Operational Earthquake Forecasting in Japan: A Study of Municipal Government Planning for an Earthquake Advisory or Warning in the Nankai Region

A Collaborative Project of the Disaster Prevention Research institute, Kyoto University and the Natural Hazards Center, University of Colorado, Boulder

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A Report to the US-Japan Foundation and the Japan Society for the Promotion of Science

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Abstract

A team of social scientists from the US and Japan have conducted a study exploring the extent to which municipal governments in Japan including prefectures, cities, towns and villages have developed plans for response to an operational earthquake forecast (OEF) from the Japan Meteorological Agency (JMA) indicating that seismic activity in the Nankai Trough region has elevated the short-term probability that a major and possibly tsunami-genic earthquake may occur. Employing both survey research and in-depth interviews, our team explored various aspects of the science behind the alerting system, guidance from the national government of Japan, planning by local jurisdictions and other aspects of the planning environment focused on a possible future Nankai Trough major earthquake. The survey included questions regarding actual planning actions that might have been included in a response plan for receipt of "special earthquake warning information (SEWI)" as well as questions regarding challenges in the planning process, expectations that an earthquake would follow the issuance of an alert and whether planning would reduce the number of fatalities and injuries if the earthquake occurs during the alerting period. We also conducted in-depth interviews that explored the scientific basis for the alerting system, sought insights from those who had conducted previous studies of local planning and asked working disaster managers in the Nankai region what they had done to plan and if plans had not been developed, the reasons for not planning. Our survey netted 469 responses from a total of 736 jurisdictions included by the Japanese government in the Nankai region, both prefectures and municipal governments, a response rate of 63%. We conducted a total of 17 in-depth interviews. In general, we found that a majority of jurisdictions have response plans for receipt of an alert from the JMA; however, the plans lacked a number of planning elements considered important from a disaster management perspective. In addition, many smaller jurisdictions lacked the staffing, resources and guidance to form comprehensive response plans. Our report identifies both the strengths and weaknesses of existing plans and outlines a program for improving planning in the region.

Key Words: Operational earthquake forecasting, Nankai region, municipal government, special earthquake warning information (SEWI)

I. Introduction

At first glance, one might point to the catastrophic March 11, 2011 Great East Japan Earthquake and Tsunami which caused 18,000 fatalities and a major nuclear accident at Fukushima and conclude that the current effort to identify precursory seismic activity in advance of a possible similar event in the Nankai region is a direct result of the 2011 catastrophe. But this conclusion would fail to consider the history of scientific efforts to forecast major earthquake events in Japan which date back to the mid-1970's. It was during the decade of the 1970's that optimism emerged that scientists would soon predict earthquakes, that is, issue statements on a routine basis identifying the time, location, and magnitude of a future earthquake with a relatively high level of accuracy. This optimism stemmed to a large degree from an apparent successful intermediate and short-term prediction in China for a magnitude 7.3 earthquake that struck the Haicheng area (Liaoning Province) on February 4, 1975. The Haicheng earthquake prediction was the first successful scientific forecast that was followed by an evacuation of residential buildings credited with saving thousands of lives. Subsequent earthquake prediction failures in China and elsewhere dampened but failed to extinguish attempts to forecast future earthquake occurrences (Bolt, 2006; Hough, 2016)

In Japan, an early attempt to predict an earthquake focused on the Tokai region. The region has a long history of major earthquakes the most recent of which are the 1707 Hoei magnitude 8.6 event and two earthquakes in 1854, the Ansei Tokai and Ansei Nankai earthquakes, both magnitude 8.4 events which occurred 32 hours apart (Matsu'ura, 2017). Based on the history of large magnitude earthquakes in the Tokai region, seismologists placed the average recurrence interval at approximately 120 years. Thus, the Tokai region, an area of central Japan along the Pacific Coast between Nagoya and Tokyo, became the focal area for prediction of a major earthquake. The scientific effort to accurately predict the next Tokai earthquake was accompanied by legislation identifying how the national government would respond should precursory seismic activity warrant a short-term warning for the region (Rikitake, 1979).

The Large-Scale Earthquake Countermeasures Act of 1978 passed during the 84th session of the Japanese Diet in June 1978 and was enacted in December of the same year. The Act has as its objective the mitigation of earthquake hazards in the Tokai region (Rikitake, 1979) which was to be designated "an area under intense measures against earthquake disaster" (p. 553). These measures included a dense monitoring network including sea bottom seismographs, tiltmeters, volume strainmeters, tide gauges, and instruments for monitoring groundwater level and radon contents. If this network revealed anomalies believed to be consistent with the imminent occurrence of a major earthquake, as assessed by the Prediction Council (a suborganization of the Coordinating Committee for Earthquake Prediction), a warning would be conveyed to the Prime Minister via the Director General of the JMA. Upon receiving such a warning, the Prime Minister could exercise emergency powers granted by the Countermeasures Act to initiate actions that would mitigate the hazards that a major earthquake in this heavily populated region would pose (Goltz and Roeloffs, 2020).

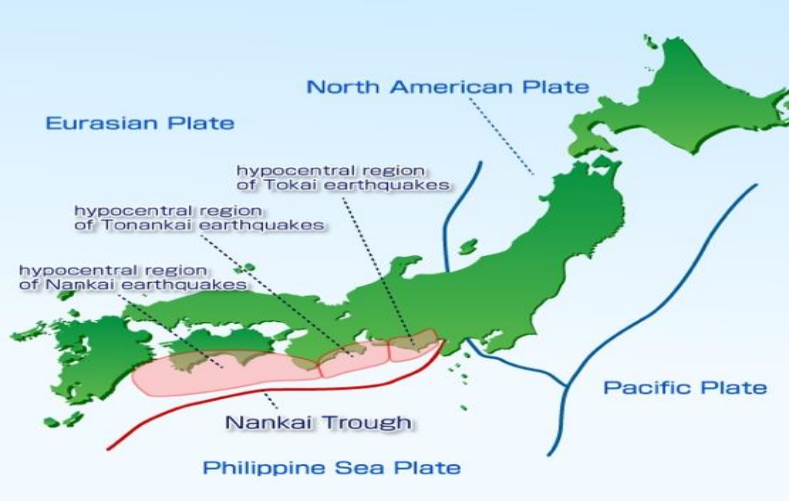
These actions included the creation of a Central Disaster Prevention Council that would be chaired by the Prime Minister and formulate a basic response plan for the period of the warning, which though unspecified in the legislation, was "short-term" encompassing "several hours to a few days" (Rikitake, 1979, p.555). Also mandated to develop response plans were prefectures, municipal governments and organizations of the private sector including hospitals, bus and rail transportation companies, refineries, hotels and department stores. The Countermeasures Act gave the Prime Minister emergency powers that included mobilization of the Self Defense Forces and their deployment in the region prior to the predicted earthquake. Emergency powers were also extended to prefectural and municipal governments allowing them to order suspensions of rail and oil refinery operations, regulate highway traffic and utilize privately held resources for emergency use. In the ensuing 43 years since the act was implemented, an earthquake emergency that would have caused these measures to be invoked has not occurred.

