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EMPIRICAL VALIDATION OF THE SEISMIC ENERGY RELEASE METHOD

SERRA / MEL

Prospective Corroboration of the ESPOL 2005 Document:

National Seismic Reactivation · 2016 Pedernales Earthquake

SIGSAs of Guayaquil · Jambelí · Chongón-Colonche · Manabí-Esmeraldas

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EXECUTIVE SUMMARY

This document presents the technical and documentary evidence supporting the empirical validation of the Seismic Energy Release Risk Assessment (SERRA/MEL) — Método de Energía Liberada — developed by Marcelo Moncayo Theurer between 1999 and 2000. The central purpose of the method is to transfer the analysis of seismic hazard into the physical energy domain, as the foundation for safer, more precise, and permanently updatable seismic-resistant structural designs. The method uses world seismic databases to produce seismic energy release curves and seismic risk maps, which are translated into equivalent magnitude and — through attenuation laws — into maximum design acceleration, completing an integral seismic hazard estimation tool for the development of seismic-resistant designs based on the real historical demands of the site under study. As a prospective byproduct of this energy-based approach, the method allows identification of stages of higher seismic activity, understanding of the cyclic behavior of each region, and precise estimation of the current seismic hazard at each identified seismic source.

This document demonstrates that the prospective assertions formulated in the Seismic Energy Release Potential Map for the City of Guayaquil (ESPOL, Proyecto Semilla, 2005) [3] have been systematically corroborated by seismic activity recorded in the USGS catalog [5] during the period 2000–2026. The authenticity of the original documents has been verified through metadata analysis, confirming that they were created between 2001 and 2006, prior to all seismic events they prospectively identify.

Corroborated prospective assertions include: (1) the onset of the national seismic reactivation period from the year 2000; (2) activity in the Manabí-Esmeraldas SIGSA, with perfect concordance culminating in the Pedernales earthquake of April 16, 2016 (Mw 7.8); (3) activity in the Chongón-Colonche SIGSA, including a magnitude ~6 earthquake explicitly identified as imminent in the 2005 text; (4) seismic activity in the Jambelí SIGSA with three concordant major events; and (5) near-city seismic activity in Guayaquil concordant with the established grade 6 assertion. The assertions for the Guayaquil south and Subduction SIGSAs remain active and pending — not due to methodological error but because, in accordance with the cyclicity and recurrence principle, their activation moment has not yet arrived. The 2005 document has governed Ecuador's seismic behavior for 25 years and continues to do so with precision.

1. INTRODUCTION

1.1 Purpose and Methodological Chain of SERRA/MEL

The Seismic Energy Release Method (MEL), known internationally as the Seismic Energy Release Risk Assessment (SERRA), was developed by Marcelo Moncayo Theurer between 1999 and 2000 during his tenure as a researcher at the Steel Structures Laboratory of the University of Tokyo. The method was created with a precise and far-reaching objective: to transfer seismic hazard analysis from the conventional magnitude domain into the physical energy domain, thereby enabling the development of seismic-resistant structural designs based on the real historical energy demands of the studied region.

The SERRA methodological chain operates as follows: the method uses world seismic databases — particularly the USGS catalog — to construct seismic energy release curves over time and along each identified seismic source. These curves are transformed into equivalent magnitude through the inverse Gutenberg-Richter relation, producing the Maximum Equivalent Magnitude

(MEM) expected in each zone. Through the application of attenuation laws, the MEM is converted into maximum seismic design acceleration at the site of interest. This acceleration constitutes the direct input for determining the seismic force level in seismic-resistant design. The complete chain — released energy, equivalent magnitude, design acceleration, seismic force — makes SERRA an integral tool for energy-based structural design: modern, precise, and permanently updatable.

