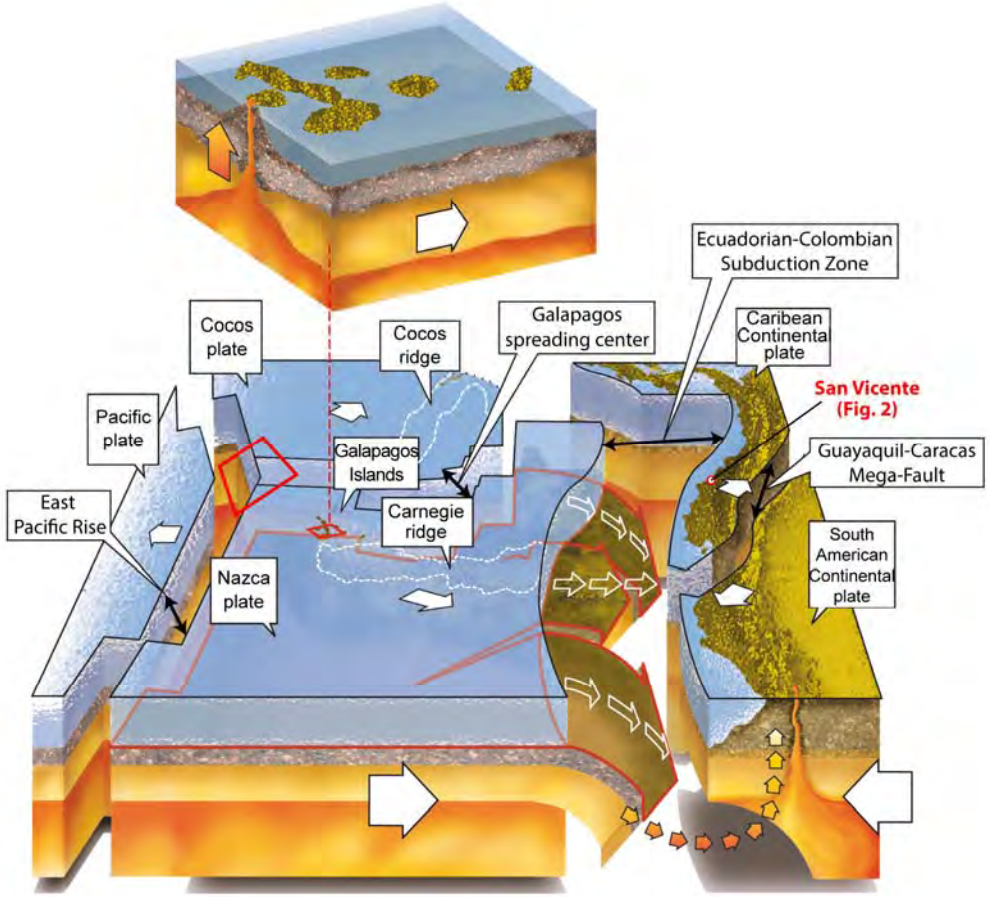


April 16, 2016 (M_w 7.8), April 20 (M_w 6.2 and 6.0),

April 22 (M_w 6.0) and May 18 (M_w 6.7 and 6.8)

Geodynamic setting of Ecuador, the Galapagos Islands and the Carnegie Ridge. Adapted from Toulkeridis, 2013





Near twenty Ecuadorian volcanoes are considered to be active for the last century, five of these erupted in the last 17 years. Left: Eruption of Guagua Pichincha (0°10'14.88"S, 78°36'45.36"W) on October 7th, 1999; Upper right: Typical smaller and frequent eruption of Tungurahua in 2002 (1°28'12.71"S, 78°26'41.28"W); Centrer: Eruption of Sangay in 2001 (2°00'17.99"S, 78°20'26.88"W); Lower right: Biggest eruption in past decades of Reventador in 2002 (0°04'39.00"S, 77°39'20.87"W). Photos by Alois Speck and Anonymous (Reventador).

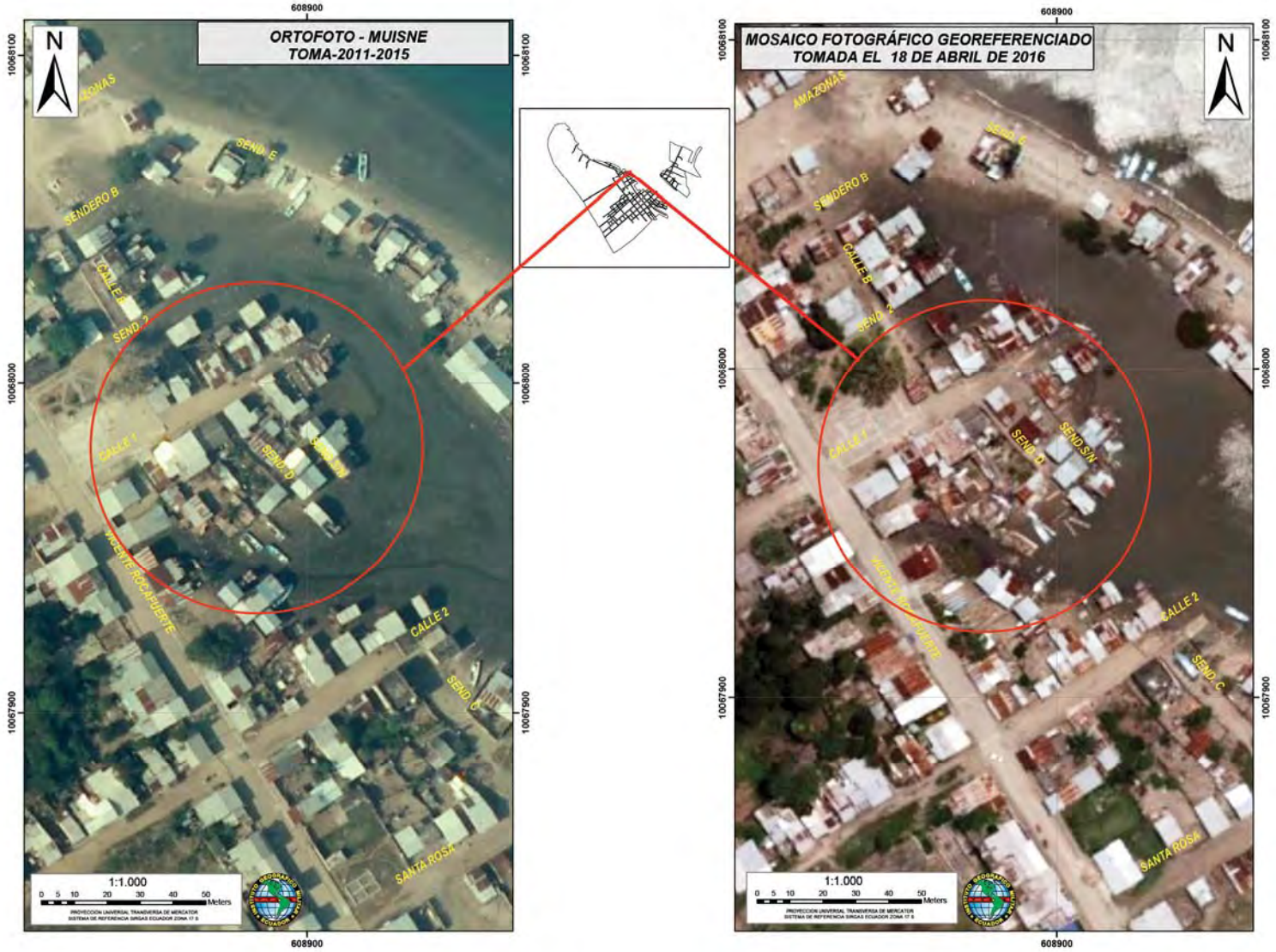
HUMANS

earthquake left 667 fatalities, over 16000 injured and 20000 displaced.