The spirit of optimism regarding earthquake prediction was not universally shared among seismologists of the time and the Large-Scale Earthquake Countermeasures Act, with its assumed high probability that precursory seismic activity would be followed by a major earthquake and the extensive interventions it facilitated, were controversial from the beginning. An editorial in the Japan Times (2016) that examined the history of the act and the controversy that followed recalled that the National Land Agency which at the time the Countermeasures Act was passed had responsibility for disaster prevention, was reluctant to implement the law due to a lack of scientific consensus that accurate short-term predictions could be made with confidence, certainly with the confidence implied in the Act. The most outspoken critic of the Act and the Tokai prediction has been seismologist Robert Geller, of Tokyo University who in an April 2011 issue of Nature argued "it is time to tell the public frankly that earthquakes cannot be predicted, to scrap the Tokai prediction system and to repeal the LECA (Large-Scale Earthquake Countermeasures Act)" (Geller, 2011, p. 409). Geller further argued that the characteristic earthquake model and the seismic gap hypothesis that were the basis for the prediction had failed to identify the source zones of most large earthquakes that had occurred after the Act was passed, including the Great East Japan Earthquake of March 2011 which was regarded as having a low probability of generating a huge tsunami-genic earthquake (Geller, 2011).

Criticism of the Countermeasures Act, including intense scientific criticism, did not result in revision or repeal of the legislation, though growing concern about the hazard posed along the entire length of the subduction zone (Japan Trough) off the Pacific Coast of Japan increased after 2000. In 2002 the Japanese Diet passed the Act on Special Measures for Promotion of Tonankai and Nankai Earthquake Disaster Management (see Figure 1 for this region) a law that gave the Prime Minister the power to designate "countermeasures promotion areas" within which disaster prevention measures must be implemented including mandating the development of earthquake disaster response plans by local governments in the extended region due to significant risk of major earthquakes in the Tonankai and Nankai regions (Umeda, 2013; Japan Times, 2017). Acknowledging the scientific inability to make high probability forecasts, additional legislation and public policy required enhanced seismic monitoring in these regions, but set aside

the declarations and aggressive response measures contained in the Large-Scale Earthquake Countermeasures Act of 1978.

Figure 1: Tokai, Tonankai and Nankai Regions of the Nankai Trough



Source: Japan Agency for marine-Earth Science and technology
(https://www.jamstec.go.jp/donet/rendou/en/about/index.html)

The Great East Japan Earthquake and Tsunami of March 11, 2011, which occurred in the northern portion of the Japan Trough, reinforced an existing seismological assessment that the subduction zone along the entire length of the Pacific Coast of Japan presented a major risk of large magnitude tsunami-genic earthquakes. This risk assessment combined with an understanding that short-term high probability forecasts were not possible, created a dilemma for both scientists at the Japan Meteorological Agency (JMA) and local jurisdictions in the Nankai region where the long-term forecast for a major earthquake was estimated to be 70-80% in the next 30 years. It must be noted that the provisions and measures including the emergency powers available to the Prime Minister under the 1978 Act were never modified or suspended; however, it is unlikely that these powers and measures would be invoked based on potential precursory seismic activity in the Nankai region. In summary, we can conceptualize the current status of anticipating earthquake occurrences in Japan as a gradual transition from a bold earthquake prediction for a specific region to an extension of the zone of concern to the south of Tokai and a more nuanced and cautious approach to response to possible earthquake precursors. This approach is consistent with what seismologists now define as operational earthquake forecasting.

II. Operational Earthquake Forecasting (OEF) in Theory and Practice

While acknowledging that accurate short-term earthquake prediction is not possible based on current scientific understanding of the earthquake rupture process, a group of seismologists following the L'Aquila, Italy earthquake of April 6, 2009 convened an international commission to discuss how potentially precursory seismic activity could be handled from a public

risk communication perspective. That is, if earthquake activity such as earthquake swarms (the occurrence of small to moderate size earthquakes in a relatively confined space time window), somewhat larger earthquakes in areas known to have experienced large damaging earthquakes in the past or anomalous changes in measured crustal activity (e.g., slow slip events) occur, the probability of large earthquakes may increase over a short period of a few days. As explained by seismologist Thomas Jordan, "the probability of large earthquakes in a region known to be seismically active is not constant, but varies over time based on the occurrence of seismic activity in that region" (Jordan et al., 2014, p. 955). Thus, operational earthquake forecasting has been defined as involving two key activities: "the continual updating of authoritative information about the future occurrence of potentially damaging earthquakes, and the officially sanctioned dissemination of this information to enhance earthquake preparedness in threatened communities" (Jordan et al., 2011). OEF can be examined from the standpoints of both science and practice.

From a scientific perspective, proponents of OEF distinguish between a prediction as "a deterministic statement that a future earthquake will or will not occur in a particular geographic region, time window, and magnitude range" from a forecast which "gives a probability (greater than zero but less than one) that such an event will occur" (Jordan, et al., 2011, p. 319). These authors further note that over days and weeks, earthquake sequences show clustering in time and space, for example, the occurrence of aftershocks following large events. This clustering can be used to formulate forecasts that account for changing earthquake probabilities in the short-term. While the value of long-term forecasting for seismic safety is well established, short-term forecasts are problematic in that earthquake probabilities "may vary over orders of magnitude, but (are) typically low in an absolute sense (<1% per day)" (op cit., p.319). There are many phenomena that have been proposed as precursory to earthquakes including earthquakes that later prove to be foreshocks to large events, slow slip events (episodic tremor and slip), strain rate, seismic velocity and electrical conductivity changes, radon emissions, electro-magnetic signals, thermal anomalies and even unusual animal behavior (Jordan et al., 2011). Models employed to forecast earthquakes also vary, but models based on earthquake clustering and statistical seismology seem to be the most robust at present (Jordan et al., 2011).

From a practical perspective, there has been a debate in the seismological literature (Jordan, 2013; Jordan et al., 2014; Wang and Rogers; 2015) about whether changes in regional seismic activity, including measured changes in the absence of earthquakes, justify public announcements of enhanced short term seismic risk. This debate has centered around three basic questions: can large earthquakes be forecast with short term probabilities high enough to be useful in promoting seismic safety; how can forecasts be used by government entities to promote seismic safety; and, how best to communicate information on short-term enhanced seismic risk to the public? (Jordan et al., 2010). Critics contend that the probabilities, in the short-term of a few days, are too low for serious levels of hazard mitigation (e.g., vacating seismically vulnerable structures), that OEFs should not be employed by governmental agencies except as aftershock forecasts and that the risk of adverse public reactions do not justify releasing forecasts to the public (Wang and Rogers, 2015).