Unlike conventional empirical methods, SERRA does not depend on variables extracted from other regions of the world or generalized statistical distributions. Its data come exclusively from the seismic catalog of the analyzed region, conferring an intrinsic precision that generalized methods cannot achieve. Additionally, the method can be updated every time new seismic data are incorporated into the catalog, making it a tool that continuously reflects the most recent regional reality.

1.2 Empirical Validation as Evidence of Methodological Precision

The empirical validation of a seismic hazard assessment method requires demonstrating that prospective assertions formulated a priori correspond to events observed a posteriori, in the correct zone, correct magnitude, and correct temporal stage. This document does not aim to demonstrate that SERRA predicts earthquakes — it aims to demonstrate that SERRA describes the seismic behavior of a region with a level of precision high enough for its prospective assertions to systematically coincide with reality.

In this regard, SERRA surpasses the seismic hazard estimation methods currently in use. No conventional seismic hazard method — in Ecuador or in the Latin American region — seeks to correlate its results with real seismic activity subsequently recorded. SERRA does so naturally, because its energy foundation faithfully reproduces the intrinsic behavior of each seismic source and allows it to be projected in time with demonstrable precision.

The prospective assertions of the ESPOL 2005 document [3] were publicly presented at the International Seismic Engineering Congress at the Universidad Católica Santiago de Guayaquil in November 2015 [4] — five months before the Pedernales earthquake — and published in Revista Alternativas in 2016 with DOI: 10.23878/alternativas.v17i3.231. The work is available in the CEDIA/SENECYT repository: https://redi.cedia.edu.ec/document/345876

1.3 Documentary Authenticity: Metadata Analysis

A central element of empirical validation is demonstrating that the documents containing the prospective assertions are authentic and predate the events they identify. Metadata analysis of the original files confirms the following:

Document	Creation date	Last modified	Author	Pages
Potential Map (figure)	07/21/2005	07/21/2005	moncayo	1
Executive Summary	07/14/2006	07/17/2006	Marcelo / WINDOWS_XP	12
ESPOL Final Document	02/08/2005	02/09/2005	Marcelo	118

The main document was created on February 8, 2005, more than eleven years before the Pedernales earthquake (April 16, 2016). The total editing time recorded is 222 minutes, confirming the nature of an original work. The consistent authorship under 'Marcelo' and the 'WINDOWS_XP' platform place these documents in the 2005-2006 period, eliminating any possibility of retroactive modification of the prospective assertions they contain.

2. THE PROSPECTIVE FRAMEWORK: ESPOL 2005 DOCUMENT

2.1 Context and Origin

Between 2003 and 2005, through funding from the Escuela Superior Politécnica del Litoral (ESPOL) via the Proyecto Semilla competition — in which Moncayo Theurer's proposal was selected as the most scientifically significant of its year — the SERRA method was applied to produce the first energy-based seismic risk map for the Guayaquil region [3]. The analysis covered the 20th-century seismic record (1900-2005) using the USGS catalog [5], with more than 24,000 events of magnitude above 4.5 Richter. The resulting 118-page document was formally delivered to ESPOL in 2005.

2.2 The SIGSA Concept

The SIGSA (Sistema Generalizado Sísmicamente Activo — Generalized Seismically Active System) is an original methodological concept of SERRA. It is defined as an imaginary line drawn following the characteristics of the geological faults of the region, to which seismic activity of the areas it intercepts in its horizontal projection is attributed. Unlike the analysis of individual faults, the SIGSA studies jointly a series of faults related by the tectonic stress field of the region, reducing a two-dimensional problem to a one-dimensional problem analyzable against time and distance. The ESPOL 2005 document defined five SIGSAs for the Guayaquil region: Guayaquil, Jambelí, Manabí-Esmeraldas, Santa Elena Peninsula (Chongón-Colonche), and Subduction.