ECONOMICS


AVIÓN
CESSNA CITATION II
AVIONETA
CESSNA - T206 H
VEHÍCULO AÉREO NO TRIPULADO
UX 5

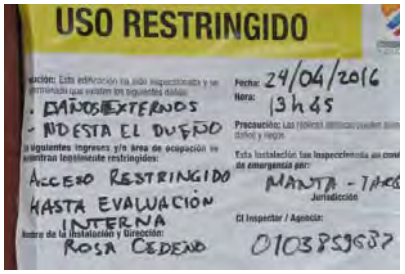
METODOLOGY


ORTOFOTO - MUISNE
TOMA-2011-2015
MOSAICO FOTOGRÁFICO GEOREFERENCIADO
TOMADA EL 18 DE ABRIL DE 2016
N
608900
10068100
10068000
10067900
AMAZONAS
SENDERO B
CALLE B
SEND. C
SEND. D
SEND.S/N
CALLE 1
CALLE 2
VICENTE ROCAFUERTE
SANTA ROSA
1:1.000
0 5 10 20 30 40 50 Meters

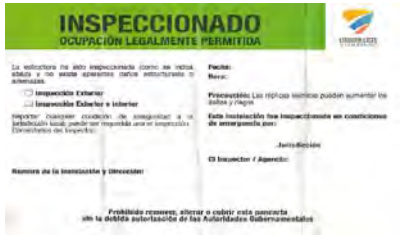
Damage Assessment/Tagging/Incorporation of ATC-20

The document has been adapted for the evaluation of buildings damaged during this earthquake (damage and conditions of a building).

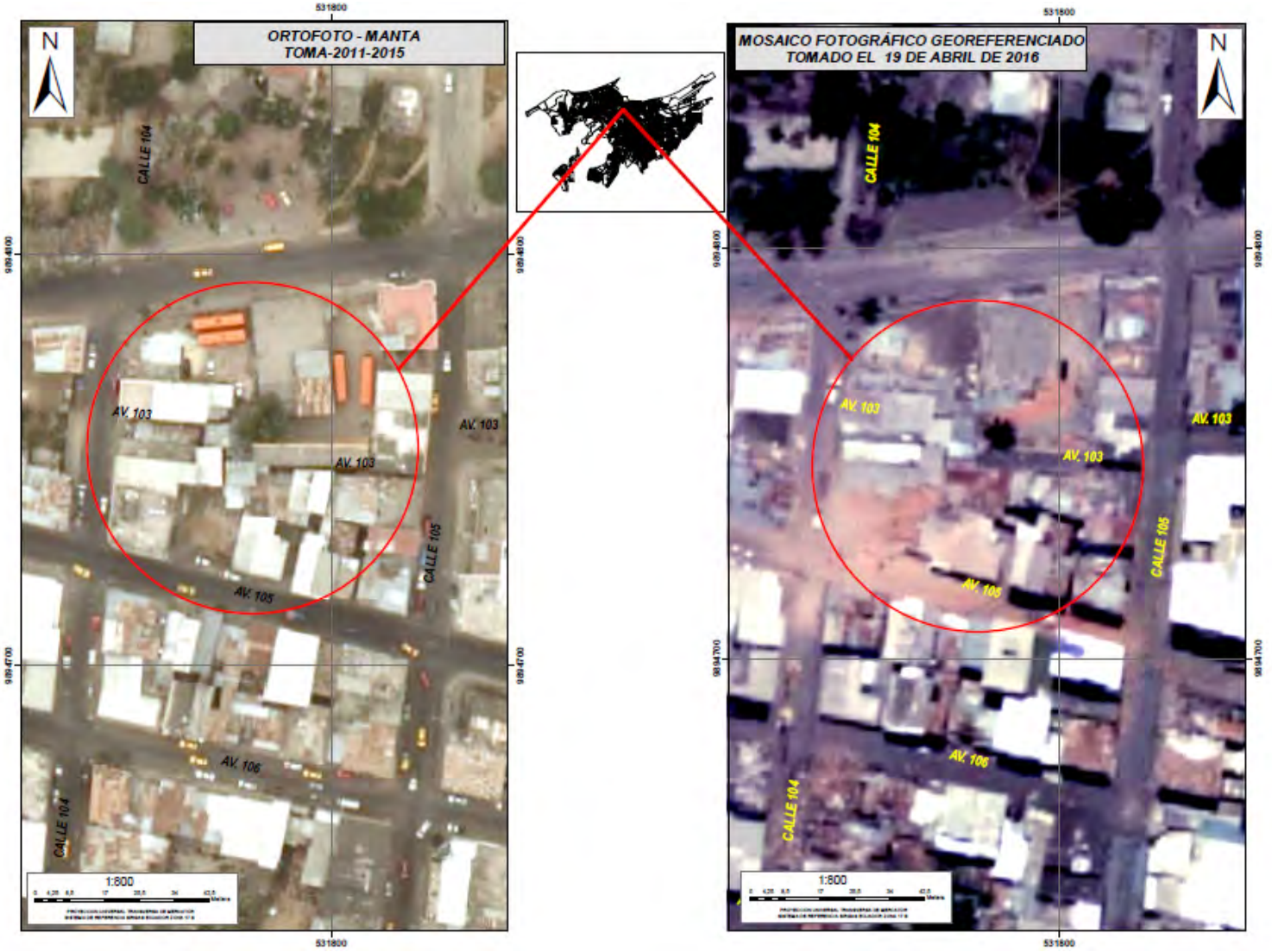
RED IS DAMAGED



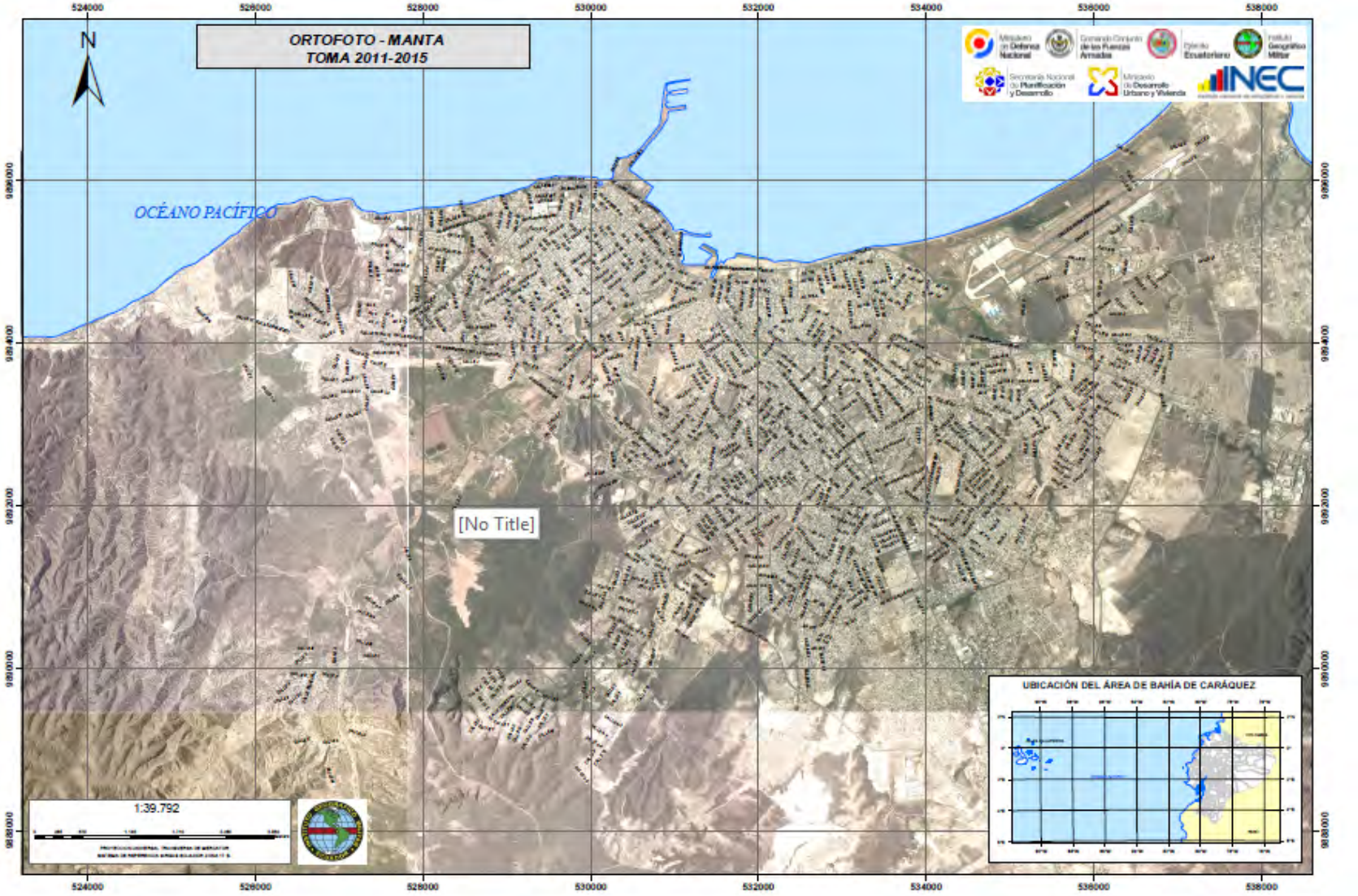
YELLOW IS DAMAGED, MY FALL IN AFTER SHOCK