Proponents of OEF have responded to this critique first by noting that short-term forecasts are not intended to be stand alone products, but one component for guiding mitigation actions based on scientific information regarding earthquake risk. More specifically, OEF critics have focused on more costly and aggressive measures like evacuating vulnerable structures as tests of OEF usefulness, when a range of far less disruptive measures that would potentially save lives and prevent serious property damage are available to disaster planners. OEF proponents respond to critic's concern with adverse societal response to short-term low probability forecasts as reflecting a poor understanding of human behavior in crisis. Proponents cite social science research indicating that people in hazard situations do not panic, but respond in a rational and adaptive manner (Clarke, 2002). Jordan et al. (2014) note that a conceit among disaster experts (and we would add some government officials) is that people fail to understand and will misinterpret probabilistic forecasts; however, social science research has shown that people in response to hazard warnings need, and will seek out consistent, authoritative information on potential hazards (Mileti and DeRoeum, 1995). This information from reliable and authoritative sources will prevent an information vacuum allowing rumor and amateur predictions to prevail (Jordan and Jones, 2010). Proponents of OEF also reject critic's assumptions that scientists who conduct earthquake hazard analyses should be the arbiters of thresholds for hazard forecasts, recognizing that those who receive alerts have different thresholds for notification and acting on hazard warnings (Jordan et al., 2014).

In demonstrating the type and level of actions that are warranted under a low probability and high consequence earthquake forecast, Field and colleagues (2015) identified a number of actions that are useful preparedness measures that are relatively low cost and minimally disruptive. Building on social science research (Mileti and Peek, 2002) that identifies periods of enhanced hazard potential as teachable moments for preparedness and response readiness, these authors recommend that organizations engaged in earthquake education re-emphasize measures like having an emergency supply of water and food, having a family emergency plan, reviewing safety strategies during the shaking, securing heavy household furnishings and spending less time in potentially vulnerable buildings. Organizations with relatively low warning thresholds like hospitals, utilities, transportation lifelines and emergency services can review emergency plans, cancel leaves, open emergency operations centers and hold drills and exercises during the warning period. Given that our principal interest in this study is in local government actions in response to an advisory or warning for a major tsunami-genic earthquake in the Nankai Trough, we were eager to know whether actions including evacuation of vulnerable people in tsunami zones, the identification of safe evacuation sites, establishment of shelter sites, provisioning of those shelters, having a plan to communicate with residents during a forecast and other measures had been implemented.

III. OEF in the Nankai Region: Our Study Objectives

Operational earthquake forecasting, despite being relatively new as a scientific concept has been implemented in practice in several countries including the US (Roeloffs and Goltz, 2017, Goltz, 2015, Bakun et al., 1987), Italy (Marzocchi et al.,2014), New Zealand (Gerstenberger et al., 2014) and other seismically active nations. It has now been implemented in Japan. As in other

nations in which OEF programs are in operation, the program in Japan is not explicitly labeled as OEF, but the program that exists in the Nankai region and, as of December 2022, on the entire Pacific Coast of Japan is clearly an OEF program. Cabinet Office (Government of Japan) White Papers in 2015 and 2019 outlined the program, identified the Nankai region which extends from Suruga Bay (Shizuoka Prefecture) to the northeast facing area of Kyushu Island, as the region at highest risk of large potentially tsunami-genic earthquakes. The region includes 707 municipal governments (cities, towns and villages) located in 29 prefectures (Cabinet Office, 2015). These jurisdictions were defined as those that would be subject to 6- shaking intensities on the Japan Meteorological Agency's intensity scale (See Figure 2). A total of 139 jurisdictions (See Figure 3) were identified as being at risk of both strong earthquake shaking and a tsunami of 30 centimeters or more that would arrive within 30 minutes of a major earthquake (Areas of Special Reinforcement of Nankai Earthquake Tsunami Evacuation Measures).

Figure 2: Map of Maximum Intensity Distribution in the Nankai Region

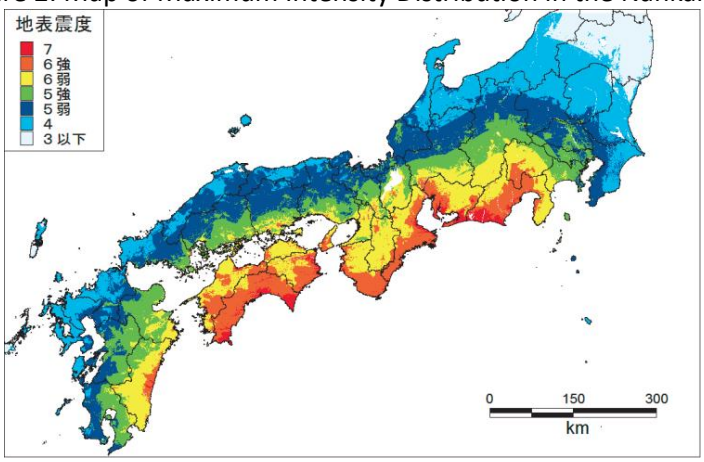
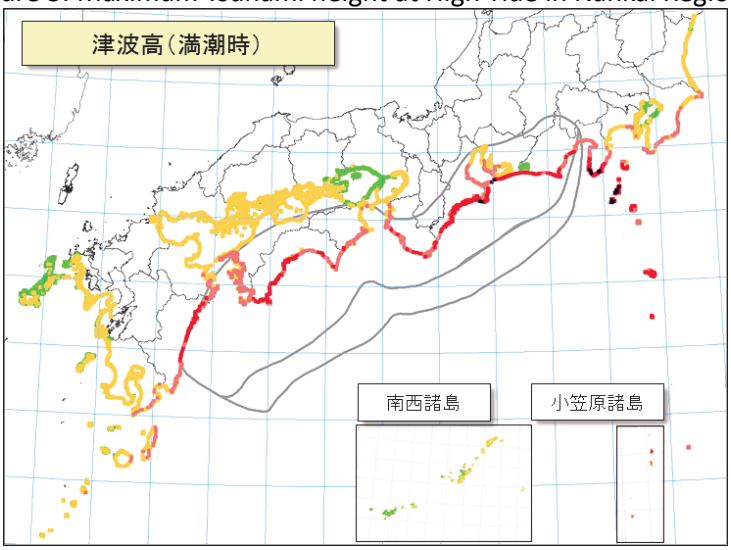


Figure 3: Maximum Tsunami height at High Tide in Nankai Region



Source: Cabinet Office, Government of Japan, White Paper: Disaster Management in Japan 2015

Once established as the region of greatest concern for a major earthquake and tsunami, the Nankai Megaquake Countermeasures Working Group, set up in 2012 within the Central Disaster Management Council, developed estimates of the impact of a very large tsunami-genic earthquake. The estimates (published in May 2013), depending on the location of the earthquake in the Nankai Trough, would claim between 32,000 and 323,000 lives, destroy between 940,000 and 2,386,000 structures and cause JPY169.5 trillion in direct losses (See Tables 1 and 2). Following the release of the various reports on the seismic potential in the Nankai Trough including the impact estimates in 2013, the Special Measures Act for Tonankai and Nankai Earthquakes (Act No. 92 of 2002) was amended to advance comprehensive earthquake disaster risk reduction actions that addressed response to an earthquake and tsunami.