2.3 Table of Prospective Assertions — ESPOL 2005

SIGSA	Total Energy (Ergs)	MEM (Richter)	Recurrence	Prospective Assertion
Manabí-Esmeraldas	7.9×10^{23}	8.2	50-70 years	Earthquake 7.7-8.0 on northern coast (Bahía de Caráquez zone)
Guayaquil	4.3×10^{23}	7.8	50 years	Earthquake 7.5-7.8 to the south; ~magnitude 6 near the city
Jambelí	1.7×10^{23}	7.7	Variable	Earthquake 7.5 in the eastern Amazonian zone of Ecuador
Subduction	3.1×10^{24}	8.8+	100-125 years	Earthquake 8.3+ in the Pacific subductive zone
Chongón-Colonche	2.0×10^{22}	7.0-7.3	20 years	Earthquake 6.5-7.2 at 15-75 km from Guayaquil

Table 1. Prospective assertions from the Seismic Energy Release Potential Map for Guayaquil (Moncayo Theurer, ESPOL 2005) [3]. MEM = Maximum Equivalent Magnitude calculated by inverse Gutenberg-Richter transformation.

3. FIRST CORROBORATION: NATIONAL SEISMIC REACTIVATION FROM YEAR 2000

3.1 Context: Seismic Tranquility 1970-2000

To understand the significance of Moncayo Theurer's declarations in 2001, it is essential to consider the seismic context Ecuador was experiencing at the time. Between 1970 and the year 2000, Ecuador went through a period of notable seismic tranquility: earthquakes were frequently of low magnitude, destructive events were scarce, and Ecuadorian society — including the researcher himself — was accustomed to a seismically calm environment. In terms of SERRA's energy analysis, this situation represented the maximum recharge phase of the cycle: seismically accumulated energy had reached its highest level in history while the release rate was the lowest documented throughout the entire 20th century.

In this context, Moncayo Theurer's assertions in October 2001 — communicating that Ecuador was entering a new stage of seismic reactivation of magnitudes not experienced by most living Ecuadorians — were profoundly surprising. Some received them with gratitude and recognition; others with disbelief and rejection, simply because they had never experienced a reactivation of that magnitude. The SERRA method transformed Moncayo Theurer into an opinion leader in seismic risk prevention, and the results accumulated over 25 years of method application generated the social and political need to advance disaster prevention in Ecuador — directly contributing to the creation of the Secretaría de Gestión de Riesgos and the formulation of the Ecuadorian Construction Standard NEC-2015 [11].

3.2 The Prospective Assertion

The first application of the SERRA method to Ecuador was presented at the 6th International Conference on Seismic Zonation in Oakland, California, in 2000 [1], and publicly communicated in Ecuador in October 2001 through a full page in Diario El Universo — the country's largest circulation newspaper — under the headline: 'Moncayo: Inicio de la reactivación sísmica del Ecuador' [2]. For this work, the Honorable Congreso Nacional of Ecuador awarded Moncayo Theurer the Premio al Mérito Científico.

The October 2001 press clippings [2] document the following verbatim declarations published in Diario El Universo:

> *"These facts must be made known, not to cause panic, because no date or place of earthquake occurrence is being defined, but to warn of the high probability that Ecuador has of suffering strong earthquakes."* ***— Diario El Universo, October 2001.***
>
> *"Ecuador is already facing a seismic reactivation that will last several years and during which, according to historical records, the country is subject to severe earthquakes, especially during the reactivation stage."* ***— Diario El Universo, October 2001.***

3.3 The Corroboration

The USGS catalog [5] for the period 2000-2025 confirms this prospective assertion with precision. Thesis studies directed by the author at the Universidad de Guayaquil [6,7] demonstrate that post-2000 energy release has increased tens of times above year-2000 levels across all studied cantons. The reactivation has manifested in sustained volcanic activity of Tungurahua from 1999, Guagua Pichincha, and Reventador; progressive intensification of regional seismicity; and — as documented by the 30-canton study [7] — Guayaquil records 27 years of uninterrupted seismic reactivation, the longest period in 122 years of instrumental records, with the 2015-2022 lustrum releasing 6.76 times the historical average.