GREEN IS HABITABLE

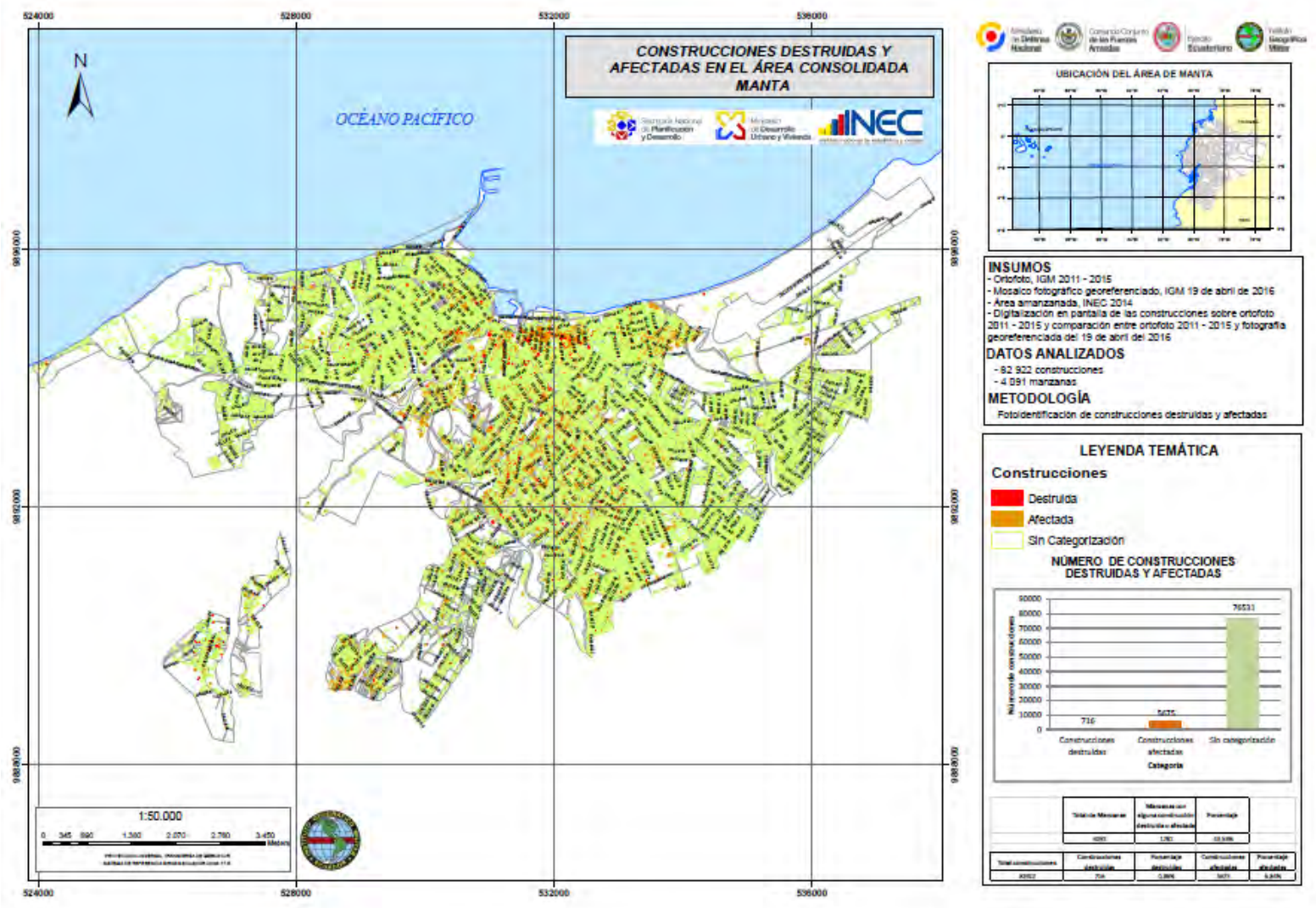

ORTOFOTO - MANTA
TOMA-2011-2015
MOSAICO FOTOGRÁFICO GEOREFERENCIADO
TOMADO EL 19 DE ABRIL DE 2016
N
CALLE 104
AV. 103
AV. 105
AV. 106
CALLE 105
1:800
531800
531600
9894800
9894700

SOURCE: IGM


ORTOFOTO - MANTA
TOMA 2011-2015
N
OCÉANO PACÍFICO
[No Title]
UBICACIÓN DEL ÁREA DE BAHÍA DE CARÁQUEZ
1:39.792
524000
526000
528000
530000
532000
534000
536000
538000

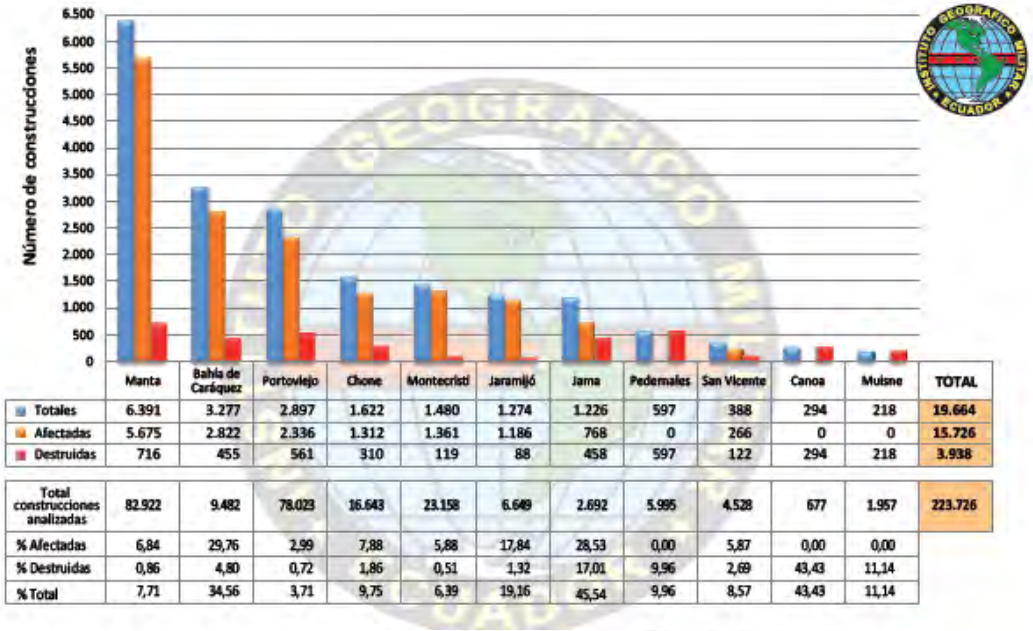
SOURCE: IGM

G..


CONSTRUCCIONES DESTRUIDAS Y AFECTADAS EN EL ÁREA CONSOLIDADA MANTA
OCÉANO PACÍFICO
N
524000
528000
532000
536000
9896000
9892000
9888000
1:50.000
UBICACIÓN DEL ÁREA DE MANTA
INSUMOS
- Ortofoto, IGM 2011 - 2015
- Mosaico fotográfico georeferenciado, IGM 19 de abril de 2016
- Área amanzanada, INEC 2014
- Digitalización en pantalla de las construcciones sobre ortofoto 2011 - 2015 y comparación entre ortofoto 2011 - 2015 y fotografía georeferenciada del 19 de abril del 2016
DATOS ANALIZADOS
- 82 922 construcciones
- 4 091 manzanas
METODOLOGÍA
Fotoidentificación de construcciones destruidas y afectadas
LEYENDA TEMÁTICA
Construcciones
Destruida
Afectada
Sin Categorización
NÚMERO DE CONSTRUCCIONES DESTRUIDAS Y AFECTADAS
716
5675
76531
Construcciones destruidas
Construcciones afectadas
Sin categorización
Categoría