Table 1: Estimate of fatalities and Damage to Structures (August 2012)

	Number of Structures Destroyed and/or Burned Down	Fatalities
If major damage sustained in the Tokai Region	954,000-2.382,000	80,000-323,000
If major damage sustained in the Kinki Region	951,000-2,371,000	50,000-275,000
If major damage sustained in the Shikoku Region	940,000-2,364,000	32,000-226,000
If major damage sustained in the Kyushu Region	965,000-2,386,000	32,000-229

Source: Cabinet Office, Government of Japan, White Paper 2015, Disaster Management in Japan

Table 2: Estimates of Economic Impact (March, 2013)

Damage to Assets (Affected Regions)	Estimated Value of Damage
• Total Losses • Private Sector • Quasi-Public Sector (Electricity, Gas, Telecommunications and Railways) Public Sector	JPY169.5 trillion JPY148.4 trillion JPY 0.9 trillion JPY 20.2 trillion
• Impact on Economic Activity (All of Japan) • Due to Lower Production/Service levels. Due to Disrupted Transportation/Road and Railway	JPY44.7 trillion JPY6.1 trillion

Source: Cabinet Office, Government of Japan, White Paper 2015, Disaster Management in Japan

Having laid the legislative groundwork for comprehensive response planning for a major Nankai Trough earthquake and tsunami, the Cabinet Office in March 2018 established the Working Group on Disaster Risk Management for Anomalous Phenomena along the Nankai Trough (Cabinet Office, 2019). It was this working group that established what would become Japan's OEF system. Three scenarios were identified and described, that if they were to occur, the Japan Meteorological Agency (JMA) would convene a council of scientists to determine whether an alert will be sent to jurisdictions in the defined Nankai region warning them that the probability

of a major earthquake had increased for a period of a few days. These scenarios included a magnitude 8 class event, a "partial area rupture," deemed most likely in the eastern portion of the Nankai Trough. The occurrence of this scenario earthquake is estimated to occur once in 100 to 150 years and would represent a significant probability gain, that is, a follow-on similar or larger event is 100 times more likely than the normal background seismicity rate. The scenario is based on the two most historically recent major earthquakes in the region including the 1944 M_W 8.2 Tonankai earthquake and the 1946 Mw8.6 Nankai event. Previous major earthquakes (both Mw 8.6) in Tokai and Nankai occurred 32 hours apart in 1854.

Two additional scenarios were regarded as raising the short-term probability of a major earthquake and tsunami. The first is a magnitude 7 class event, a "limited area rupture" expected to occur in the region with a frequency of once in 15 years and represents a probability gain of "once in a few hundred times." (Cabinet Office, 2019, p. 56). A slow slip event as recorded on strainmeters may, after qualitative assessment and if regarded as anomalous, constitute the third scenario that could trigger an alert by the JMA to local jurisdictions in the region. Such events occurred in the days prior to the March 11, 2011 Great East Japan Earthquake and Tsunami. The three scenarios represent two levels of assumed risk. The magnitude 8 scenario would be a major damaging event whether or not a follow on "twin earthquake" were to occur and in addition to triggering a major response effort and would prompt a "major earthquake warning" for adjacent regions within the Nankai Trough. Magnitude 7 class earthquakes ("limited area rupture") or slow slip events are expected to occur more frequently and, in the case of the earthquake, cause far less damage. These scenario events would be evaluated by the JMA and, if deemed precursory to a much larger earthquake, an earthquake advisory would be announced.

The scenarios determine the actions recommended by the Cabinet Office which differ for a warning and advisory. First, we should point out the protocol to be followed upon the occurrence of any of these scenario events. The JMA will evaluate the occurrence of an earthquake or measured seismic activity that conforms to one or more of the scenarios and report to the national government within 2 hours; the national government will provide instructions to prefectural and municipal governments in the designated Nankai region on disaster management actions that should be taken during the period (one week) in which the major earthquake risk has increased; and, if during the week-long period a major earthquake does not occur, local governments in the region are instructed to stand-down (evacuation is specifically mentioned), but encourages residents to remain alert. After scientists have assessed the situation and determined that the earthquake risk has increased based on one or more of the scenarios, and in consultation with the national government, the JMA will release an alert (either an advisory or warning) via a nationwide press conference. The national government will set up a disaster management headquarters and encourage prefectures and municipal governments to do the same. The most fundamental disaster management recommendation in the 2019 White Paper and elaborated in a 2022 White Paper is the evacuation and sheltering of vulnerable populations, both elderly residents and those with mobility limiting disabilities at the outset of an alert.

As a caveat in presenting recommended planning activities for local government (including residents) and business and industrial organizations, the Guidelines for Formulating Disaster Risk Management Measures Based on Various Nankai Trough Earthquake Scenarios (1st Edition) on March 29, 2019 caution that in planning, entities must seek a balance between the risk of an earthquake and the impact of disaster management measures on the maintenance of day-to-day life and business activities. And second, those encouraged to plan for "special earthquake warning information" are advised that accurate prediction of the timing of an earthquake is impossible, nor is it possible that disaster management measures will assure safety.

With these cautions stated, the guidelines provide the following recommended actions for a warning based on a partial area rupture (Mw8). Local governments with mapped tsunami inundation zones are advised to identify groups that because of age, disability or location (considering probable tsunami arrival time) would not be able to evacuate safely after the earthquake has occurred and plan for their evacuation upon issuance of a warning. Residents living in buildings with poor resistance to earthquake ground motion should also be advised to evacuate during the warning period. Shelter for these proactively evacuated residents must be considered in local government plans including the number of shelters needed, transportation of evacuees to these shelters and staffing and provisions for the shelters. After a week has transpired and a major earthquake has not occurred, a major earthquake advisory will be in effect for an additional 2-4 week period. For a major earthquake advisory, based on an earthquake of Mw7 or a slow slip event, local jurisdictions are advised to review earthquake preparedness and, if the advisory is based on an earthquake, consider proactive evacuations. An advisory based on an earthquake in the Mw 7 range will be in effect for a week after which residents should be advised to be alert for aftershocks while returning to normal activities. In an advisory based on a slow slip event, the period in which the advisory is in effect will vary and may extend beyond a week based on scientific assessments as to the length of the slip event.