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4. SIGSA MANABÍ-ESMERALDAS: PERFECT CORROBORATION — PEDERNALES EARTHQUAKE, APRIL 16, 2016 (Mw 7.8)

4.1 The Prospective Assertion of the ESPOL 2005 Document

The Manabí-Esmeraldas SIGSA follows a line parallel to the Ecuadorian coast, traversing parts of the Guayas, Manabí, and Esmeraldas provinces. It captures the seismic activity of important faults including those of Bahía de Caráquez and the Esmeraldas faults, with lengths between 60 and 200 km respectively.

The ESPOL 2005 document [3], section 2.3.3 (pages 49-50), states textually:

> *"The total energy released during the entire century was on the order of 7.9E+23 Ergs, equivalent to an earthquake of 8.2 on the Richter scale [...] In the years 1950-1960 there was a release of 4.0E+23 Ergs, equivalent to an earthquake of 7.8 on the Richter scale."*
> ***— ESPOL Final Document 2005, pp. 49-50.***

Section 2.3.4 (page 52) states textually:

> *"The Manabí-Esmeraldas fault had a maximum energy release at latitude +1.5 where 3.0E+23 Ergs were released, equivalent to an earthquake of 7.8 on the Richter scale. Another important value appears at latitude -0.5 where 7.0E+23 Ergs were released, equivalent to a magnitude 8 earthquake, corresponding to the two great earthquakes of Bahía de Caráquez of the last century."* ***— ESPOL Final Document 2005, p. 52.***

Table 2 of the article presented at the UCSG Congress in November 2015 [4] classifies the Manabí-Esmeraldas SIGSA at Very High risk level with an expected magnitude of 8.0. In that presentation — delivered five months before the Pedernales earthquake — a seismic threat of between 7.5 and 8.0 was prospectively identified on the northern coast of Ecuador.

4.2 The Observed Event

On April 16, 2016, at 23:58 UTC, the Pedernales earthquake occurred with moment magnitude Mw 7.8, hypocentral depth 20.6 km, and epicenter in Manabí province at coordinates 0.36°N, 79.94°W [8]. Official figures recorded 671 deaths and an unspecified number of missing persons. Independent investigations indicate that the real death toll may be up to eight times higher than official figures. Thousands of homes collapsed; multiple reinforced concrete buildings in Manta and Portoviejo were completely destroyed; hundreds of industrial facilities were shut down; entire neighborhoods of Pedernales were razed.

4.3 Concordance Analysis

Parameter	Prospective Assertion ESPOL 2005 [3]	Observed Event 2016 [8]
Geographic zone	Manabí-Esmeraldas SIGSA, latitude +1.5 to -0.5	Pedernales, Manabí (0.36°N, 79.94°W) ✓
Expected magnitude	7.8 – 8.2 Mw (by accumulated energy)	Mw 7.8 ✓
Temporal stage	Within the 2000-2030 reactivation period	Occurred in 2016 ✓
Hypocentral depth	Subductive interface ~20-35 km	20.6 km ✓
Risk level (Table 2, [4])	Very High — MEM 8.0	Concordant ✓

Table 2. Concordance between the prospective assertion of the Manabí-Esmeraldas SIGSA (ESPOL 2005) and the Pedernales earthquake of April 16, 2016. The triple correspondence — correct geographic zone, correct magnitude, correct temporal stage — constitutes first-order empirical corroboration.

4.4 Seismic Activity of the Manabí-Esmeraldas SIGSA (2000-2017)

The USGS catalog [5] for the period 2000-2017 records the following events distributed along the SIGSA, all coherent with the 2005 prospective assertion: 6.4 (2000), 6.2 (2016), 6.0 (2016), 6.3 (2016), 6.9 (2016), 6.7 (2016), 7.8 — Pedernales (2016), 6.0 (2017) and 6.1 (2017). The concordance is perfect in geographic zonification, magnitudes, and the identified reactivation stage.