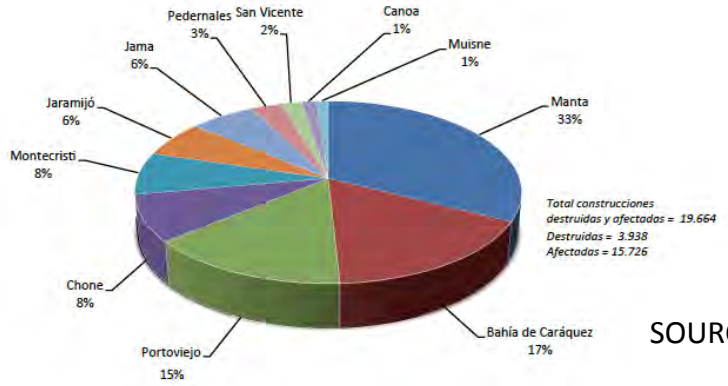
SOURCE: IGM

Damage report from IGM



	Manta	Bahía de Caráquez	Portoviejo	Chone	Montecristi	Jaramijó	Jama	Pedernales	San Vicente	Canoa	Muisne	TOTAL
Totales	6.391	3.277	2.897	1.622	1.480	1.274	1.226	597	388	294	218	19.664
Afectadas	5.675	2.822	2.336	1.312	1.361	1.186	768	0	266	0	0	15.726
Destruidas	716	455	561	310	119	88	458	597	122	294	218	3.938
Total construcciones analizadas	82.922	9.482	78.023	16.643	23.158	6.649	2.692	5.995	4.528	677	1.957	223.726
% Afectadas	6,84	29,76	2,99	7,88	5,88	17,84	28,53	0,00	5,87	0,00	0,00	
% Destruidas	0,86	4,80	0,72	1,86	0,51	1,32	17,01	9,96	2,69	43,43	11,14	
% Total	7,71	34,56	3,71	9,75	6,39	19,16	45,54	9,96	8,57	43,43	11,14	

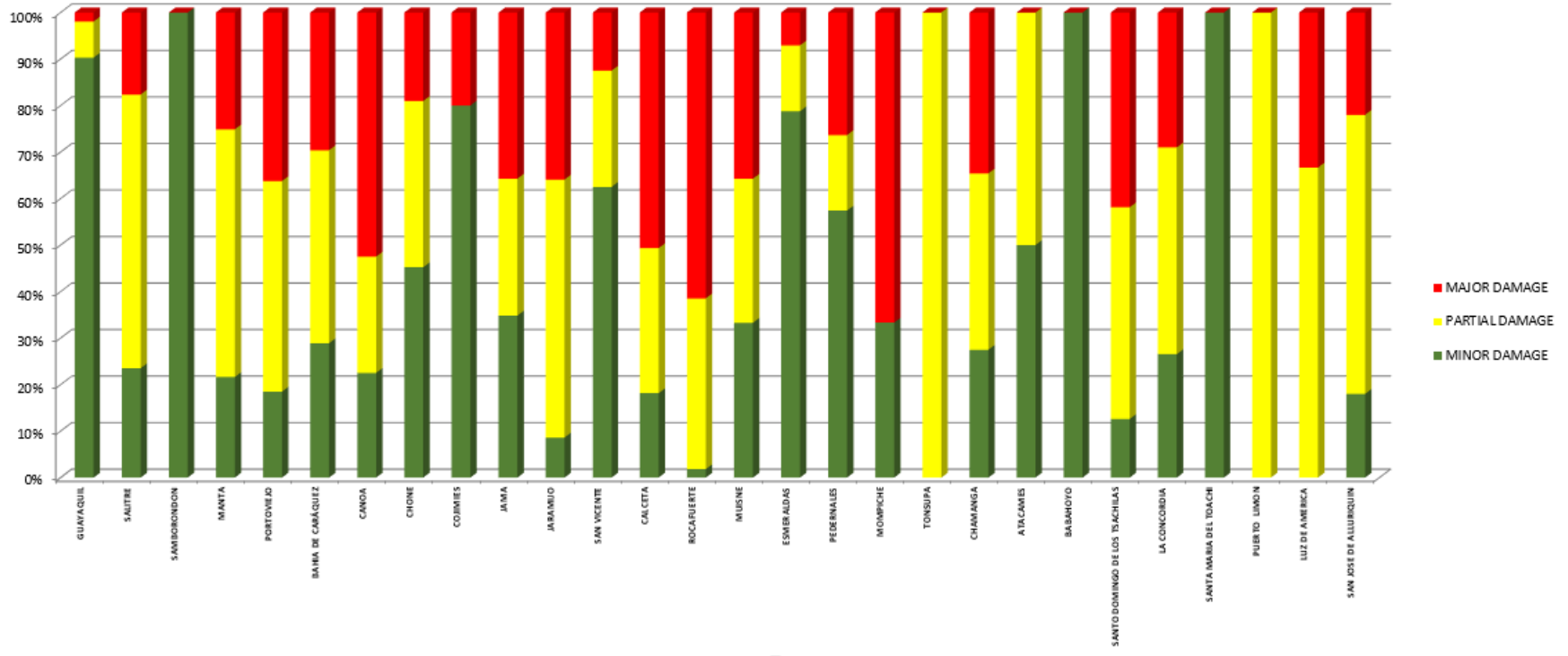
Porcentaje de construcciones afectadas y destruidas por localidad con respecto al total del país, 16/04/16