Companies in the Nankai region are advised to develop plans to protect the safety of employees and customers in the event of a major earthquake and consider measures that would not imperil the lives of employees if facilities are located in a proactive evacuation area. They are also encouraged to inspect and mitigate damage likely to occur to equipment and facilities if a major earthquake and tsunami occur. Reasonable measures should be considered to avoid hazards during a warning (e.g., changing delivery routes, and in general, modifying activities that are otherwise routine that may imperil employees during a major earthquake warning). Companies in the Nankai region are also encouraged to cooperate with municipal government by assisting in community planning. For example, providing supplies to evacuation shelters. Utility and lifeline organizations are encouraged to anticipate service levels if a major earthquake (Mw8) occurs affecting their service areas. Advice associated with a major earthquake advisory for companies includes reviewing earthquake preparedness measures and disaster management consistent with the situation posed by the occurrence of the earthquake or slow slip event (Cabinet Office, Government of Japan, 2019, 2021)

Our research group considers these recommended measures for municipal government, corporations and residents to be reasonable and consistent with a low probability, high

consequence earthquake warning or advisory for the Nankai region. Based on operational earthquake forecast planning in other nations and the disaster management experience of the first author and principal investigator of this study, these recommended measures could be supplemented with additional activities to better prepare the region for receipt of a major earthquake warning or advisory. The focus of our assessment is specifically local government; business and industry are important stakeholders, but their planning needs are outside the scope of this study. We would add to those recommendations of the Cabinet Office and the various disaster management councils that have provided guidance to local government: provisions for ongoing warning/advisory period communication between local government and residents; a program in which home preparedness is emphasized; close coordination between local government and the prefecture in which the city, town or village is located including coordination with community based groups and volunteers; and, implementation of drills and exercises, particularly exercises involving evacuation and sheltering plans. Thus, the objective of this assessment is to determine whether our sample jurisdictions in the Nankai region have OEF plans and the measures existing plans contain. We also wish to discover the concerns local disaster managers have in planning for receipt of special earthquake warning information including their views on the likelihood that an earthquake will follow a warning or advisory and whether planning will save lives and avoid major property damage.

IV. Methods of Study

The study employed multiple methods in this assessment of local government organizational response to possible receipt of a short-term earthquake advisory or warning from the Japan Meteorological Agency. We reviewed documents published by the Japanese government explaining the underlying scientific basis for the forecasting system and accompanying recommendations regarding possible actions that could be taken by affected local jurisdictions and businesses and industries if an alert is issued. We also examined previous assessments of response options and challenges in responding to a possible alert conducted by news organizations.

The centerpiece of our assessment was a survey with questions assembled by the study team and administered by the Survey Research Center Company LTD based in Tokyo. The survey questions (See Appendix A) explored a range of issues associated with prefectural and municipal response to a low probability, high consequence alert which included: whether governments had, or had not, developed plans; concerns and issues encountered in developing plans; the type and level of support from higher levels of government needed for effective planning; assessments of the efficacy of planning (i.e., whether planning would save lives and protect property); sources of planning assistance; and, a battery of specific planning actions that included proactive evacuation of vulnerable people, promotion of preparedness actions by residents, provisions for public information during an alert, cooperative actions involving various segments of the community (e.g., with community-based groups, businesses, other levels of government etc.), internal procedures for mobilizing within the government itself, measures to curtail social and economic activities in the interests of public safety and provisions for canceling an alert that was not followed by an earthquake. The survey questionnaire was emailed to 736 municipal government

organizations (29 prefectures and 707 municipal governments) identified by the national government as at risk of a major earthquake and possible tsunami, targeting the agency within jurisdictions responsible for planning (typically a disaster management department or section). We received 469 responses, a return rate of 63.7% and the sample was generally representative of the jurisdictions in terms of population and jurisdiction size. See Table 3 below. Figures 4 and

Table 3: Survey Sample and Total Nankai Region by Jurisdiction Population

		Region Total	Sample Total	% Total Population
Valid	Prefectures	29	23	79.3
	Over 500,000	14	10	71.4
	200,000 - 499,999	41	28	68.3
	50,000 - 199,999	182	124	68.1
	15,000 - 49,999	236	153	64.8
	8,000 - 14,999	78	48	61.5
	5,000 - 7,999	64	37	57.8
	Up to 4,000	92	46	50.0
	Total	736	469	63.7

5 identify the jurisdictions included by the national government in the designated Nankai Region. Figure 4 identifies those municipal governments with a significant risk of tsunami in a major earthquake. Figure 5 includes all jurisdictions likely to experience 6- intensities on the JMA intensity scale that includes 9 intensities with 7 being the strongest.

Figure 4: Jurisdictions at risk of Tsunami

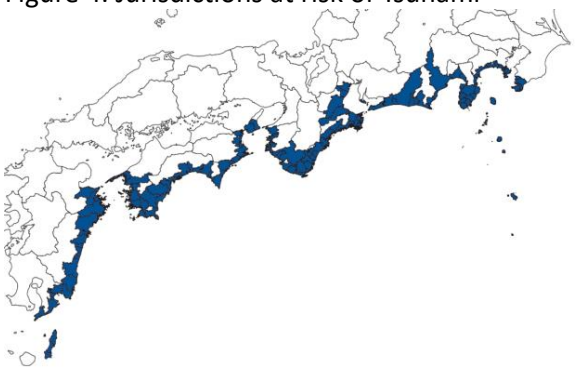
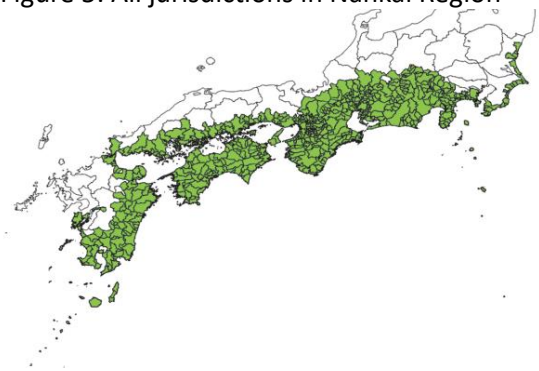


Figure 5: All jurisdictions in Nankai Region



Source: Cabinet Office, Government of Japan, White Paper, Disaster Management in Japan

Our survey was supplemented by 17 in-depth interviews with scientists (primarily seismologists with the JMA and universities), journalists who had reported on and, in some cases conducted their own studies of planning, and disaster managers responsible for earthquake planning. The purpose of these interviews was to better understand the rationale for setting up the forecasting system, identify and expand our understanding of how local governments assessed the need for planning and explore any special circumstances or contingencies that

existed for individual local governments. In some cases, the interviews were conducted in English though most were in Japanese and translated for the American on the study team. All were conducted via video conference and were of approximately one hour in duration. There was no set format as the questions varied depending on whether a scientist, journalist or disaster manager was being interviewed.