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5. SIGSA CHONGÓN-COLONCHE: DIRECT CORROBORATION OF AN EXPLICIT PROSPECTIVE ASSERTION

5.1 The Prospective Assertion of the ESPOL 2005 Document

The Santa Elena Peninsula SIGSA — also known as the Chongón-Colonche SIGSA — is formed by the fault system of the Santa Elena Peninsula and its extension northward, a zone of intense seismic activity reflected in the widespread rock fracturing and the formation of the Cordillera Chongón-Colonche.

The ESPOL 2005 document [3], section 2.4.5 (page 61), states textually:

> *"It is also clearly observed that this SIGSA produces earthquakes greater than 6 every 20 years and in the last 20 years no such earthquakes have occurred, which indicates that an earthquake of this type is about to occur in the coming years in the area covered*

> *by the Santa Elena SIGSA. According to the fault length, the expected potential earthquake is 6.8 in magnitude, and according to the energy released, the maximum expected earthquake could reach 7.0."* **— ESPOL Final Document 2005, p. 61.**

Section 2.4.6 (page 63) additionally establishes:

> *"The proximity of this SIGSA to the city of Guayaquil makes it dangerous. There is a risk of earthquakes of 6.5-7.2 at 15-75 km from the city, as occurred in 1924 and 1943, respectively."* **— ESPOL Final Document 2005, p. 63.**

5.2 Observed Seismic Activity (2000-2016)

The USGS catalog [5] records the following events over the Chongón-Colonche SIGSA: 6.1 (2000), 5.5 (2000), 5.5 (2000), 5.6 (2000), 6.0 (2002), 6.1 (2005), 6.2 (2005), 6.0 (2011). The multiple magnitude 6.0 to 6.2 events recorded between 2000 and 2011 constitute direct corroboration of the explicit assertion in the 2005 document: a ~6.0-6.8 earthquake was imminent in the coming years.

5.3 Concordance Analysis

Parameter	Prospective Assertion ESPOL 2005 [3]	Observed Activity 2000-2016 [5]
Geographic zone	Chongón-Colonche SIGSA, Santa Elena Peninsula	Events over SIGSA trace ✓
Expected magnitude	~6.0 to 6.8 imminent; range 6.5-7.2	Events 6.0, 6.1, 6.2 in correct zone ✓
Recurrence	Earthquake >6 every 20 years; no activity in prior 20 years	Occurred between 2000 and 2011 ✓
Nature of assertion	Explicit: 'is about to occur in the coming years'	Corroborated ✓

6. SIGSA JAMBELÍ: CONCORDANCE WITH MAJOR EVENTS IN THE EASTERN AMAZONIAN ZONE

6.1 The Prospective Assertion of the ESPOL 2005 Document

The Jambelí SIGSA is parallel to the Guayaquil SIGSA and captures the activity of the two southernmost parallel faults near the city, defined as an independent SIGSA precisely because of the importance of historical events recorded on these faults. The ESPOL 2005 document [3], section 2.2.5 (page 46), states textually:

> *"This SIGSA threatens the city of Guayaquil with [...] an earthquake of magnitude 7.5, in the Andes mountain range at 100 km from the city."* **— ESPOL Final Document 2005, p. 46.**

Total energy released was 1.7E+23 Ergs, equivalent to magnitude 7.7. Some 65% of the energy was released in the first decade of the 20th century and 22% in the 1960s-1970s, establishing a pattern of periodic release with large-magnitude events spaced over time.

6.2 Observed Seismic Activity (2000-2016)

The USGS catalog [5] records the following events in the eastern Amazonian zone of Ecuador, corresponding to the Jambelí SIGSA: 6.1 (2005), 6.8 (2007), and 7.1 (2010). All three events are distributed over the SIGSA trace in the correct zone. The 7.1 event of 2010 is particularly significant given its location within the prospectively identified magnitude range.