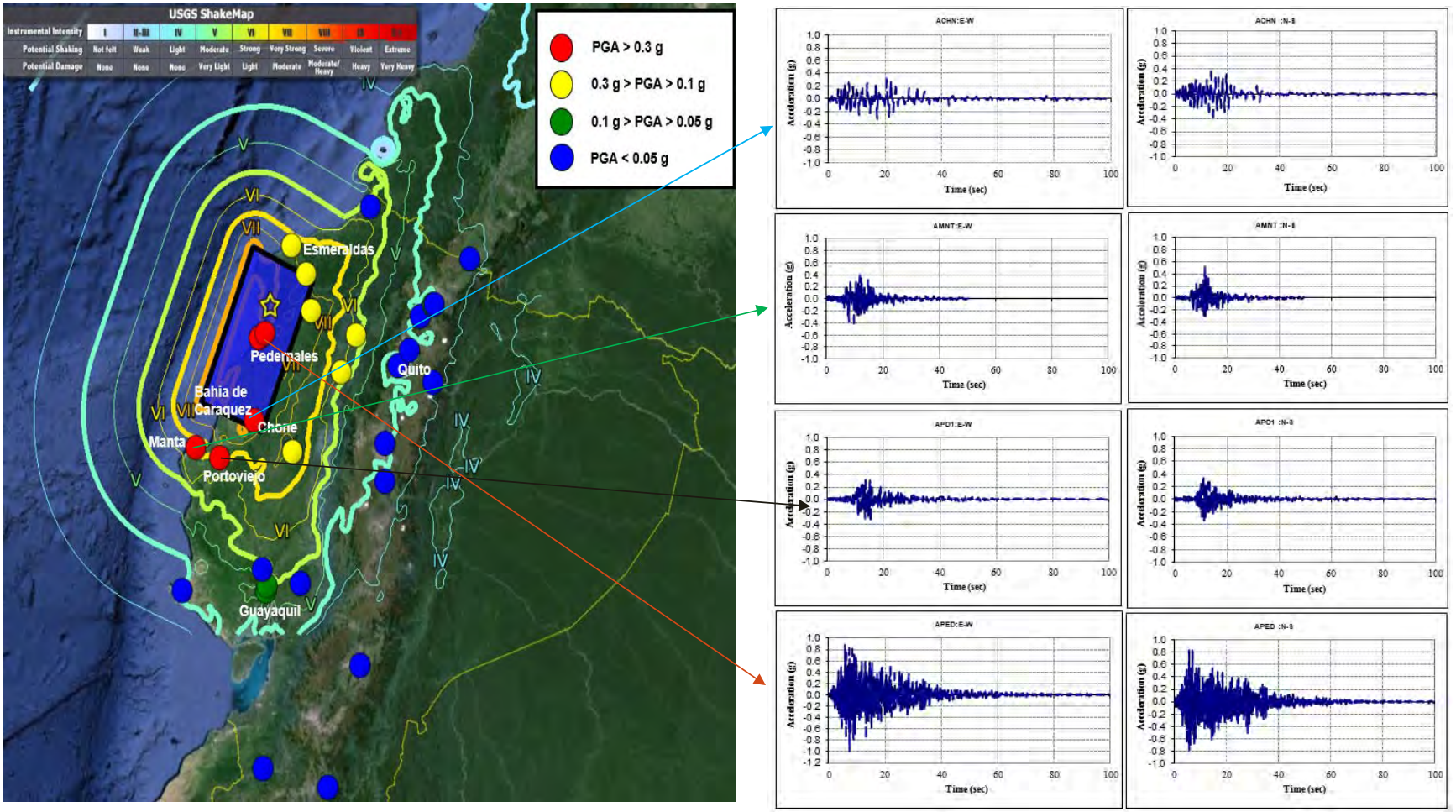
SOURCE: IGM

Damage report from GEER

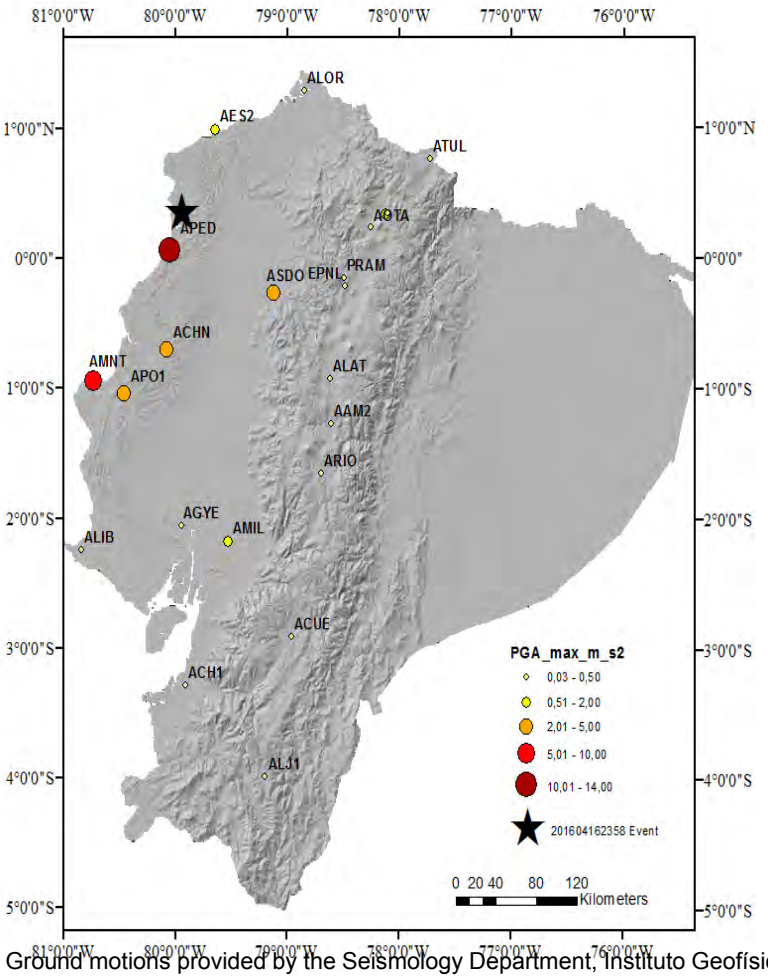
SOURCE: GEER

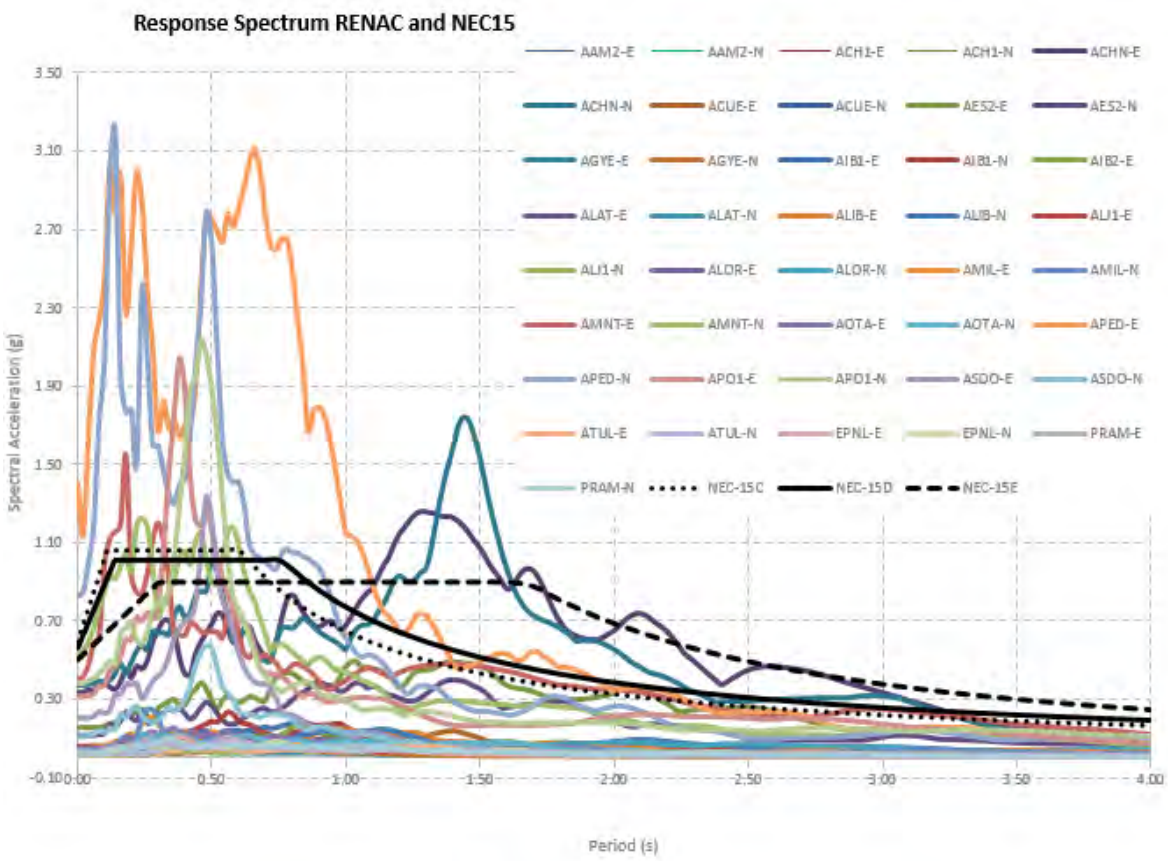


Contours of Intensity from USGS and strong motion stations (SMS) color coded by the intensity of the motion in terms of the geo-mean peak ground acceleration (PGA) and Acceleration time series in the EW and NS component overlying a map of Ecuador with the main cities and stations.



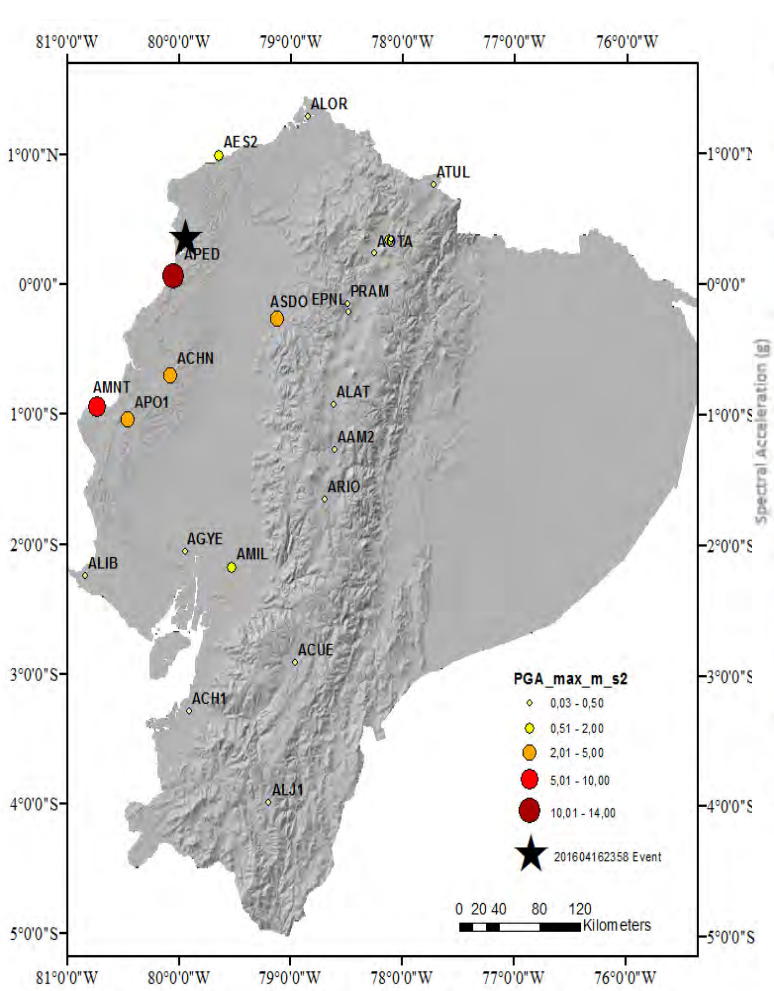
- Response Spectrum and Code-Based Design Spectra NEC-2015 (a return period 475yr prob. of exceedance of 10% in 50 years)