Survey data analysis employed SPSS Version 29 to carry out basic frequency counts and non-parametric statistics for variables that were a combination of nominal, ordinal and continuous levels of measurement. The unit of analysis was local government based on questionnaires completed by disaster management officials who represented sample jurisdictions. The in-depth interviews conducted among municipal disaster managers included questions designed to probe more deeply issues raised in the survey questionnaire or pursue trends that were unanticipated at the outset of the study. In general, the in-depth interviews deepened our understanding of disaster management issues, clarified scientific assumptions behind the forecasting systems and, in the discussions with journalists, provided an outside perspective which perhaps better reflected the views of the general public regarding the hazards posed by earthquakes in Japan. The insights gained in these interviews will be reported as paraphrased statements rather than direct quotes; the interviews were conducted mainly in Japanese and translated into English by members of the research team.

V. Findings

Factors Associated with Having a Plan

At the most basic level of our assessment, 84.4% of all jurisdictions in our survey sample of 469 jurisdictions reported having plans for receipt of an earthquake alert from the JMA and 15.6% indicated that they had no plan. This distinction marks a starting point for additional analyses which consider the characteristics of jurisdictions with and without plans. Additional questions probed other factors that may influence planning including: jurisdiction type (prefecture, city, town or village), size (population), having a separate disaster management department and the size of the department, geographic distance from the likely source of the earthquake, having tsunami inundation zones within their borders, challenges faced in developing a plan and respondent assessment of the efficacy of planning. We examined each of these potential factors quantitatively examining basic frequency counts and the non-parametric statistic Pearson Chi Square. We supplemented or survey findings with information from our in-depth interviews.

<u>Jurisdiction Type</u>

We first examined planning for an alert from the JMA by jurisdiction type. There was a significant difference (Chi Square<.001) in planning between cities and prefectures on one hand and towns and villages on the other. Towns and villages were less likely than cities and prefectural governments to report having plans for response to receipt of an advisory or warning from the JMA for a major earthquake in the Nankai region. See Table 4 below.

Table 4: Planning by Jurisdiction Type

			Jurisdiction Type				
			City	Prefecture	Town	Village	Total
Plan for SEWI Info?	1 Yes	Count	226	23	131	16	396
		%	90.0%	100.0%	78.0%	59.3%	84.4%
	2 No	Count	25	0	37	11	73
		%	10.0%	0.0%	22.0%	40.7%	15.6%
Total		Count	251	23	168	27	469
		%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	28.594[a]	3	<.001
Likelihood Ratio	29.186	3	<.001
N of Valid Cases	469		

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is 3.58.

Population Size

A second test that overlaps jurisdiction type was to examine planning based on the population of jurisdictions, assuming that the differences detected based on jurisdiction type are a reflection of the size of the jurisdiction and thus the resources and personnel available to plan for receipt of an alert that the short-term risk of a large potentially tsunami-genic earthquake has increased. We found that population of the jurisdiction was significantly associated with the likelihood that a jurisdiction has planned for this contingency. We found that prefectures and larger jurisdictions were significantly (Chi Square<.001) more likely to have a plan than smaller jurisdictions with populations of 49,999 or fewer. See Table 5 below.

Table 5: Planning for SEWI Information by Jurisdiction Population

			Plan for Extra Info?		
			1 Yes	2 No	Total
Population Grouped	Prefecture	Count	23	0	23
		%	100.0%	0.0%	100.0%
	Over 500,000	Count	10	0	10
		%	100.0%	0.0%	100.0%
	200,000 - 499,999	Count	27	1	28

		%	96.4%	3.6%	100.0%
	50,000 - 199,999	Count	114	10	124
		%	91.9%	8.1%	100.0%
	15,000 - 49,999	Count	123	30	153
		%	80.4%	19.6%	100.0%
	8,000 - 14,999	Count	35	13	48
		%	72.9%	27.1%	100.0%
	5,000 - 7,999	Count	29	8	37
		%	78.4%	21.6%	100.0%
	Up to 4,000	Count	35	11	46
		%	76.1%	23.9%	100.0%
Total		Count	396	73	469
		%	84.4%	15.6%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	24.676[a]	7	<.001
Likelihood Ratio	30.667	7	<.001
Linear-by-Linear Association	18.666	1	<.001
N of Valid Cases	469		

a. 3 cells (18.8%) have expected count less than 5. The minimum expected count is 1.56.

Disaster Management Department

Since jurisdiction type and population suggest that smaller jurisdictions are less likely to have plans than larger jurisdictions, we hypothesized that a contributing factor might be whether or not the jurisdiction has a separate department with the responsibility for disaster management. One might think that in a nation as disaster prone as Japan, all municipalities would have a unit responsible for risks faced by communities within their borders, but some very small jurisdictions may have so few staff that responsibility for disaster management falls on one or more staff whose primary responsibility is something else. Thus, a further test was to learn whether or not a jurisdiction has a separate dedicated disaster management unit within the jurisdiction and having a plan or not. See Table 6 below. There was a significant

Table 6: Planning for SEWI With and Without a Disaster Management Department

			Does municipality have dedicated disaster management unit?		
			1 Yes	2 No	Total
Plan for SEWI Info?	1 Yes	Count	307	89	396
		%	86.7%	77.4%	84.4%
	2 No	Count	47	26	73
		%	13.3%	22.6%	15.6%
Total		Count	354	115	469
		%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.752[a]	1	.016		
Continuity Correction[b]	5.064	1	.024		
Likelihood Ratio	5.378	1	.020		
Fisher's Exact Test				.025	.014
Linear-by-Linear Association	5.739	1	.017		
N of Valid Cases	469				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 17.90.

b. Computed only for a 2x2 table

relationship (Chi Square<.05) between having a dedicated disaster management unit within municipal government and having planned for a SEWI alert. Those jurisdictions without such a unit are significantly more likely to have not planned for receipt of a SEWI alert from the JMA than those that have a dedicated disaster management unit.

Size of Disaster Management Department

For jurisdictions that have a disaster management department, the question arose as to whether the size of the department makes a difference in whether or not the jurisdiction has planned for receipt of a SEWI alert (See Table 7). Thus, another test was to examine the number of persons in disaster management sections within municipalities and having or not having a SEWI plan. We found that the probability that a city has not planned for SEWI is highest among cities

with 4 or fewer personnel assigned to a disaster management section within the municipality (Chi Square <.001).