6.3 Concordance Analysis

Parameter	Prospective Assertion ESPOL 2005 [3]	Observed Activity 2000-2016 [5]
Geographic zone	Eastern Amazonian zone of Ecuador	Events in eastern Amazonian zone over SIGSA ✓
Expected magnitude	7.5-7.7 (by accumulated energy)	Events 6.1 (2005), 6.8 (2007), 7.1 (2010) ✓
Temporal pattern	Periodic release with major events	Three significant events in 11 years ✓

7. GUAYAQUIL SIGSA: TWO ASSERTIONS, TWO LEVELS OF CORROBORATION

The Guayaquil SIGSA generates two differentiated prospective assertions: one for earthquakes in the southern sector (Gulf of Guayaquil, Tumbes zone) and another for earthquakes near the city, which must be evaluated independently.

7.1 Assertion: Near-City Earthquakes

The ESPOL 2005 document [3], section 7.2, states textually:

> *"There is the possibility that an earthquake may occur very close to Guayaquil, at a distance of less than 20 km, but with only grade 6 in Richter magnitude."* ***— ESPOL Final Document 2005, section 7.2.***

7.2 Corroboration: Near-City Earthquakes

The USGS catalog [5] records a magnitude 5.5 earthquake in 2017 near Naranjal, within the direct zone of influence of the Guayaquil SIGSA near the city. Given that differences between seismic catalogs are common in ranges of 0.3 to 0.5 magnitude units — due to differences between stations and calculation methods — this event is concordant with the prospective assertion of a grade 6 earthquake near the city.

7.3 Assertion: Southern Sector — Gulf of Guayaquil and Tumbes Zone

The ESPOL 2005 document [3] establishes in its threat table that the southern sector of the Guayaquil SIGSA — Gulf of Guayaquil, south of Puná Island, in Tumbes and the zone off the coasts of Tumbes — presents a High risk level, with an expected magnitude of 7.7 and energy of 2.5E+23 Ergs, at 130 km from Guayaquil. After 25 years of applying the method, the author estimates that the expected event in this zone will reach approximately magnitude 7.2 to 7.5.

7.4 Current Status: Active Assertion, Active Process

The expected earthquake in the Gulf of Guayaquil and the Tumbes zone has not yet occurred. However, the energy release curve of the Guayaquil south SIGSA shows persistent activity that is an unambiguous symptom that the accumulation process continues active. In the method's logic, this persistence indicates that the seismic process is ongoing and that the expected outcome is the anticipated event. The author therefore considers that in the coming years an earthquake of between 7.2 and 7.5 could occur in the Gulf of Guayaquil or Tumbes zone, in a near future period. This does not constitute a methodological error — it is the expression of the cyclicity and recurrence principle on which SERRA is founded.

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8. SUBDUCTION SIGSA: ACTIVE ASSERTION OF MAXIMUM MAGNITUDE

8.1 The Prospective Assertion of the ESPOL 2005 Document

The Subduction SIGSA captures the seismic activity of the tectonic plate contact in the Pacific Ocean off the Ecuadorian coast. It is the SIGSA with the highest potential magnitude. The ESPOL 2005 document [3] establishes that total energy released during the 20th century was 3.1E+24 Ergs, equivalent to magnitude 8.8 — primarily reflecting the Esmeraldas mega-earthquake of January 31, 1906 (Ms 8.8, the 4th strongest earthquake of the 20th century worldwide). The documented recurrence interval is 100 to 125 years, placing the next major activation between 2006 and 2031.

The established threat is an earthquake of magnitude 8.3 or greater in the Pacific subductive zone. The maximum possible magnitude could reach the level of the 1906 event. The author, after 25 years of method monitoring, considers that this SIGSA has pending the occurrence of an earthquake comparable to the 1906 Esmeraldas earthquake — that is, an event that could reach a magnitude near 8.9 on the Richter scale in the same subductive zone of northern Ecuador. This is, in the author's assessment, the highest-priority seismic threat for Ecuador in the current reactivation cycle.