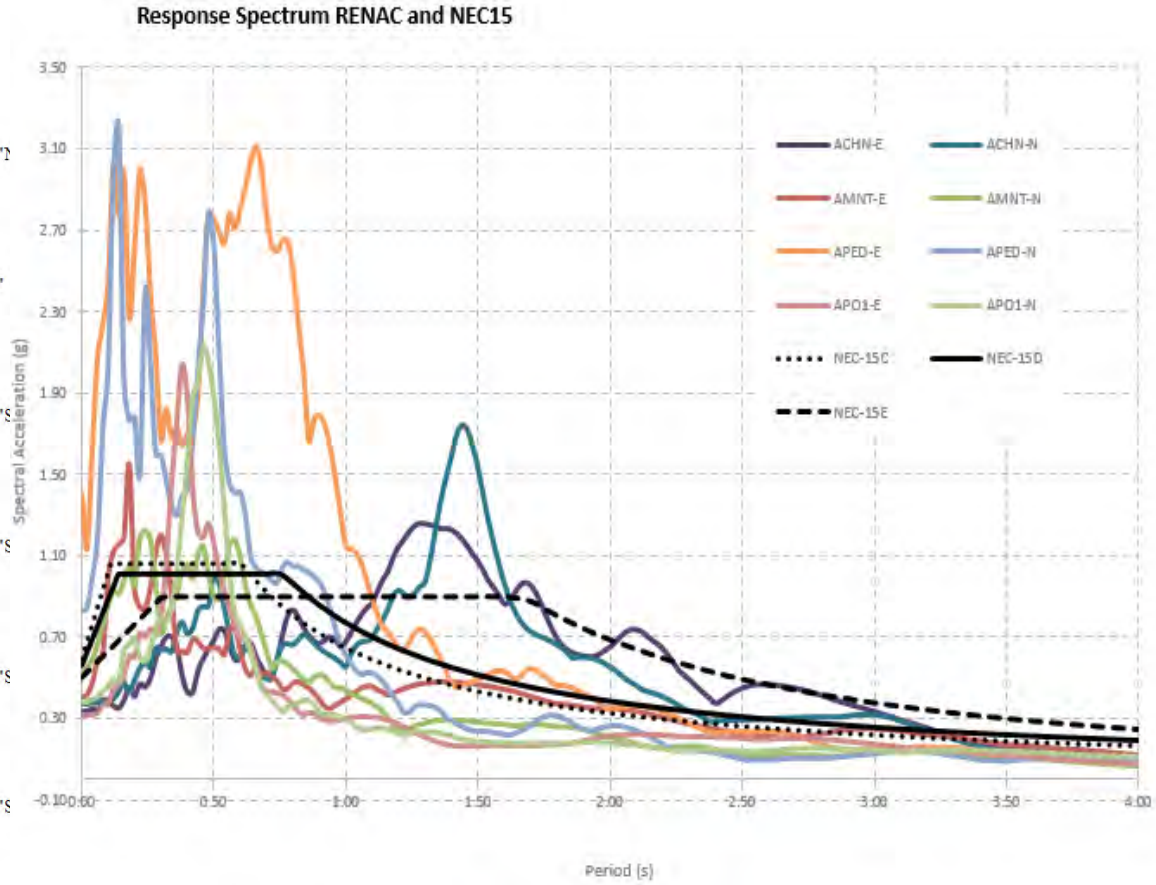




Ground motions provided by the Seismology Department, Instituto Geofísico, Escuela Politecnica Nacional, Ecuador with details in their report Singaucho, J., Laurendeau, A., Viracucha, C., Ruiz, M. (2016). “Observaciones del Sismo del 16 de Abril de 2016 de Magnitud Mw 7.8”

- Response Spectrum. NEC-2015 (475yr)





Ground motions provided by the Seismology Department, Instituto Geofísico, Escuela Politecnica Nacional, Ecuador with details in their report Singaucho, J., Laurendeau, A., Viracucha, C., Ruiz, M. (2016). “Observaciones del Sismo del 16 de Abril de 2016 de Magnitud Mw 7.8”

Housing and building inventory and Construction- This presents the type of buildings in the area affected by the earthquake

Wood houses

Residential Building with commercial first floor

Reinforced Concrete Building

There were several buildings that completely collapsed

Portoviejo

SOURCE: GOOGLE

Pedernales

SOURCE: EL COMERCIO

Bahia de Caráquez

SOURCE: UB TEAM

Portoviejo(170km, PGA=0.37g)

Ecuatorian Institute Social Security

Main structural Observation The damage at each building was dependent on the structural system, poor seismic detailing, poor construction practices, quality of materials, and intensity of the ground motion.

Portoviejo **Manta** **Bahia de Caráquez**

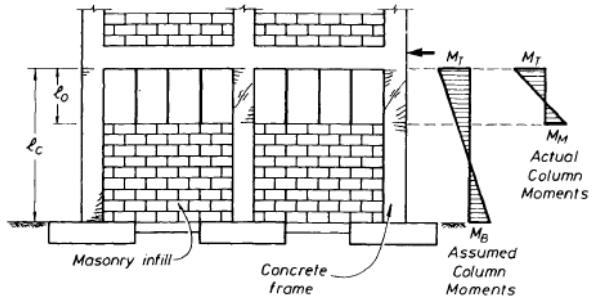
Soft Story failure. The first floor of these buildings collapsed

Main structural Observation

Sings of several corrosion on reinforced steel , collapsed electrical pole with corrosion and reduction of effective area of longitudinal steel.

Hospitals

Plastic hinges formed in the columns of the buildings and residential houses. The masonry walls between columns restrained the column height and increases the shear demand when the plastic flexural demand concentrated at their ends.



Main structural Observation

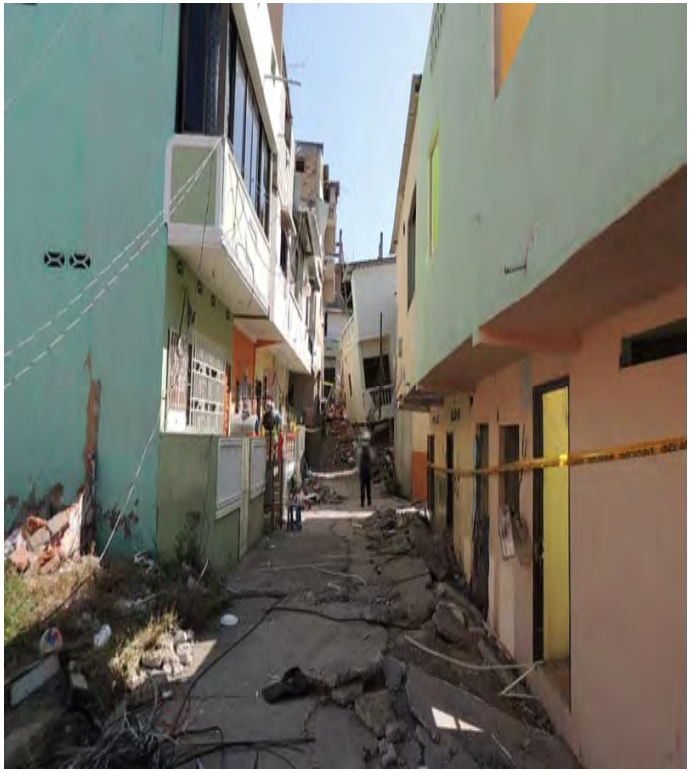
Reinforced concrete detailing:

Stirrup spacing and discontinuity in the longitudinal rebars were observed in columns of some older multistory moment frame buildings.