Table 7: Having a Plan by Number of People in Disaster Management Unit

			Number of people in disaster management unit?				
			Up to 4	5 - 6	7 - 10	11+	Total
Plan for SEWI Info?	1 Yes	Count	77	77	76	77	307
		%	73.3%	87.5%	91.6%	98.7%	86.7%
	2 No	Count	28	11	7	1	47
		%	26.7%	12.5%	8.4%	1.3%	13.3%
Total		Count	105	88	83	78	354
		%	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	27.833[a]	3	<.001
Likelihood Ratio	30.456	3	<.001
Linear-by-Linear Association	26.092	1	<.001
N of Valid Cases	354		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 10.36.

Concerns Expressed Regarding Planning for SEWI

Having established that smaller municipal governments are less likely to have plans and that those with no or very small disaster management departments are also less likely to plan, we turned to concerns expressed by survey respondents regarding challenges in planning for a SEWI alert. The test consisted of cross-tabulating having a plan or not and concerns expressed about planning for SEWI. For example, are jurisdictions without SEWI plans more likely to cite staff shortages and other resource shortfalls as major deterrents to planning? See table 8.

Table 8: Having a Plan by Primary Concern about Planning for a SEWI Alert

			larger quake within a few days is unlikely	We do not want to disrupt business activity	We do not want to trigger panic	Scientists lack skill to forecast quake	Our jurisdiction not at risk	Lack time to plan	Lack resources and staff to plan	Other, please specify	We have no concerns	
Plan for SEWI Info?	1 Yes	Count	11	15	209	7	9	16	73	9	47	396
		%	2.8%	3.8%	52.8%	1.8%	2.3%	4.0%	18.4%	2.3%	11.9%	100.0
	2 No	Count	2	2	23	3	2	8	18	1	14	73
		%	2.7%	2.7%	31.5%	4.1%	2.7%	11.0%	24.7%	1.4%	19.2%	100.0
Total		Count	13	17	232	10	11	24	91	10	61	469
		%	2.8%	3.6%	49.5%	2.1%	2.3%	5.1%	19.4%	2.1%	13.0%	100.0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	17.231[a]	8	.028
Likelihood Ratio	16.205	8	.040
Linear-by-Linear Association	8.434	1	.004
N of Valid Cases	469		

a. 6 cells (33.3%) have expected count less than 5. The minimum expected count is 1.56.

There is weak but significant relationship (Chi Square <.05) between the concerns expressed about planning and having, or not having a plan. Those jurisdictions that have not developed a plan are more likely than those with a plan to indicate that a lack of time, staffing and resources was a primary concern and though the numbers are small, those without a plan were more likely to express doubt that scientists had the skill to accurately forecast an earthquake in the Nankai region. Though the option was not specific, those without a plan were more likely to indicate that they have no concerns, perhaps an expression that the prospect of an earthquake or more likely, the short-term forecast of an earthquake, is not of concern.

Our in-depth interviews revealed considerable diversity among local governments in their planning and concerns about planning for receipt of SEWI information. In our interviews (2) with Kuroshio Town (Miyaue, 2022) we learned that, like many smaller jurisdictions, they had no plan as of the beginning of 2022; however, the Hyuga-ken earthquake (IISEE, Building Research Institute, 2022) of January 22, 2022, a magnitude 6.6 (initially reported as magnitude 6.8) event in the Nankai Trough that was widely felt in the Kyushu and southern Shikoku region and though

it fell short of the criteria for an advisory, served as motivation for Kuroshio Town (population 10,262) to begin development of a plan using both national government guidelines and the example of neighboring Shimanto Town and Kochi City which had already developed SEWI plans. With mapped tsunami inundation zones, Kuroshio focused on proactive evacuations including identification of evacuees, evacuation routes and sheltering those evacuated. In Shimanto Town (population 32,692), we were told (Nishioka, 2022) that the town's plan predated the Hyuga-ken earthquake, but prompted town officials to review the plan particularly evacuation procedures for the 800-1000 people in tsunami zones. More typical of smaller jurisdictions, Tobe Town (population 20,217) in Ehime Prefecture reported having no plan in our survey, but in our in-depth interview conducted several months later indicated that SEWI was not a priority though some SEWI measures will be added to the general plan, due for revision this next fiscal year (Yasuoka, 2023). Tobe Town has no tsunami inundation zones and with a disaster management staff of 4, did not anticipate development of a separate stand-alone plan for response to a SEWI alert.

Analysis by Relative Hazard

We created a three-fold division of jurisdictions into: 1) those with significant and immediate tsunami risk; 2) those that do not have an immediate risk of tsunami, but are likely to experience significant ground shaking; and 3) those jurisdictions that have significant ground shaking risks but border jurisdictions that are outside the government designated region for high impact risk from a Nankai Trough major earthquake. This distinction set up a comparison of planning based on geographical distance from the worst effects of a major earthquake. We note from the table below (Table 9.1) that there are 91 jurisdictions that responded in our survey that

Table 9.1: Distribution of Nankai Jurisdictions Based on Relative Hazard

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 High Hazard	**91**	**19.4**	**20.4**	**20.4**
	2 Medium Hazard	**79**	**16.8**	**17.7**	**38.1**
	3 Lower Hazard	**276**	**58.87**	**61.9**	**100.0**
	Total	**446**	**94.9**	**100.0**	
Missing	System	**23**	**4.9**		
Total		**469**	**100.0**		

have both a severe shaking hazard from a major Nankai earthquake and an immediate tsunami risk, here classified as "high hazard." There are 79 jurisdictions that are subject to strong ground motion (at least JMA 6 -) and are surrounded by jurisdictions that share this level of hazard, which we classify as "medium hazard." Finally, there are 279 jurisdictions that are also at risk of strong shaking from a Nankai earthquake, but have a border with jurisdictions that are not considered part of the Nankai earthquake vulnerable region. The next step was to determine whether there was a relationship between planning and distance from the high hazard zone. The cross tabulation shown in Table 9.2 reveals that there was little difference between the high and medium hazard

jurisdictions, but a significant difference between the high and medium hazard jurisdictions and those classified as lower hazard, the latter being less likely to have plans for receipt of an advisory or warning from the JMA (Chi Square<.05).

Table 9.2: Crosstabulation of Planning by Relative Earthquake Hazard

			Plan for Extra Info?		
			1 Yes	2 No	Total
Geospec	1 High Hazard	Count	**81**	**10**	**91**
		%	**89.0%**	**11.0%**	**100.0%**
	2 Medium Hazard	Count	**72**	**7**	**79**
		%	**91.1%**	**8.9%**	**100.0%**
	3 Lower Hazard	Count	**220**	**56**	**276**
		%	**79.7%**	**20.3%**	**100.0%**
Total		Count	**373**	**73**	**446**
		%	**83.6%**	**16.4%**	**100.0%**

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	**8.277[a]**	**2**	**.016**
Likelihood Ratio	**8.840**	**2**	**.012**
Linear-by-Linear Association	**6.205**	**1**	**.013**
N of Valid Cases	**446**		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.93.