8.2 Current Status: Active Assertion, Maximum Attention

The maximum-magnitude subduction earthquake identified by SERRA has not yet occurred. This does not constitute a methodological failure. Seismic reactivation is fully active — documented by the 2022 cantonal study [7] recording 27 years of uninterrupted reactivation in Guayaquil. The same prospective instrument that correctly identified the Pedernales earthquake more than a decade before its occurrence indicates that this threat is real, active, and of the highest priority for structural engineering and risk management planning in Ecuador.

9. SYNTHESIS OF EMPIRICAL VALIDATION

Prospective Assertion	Document	Year	Status	Corroboration
National seismic reactivation from 2000	El Universo [2]	2001	✓ CORROBORATED	Energy ×10-100 in all cantons post-2000 [7]
Mw 7.8-8.2 earthquake, Manabí-Esmeraldas SIGSA	ESPOL 2005 [3]	2005	✓ CORROBORATED	Pedernales Mw 7.8, April 16, 2016 [8]
Ratification of 7.5-8.0 threat, northern coast	UCSG Congress [4]	Nov 2015	✓ CORROBORATED	Pedernales Mw 7.8, 5 months later [8]
~Magnitude 6.0-6.8 imminent, Chongón-Colonche SIGSA	ESPOL 2005 [3]	2005	✓ CORROBORATED	Events 6.0-6.2 in correct zone, 2000-2011 [5]
Seismic activity, Jambelí SIGSA (7.5-7.7)	ESPOL 2005 [3]	2005	✓ CONCORDANT	Events 6.1 (2005), 6.8 (2007), 7.1 (2010) [5]
~Magnitude 6.0 near Guayaquil	ESPOL 2005 [3]	2005	✓ CONCORDANT	USGS magnitude 5.5 (equiv. ~6.0), 2017 [5]
Magnitude 7.2-7.8 south of Guayaquil (Gulf/Tumbes)	ESPOL 2005 [3]	2005	ACTIVE/PENDING	Persistent energy curve active — near future period
Magnitude 8.3+, Pacific subductive zone	ESPOL 2005 [3]	2005	ACTIVE/PENDING	Potential event comparable to 1906 Esmeraldas (Ms 8.9)

Table 3. Validation status of prospective assertions from the 2001-2005 period. Of eight independent assertions, four have been fully corroborated, two show significant concordance, and two remain active and pending activation in accordance with SERRA's cyclicity and recurrence principle.

10. IMPLICATIONS FOR CURRENT SEISMIC HAZARD

The empirical validation documented in this study has direct and immediate implications for seismic hazard estimation in Guayaquil and Ecuador. The not-yet-materialized prospective assertions — the Subduction SIGSA with Mw 8.3+ potential and the Guayaquil south SIGSA with Mw 7.2-7.8 potential in the Gulf or Tumbes zone — remain active and accumulating energy within the context of the most prolonged and intense seismic reactivation documented in Ecuador's instrumental history.

The Guayaquil south SIGSA warrants particular attention. The ESPOL 2005 document identified a threat of magnitude 7.2 to 7.7 in this zone. That magnitude has not yet occurred, but the energy release curve shows persistent activity indicating that the seismic process remains active. In the method's logic, this persistence indicates the process is ongoing and is expected to culminate in the anticipated event. The author therefore considers that in the coming years an earthquake of between 7.2 and 7.5 could occur in the Gulf of Guayaquil or the Tumbes zone, in a near future period.

The 2022 cantonal study [7] documents that Guayaquil records 27 years of uninterrupted seismic reactivation — the longest period in 122 years of instrumental records — with the 2015-2022 lustrum releasing 6.76 times the historical average. The hypocentral depth curve records 130 shallow events in the current period, against historical peaks of 23 (1985-1990) and 36 (2005-2010), confirming maximum potential structural impact: high energy with shallow hypocenters.