Main structural Observation

Liquefaction –Soild Failure:

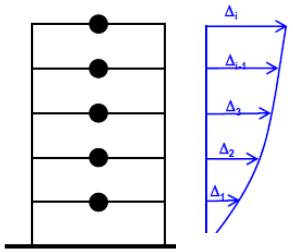
The settlement caused some building to sink.



Main nonstructural Observation

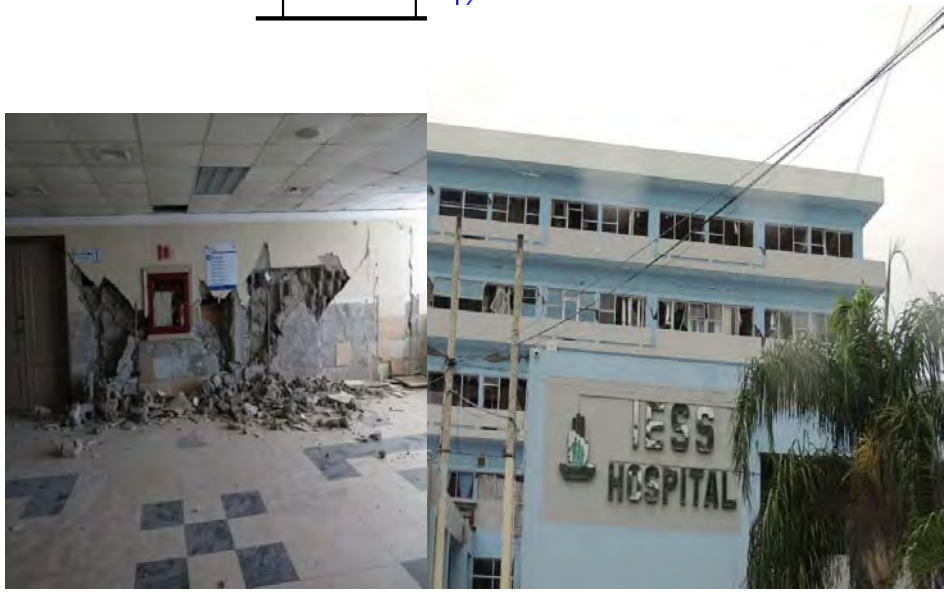
This Building/hospital suffered no structural damage, the building/hospital was completely closed because there was an extensive nonstructural damage related to nonstructural elements that are sensitive to drifts and acceleration.

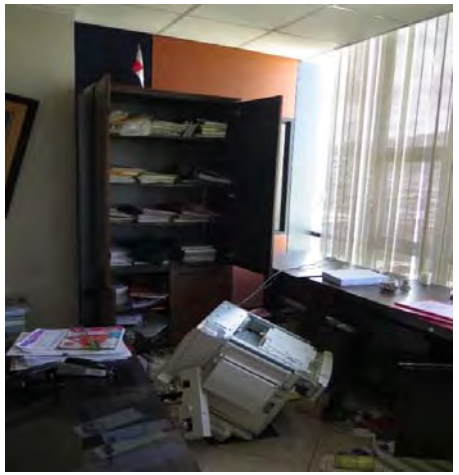
- Drift

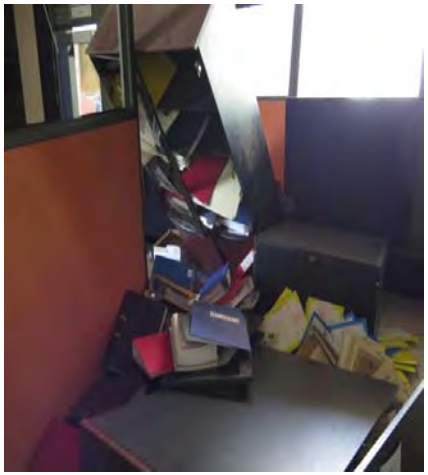


- Acceleration:

$$F_{ph} = \frac{0.4 a_p S_{DS}}{\frac{R_p}{I_p}} \left(1 + 2\frac{z}{h}\right) W_p$$







Hospitals and health infrastructure

Although none of the hospital facilities collapsed, 22 were left inoperative in the province of Manabí and Esmeraldas due to severe damage to non-structural components. Medical assistance was provided from temporary shelters, resulting in overcrowding, lack of sanitation and increasing risk of epidemic disease transmission.

IESS Hospital Manta

Solca Hospital Portoviejo

Hospital Chone

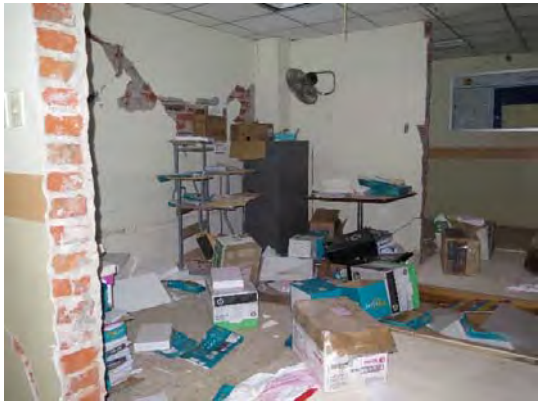
Bahia Hospital

Main Nonstructural Observation

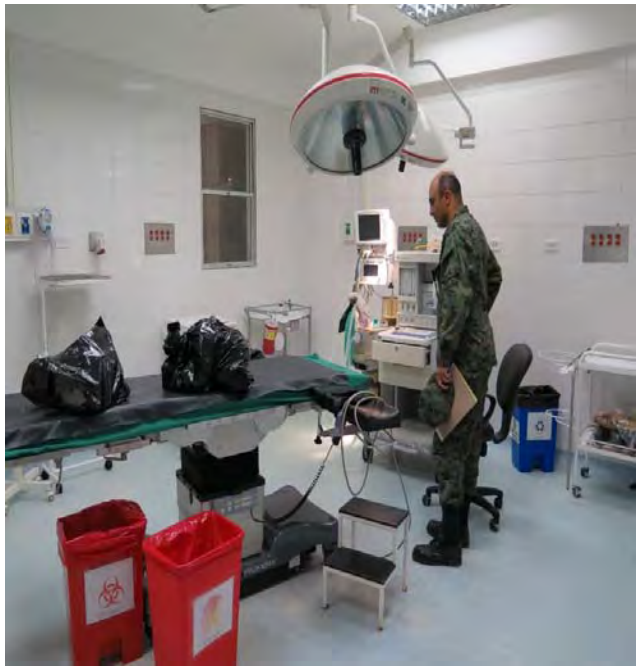
Masonry infill- Outpatient

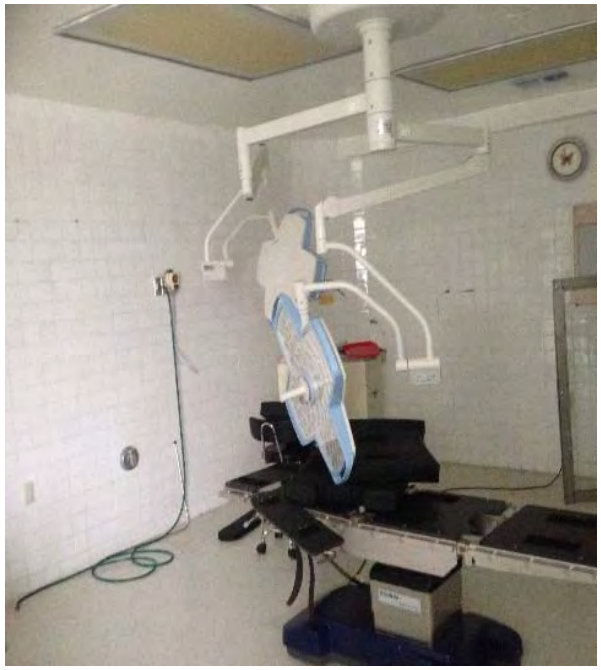
Ducts and ceilings

Nonstructural damage



Main nonstructural Observation





ASSESSMENT OF NONSTRUCTURAL COMPONENTS OF TWO HOSPITALS IN ECUADOR FOR POTENTIAL SEISMIC HAZARD IN ACOORDANCE WITH FEMA E-74.

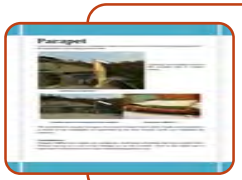
FEMA E -74 METHODOLOGY

PHASE 1

PHASE 2

PHASE 3

- Nonstructural Elements Assessed
- Visual Inspection Form



PHASE 4

- Implementation
- Checklist

Parapet

Nonstructural architectural component must be secured as it is located on the upper parts of the hospital, overlooking streets below.

Parapet, top floor right side block, Military Hospital of Guayaquil

Typically, the parapets fall and fall outwards due to telmic action.

Last floor right side box

Photo FEMA E74

The unreinforced masonry parapets are prone to failure due to their height and slenderness, as forces in the earthquake are generated at the base causing cracks and collapsing the structure.

Consequences
Parapets falling from heights are dangerous, destroying everything that lies beneath them. Persons moving in or out of the building are at risk of death. There is the added risk of further destruction to elements such as cars, mechanical equipment, etc.

Anchor Method

Photo FEMA E74 (6.3.3.1-7)

The parapets should be fastened to the ceiling or floor to prevent falling. Spaced struts are used.

This embraces the structure at a maximum distance of 6' from the top, performed by drilling metal sections through the parapet and steel plates, secured and adjusted with bolts; braces or diagonal angle profiles are anchored to the roof plates either welded or bolted.

FEMA Photo Example E74 (6.3.3.1-6)

Anchorages must be designed so that they can withstand the forces caused by the earthquake.

The outer clamp plate can be painted or otherwise finished in a way that is consistent with the facade of the building.

Experience Required
An engineer shall design the anchoring system.

Recommended Priority
Life safety, property loss. Falling elements can cause deaths.

Implementation Cost and Disruption.

Implementation cost is moderate, involves labor and masonry materials such as angle sections, bolts and welds. Disruption to hospital activity is minimal for this work since the main work to be done is on terraces and roofs.

Emergency Generator

Nonstructural mechanical component, used for electricity in an emergency.

Machine plant, Military Hospital of Guayaquil Stock

This system is needed to address the lack of electricity caused by interruption to external power supply. Strong movements may cause the generator to move and break connections, still important to check with them.

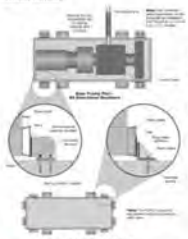
Anchor Generator

Photo FEMA E74

Emergency generators are essential equipment for the hospital; without good anchorage they can slip or tip.

Consequences
Damage caused to the wiring, fuel lines, etc., function and operation of the equipment is compromised or out of service, causing failure in the electrical system and complicating the operation of the hospital after an earthquake.

Anchor Method



Graph. FEMA E74 (6.4.7.2-3)

The generators should be placed on a concrete slab anchored to the foundation; slab must withstand seismic forces.

Place base isolators to control movement, reduce deformations and forces, ensuring the preservation and operation.

Pipes must be flexible connections to prevent breakage.

Photo. FEMA E74 (6.4.1.1-4)

Photo. FEMA 747

Required Experience
Engineer to calculate the anchorage

Recommended Priority
Safety of life, loss of function and use of equipment post-earthquake is high.

Implementation Cost and Disruption.
Implementation cost is low; labor involves masonry, reinforcing steel, bolts, etc. The disruption to hospital function is null and to equipment minimal.

Dialysis Unit

Masonry walls, plaster ceiling, lamps, floor, dialysis equipment and supplies as part of architectural considerations and medical requirements in the Dialysis Unit.

Dialysis area (Second Floor).

Strong movements may lead to dialysis equipment slipping and the connections thereof breaking. Critical patients may be injured or even die due to the lack of power supply or lack of blood. Falling television equipment may cause patient death.

Patient undergoing treatment, and at risk of collapse of TV

Items not fastened can slip, fall and suffer breaks.

Consequences

Items can fall and damage equipment and important supplies and other objects next to them.

Anchor Method

Graphic GSE Swiss seismal safety earthquakes manual

Review the items already detailed above that are situated within the Dialysis Unit.

Mobile items such as dialysis machines and equipment, tables, chairs, among others should be fastened to the walls with the appropriate supports to prevent movement.

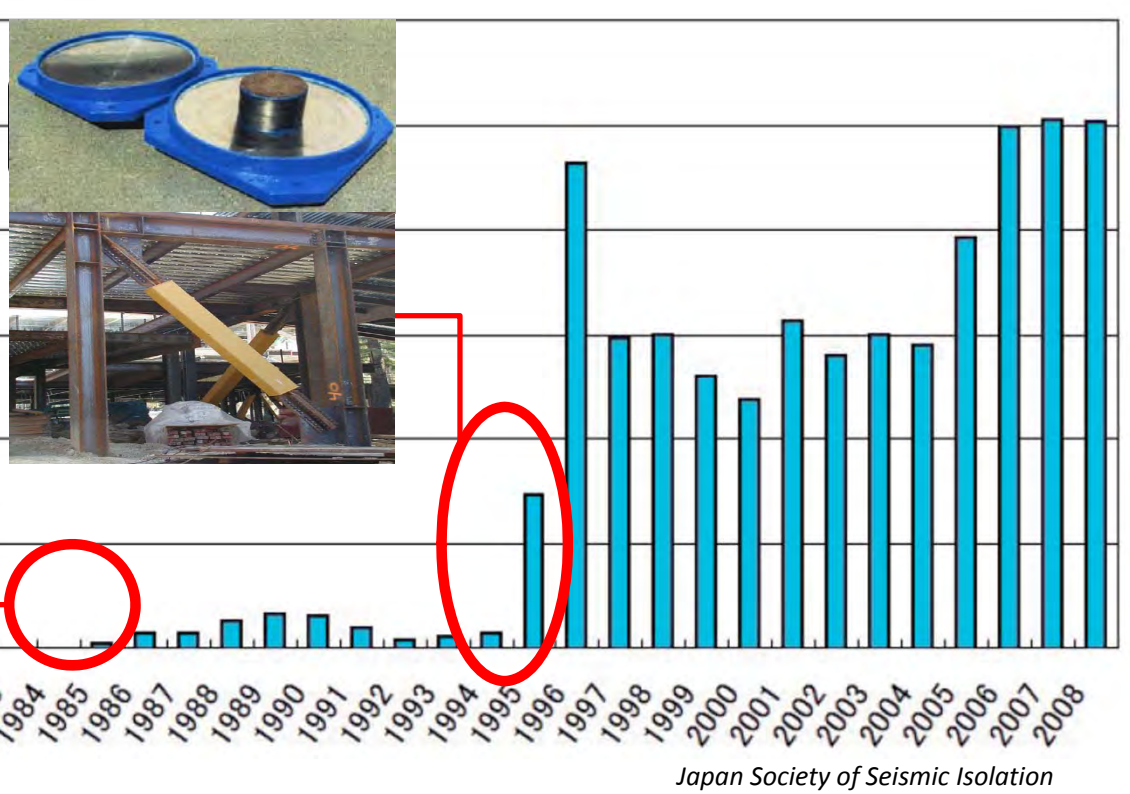
Equipment situated on top of tables should be secured in the same way as computers.

Experience Required
Work can be carried out by anyone.

Recommended Priority
Loss of function, avoids disruption of service.

Implementation Cost and Disruption
Cost of implementation is low and involves labor, masonry, bolts, fasteners and unqualified personnel. Disruption to hospital and equipment is minimal.

TECHNOLOGIES, MONITORING, PROTECTION (BIG PICTURE)



Japan Society of Seismic Isolation

CONSTRUCTION AND DESING ISSUES

- Qualified professionals doing the supervision
- Materials
  - Sea water
  - Sea sand

The poor structural performance was mainly due to the existence of many vulnerable structures and common problems of irregularity and limited ductility.

- Inspection during the construction
- Code issues addressing the probability of failure
- Role of the professionals in the designs
- Peer review of actual designs
- Education and Research

The earthquake also affected water and electricity supply, leaving many people without drinkable water and telecommunication. The nearly 50sec earthquake left 667 fatalities, over 16000 injured and 20000 displaced. The economic loss was estimated as 3billion US dollars.

The poor structural performance was mainly due to the existence of many vulnerable structures and common problems of irregularity and limited ductility. Although none of the hospital facilities collapsed, 22 were left inoperative in the province of Manabí and Esmeraldas due to severe damage to non-structural components. Medical assistance was provided from temporary shelters, resulting in overcrowding, lack of sanitation and increasing risk of epidemic disease transmission.

Some landslides and lateral spreading caused partial disruption of the transportation system hindering access to the affected areas.

The overall performance of bridges was satisfactory, except the collapse of an overpass reinforced concrete structure in the city of Guayaquil, 280km from the epicenter.

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