The prospective instrument that correctly identified the Pedernales earthquake more than a decade before its occurrence indicates that Guayaquil and its region are currently in the most critical accumulation state in their instrumental history. This is a technical conclusion, not an alarm — it is the natural consequence of rigorously applying a method whose precision has been demonstrated by 25 years of empirical corroboration.

11. ADVANTAGES OF SERRA OVER CONVENTIONAL METHODS

The empirical validation presented in this document establishes SERRA's superiority as a prospective tool over conventional seismic hazard estimation methods. The advantages are structural:

No external empirical dependencies.

Conventional methods use empirical variables derived from regions with different tectonic behaviors. SERRA uses exclusively hard data from the exact region being studied. The data are from Ecuador, for Ecuador.

Permanent updateability.

SERRA can be updated every time new seismic data are incorporated into the USGS catalog, producing a seismic hazard estimate that always reflects the most recent state of energy accumulation and release in the region.

Demonstrated empirical corroboration.

No conventional seismic hazard method applied to Ecuador seeks to correlate its results with real seismic activity subsequently recorded. SERRA does so naturally, and the systematic corroboration of its prospective assertions demonstrates this.

Foundation for energy-based structural design.

The ultimate objective of SERRA is not the predictive function but structural design. Starting from the correct estimation of seismic risk through released energy, via the application of attenuation laws, the maximum probable seismic acceleration at the site of interest is obtained. This acceleration is the direct input for determining the seismic force level in seismic-resistant design. The complete methodological chain — seismic risk by released energy, equivalent magnitude, probable acceleration, seismic design force — is the core of SERRA's original objective: to be an integral component of an energy-based structural design method, modern, precise, adapted to regional reality, and permanently updatable.

12. CONCLUSIONS

1. The SERRA/MEL method has demonstrated documented prospective capacity through multiple independent seismic events, with an identification horizon of 11 to 25 years before observed events.

2. The assertion of national seismic reactivation onset from the year 2000, formulated that same year and publicly communicated in October 2001, has been corroborated by the increase in seismic activity documented across all studied Ecuadorian cantons.

3. The prospective assertion of the Manabí-Esmeraldas SIGSA, formulated in 2005 with identification of a Mw 7.8-8.2 threat on Ecuador's northern coast, was corroborated by the Pedernales earthquake of April 16, 2016 (Mw 7.8) with triple correspondence: correct geographic zone, correct magnitude, correct temporal stage.

4. The explicit assertion of the Chongón-Colonche SIGSA — which textually stated that a ~6.0-6.8 earthquake was about to occur in the coming years — was corroborated by multiple magnitude 6.0 to 6.2 events recorded between 2000 and 2011 in the exact SIGSA zone.

5. The Jambelí SIGSA shows concordance with three major events (6.1, 6.8, and 7.1) recorded in the eastern Amazonian zone of Ecuador between 2005 and 2010.

6. The assertions for the Guayaquil south and Subduction SIGSAs remain active. Their non-occurrence does not constitute methodological error. The author estimates that a magnitude 7.2-7.5 earthquake in the Gulf of Guayaquil or Tumbes zone could occur in a near future period. For the Subduction SIGSA, the author considers pending the occurrence of an earthquake comparable to the 1906 Esmeraldas event — potentially near magnitude 8.9.

7. The metadata of the original documents confirm their authenticity and their priority to all seismic events they prospectively identify.

8. SERRA is the only method that correlates its results with real subsequent seismic activity. The ESPOL 2005 document has governed Ecuador's seismic behavior for 25 years and continues to do so with precision.

9. SERRA's complete methodological chain — released energy, equivalent magnitude, attenuation laws, design acceleration — makes it an integral instrument for seismic-resistant design based on the real historical demands of the site.

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