We would have expected a more linear trend in which the high hazard jurisdictions, which are at risk of both strong ground shaking and significant tsunami hazards, were more likely to have planned than jurisdictions with shaking hazards alone. It must be recalled, however, that many of the local governments regarded as high hazard are small coastal cities, towns and villages and that smaller jurisdictions are at a disadvantage in staffing and resources as indicated in both the survey and in-depth interviews. It is significant that 81 or 89% of these jurisdictions reported having plans despite the challenges faced by their typically small size (71.4% were jurisdictions of less than 50,000 and 30.7% were less than 15,000 in population). Cities and towns were equally likely to be in the high hazard zones, but cities usually have larger disaster management departments and greater resources for planning that towns and villages. Typical of jurisdictions in the lower hazard zone, Kai City (Yamamoto, 2023) in an in-depth interview, reported that the

main natural hazard in this Yamanashi Prefecture city of 76,038 was flooding and that the Nankai Trough was quite far away and a lower priority for disaster planning.

Exceptional Planning

We grouped the 26 planning items into 5 categories, up to 5, 6-10, 11-15, 16-20 and over 20 and examined the number reported by jurisdictions within the 29 prefectures in the sample. The average number of planning actions reported was 8.38 (warning) and 6.76 (advisory) for divided plans and 8.09 for combined plans. For combined plans, only 1 jurisdiction (in Ehime Prefecture) reported having over 20 items in their plan, 18 (13.6%) reported having 16-20 planning actions and 88, the majority (66.7%) reported having taken up to 10 actions. The modal category for combined plan jurisdictions (N=132) was category 2, 6-10 actions. For plans that distinguished between actions for an advisory and warning: advisory plan (N=230) actions fell into modal category 1 (up to 5 actions) and 78.3% fell into categories 1 and 2; for warning plans (N=247), 69.2% fell into categories 1 and 2 (up to 10 actions) and the distribution was bi-modal for these same categories. Exceptional plans defined at those with 16 or more actions for divided plans were 28 (5.9%) for warning and 20 (4.3%) for advisory plans. We cross-tabulated several variables with having an exceptional plan for both combined plans and divided plans and there were no significant relationships between having an exceptional plan and population size, number of staff in disaster management, having tsunami zones in the jurisdiction, relative hazard, jurisdiction type, main concerns in planning or jurisdiction type. In short, the factors that distinguished between municipalities with and without plans failed to differentiate between weak or average plans and those we regard as exceptional.

Prefectural Leadership and Jurisdictional Planning

To the extent possible, we examined whether prefectural leadership may have an influence on planning first by grouping cities, towns and villages into their respective prefectural governments, then comparing prefectures according to the number of jurisdictions that have plans versus those that do not. Second, we wished to know whether plans reported by jurisdictions differed by prefecture in terms of the number of plan actions contained within those plans. We received survey responses from all 29 prefectures in the Nankai region making tabular display of planning by prefecture impractical, but an examination of jurisdictions with and without plans by prefecture reveals that there were statistically significant differences in planning among prefectures for each of the two types of plans. Finally, we examined the plans of the 23 prefectures that participated in our survey to assess the extent of planning by the prefectures themselves.

In general, those prefectures with a large number of Nankai jurisdictions (the range was from 4-29 jurisdictions) tended to have larger percentages of jurisdictions with plans than prefectures with a smaller number of affected jurisdictions. In every case, a majority of sample jurisdictions within the 29 prefectures had plans, but in some cases the percentages of jurisdictions with plans were quite large. In Okayama, Tokushima and Wakayama prefectures, 100% of the reporting jurisdictions within their boundaries have plans. A Chi Square test revealed

that the differences between prefectures in whether or not the jurisdictions have plans were statistically significant (<.001). This measure does not, however, distinguish between prefectures in terms of the size of jurisdictions within prefectural boundaries. As we pointed out in previous analyses, smaller jurisdictions face significant challenges in planning.

We also sought to determine whether there was a difference in the number of planning items reported for jurisdictions by prefecture. We observed differences between jurisdictions with combined plans (that is, plans that did not differ between actions for advisories and warnings) and those that have separate plans for each type of alert. There were no significant differences between prefectures on the number of items included in jurisdictional combined plans, but there were for those that have divided plans. Since jurisdiction type and size of population were significant factors in whether or not jurisdictions had plans, that is, villages and towns and small jurisdictions in general were more likely than cities to have no plans, we examined whether differences between planning among prefectures might be due to a prefecture having a large number of smaller jurisdictions within its boundaries. Since jurisdiction size seems to be the most salient factor and those jurisdictions with up to 49,999 in population tended to be more likely not to have plans than larger jurisdictions (See Table 5), we collapsed size categories into two (Up to 49,999 and Over 50,000) and cross-tabulated having a plan (yes/no) by population in two categories for all prefectures.

The results were not straightforward. Some prefectures that had a disproportionate number of small jurisdictions had larger proportions of jurisdictions without plans. For example, Kagoshima Prefecture with 29 jurisdictions in the sample, has 23 smaller jurisdictions and 6 larger ones. In terms of planning, 19 have plans and 10 do not; of the 10 without plans, 9 are smaller jurisdictions. Similar patterns prevailed for Yamanashi and Kanagawa Prefectures that also have disproportionate number of smaller jurisdictions. On the other hand, several other prefectures with majority smaller jurisdictions have very high percentages of plans. For example, in Wakayama and Tokushima Prefectures with 21 and 22 jurisdictions respectively in the sample which are overwhelmingly smaller jurisdictions, 100% have plans. Kochi (with all smaller jurisdictions, N=23), Hiroshima, Miyazaki, Nara and Shizuoka all with a majority of smaller local governments achieved very high percentages of communities with plans.

Finally, we examined the number of planning items in the plans of the 23 prefectural governments that participated in the survey and determined that five prefectures had exceptional plans, that is, plans that contained at least 16 actions (16 actions for combined plans and at least 16 actions for either warning or advisory, for divided plans). The following prefectures had exceptional plans: Gifu, Hyogo, Kanagawa, Okayama and Shizuoka. All of these prefectures except Kanagawa had high percentages of jurisdictions with plans; however, there were no jurisdictions within any of the high performing prefectures that have exceptional plans. Thus, it is difficult to determine from the survey and statistical data whether prefectural leadership has made a difference in jurisdiction planning. We will rely on in-depth interviews with prefectural disaster managers to assess how much guidance and emphasis has been devoted to SEWI planning and on interviews with disaster managers within jurisdictions to determine the level of guidance and support they have received from their respective prefectural governments.

We interviewed a retired disaster manager from Shizuoka prefecture (Iwata 2022) which we characterized as having an exceptional plan. The prefecture is part of the Tokai area (within the Nankai region) and was of major concern under the Tokai prediction, thus knowledge about major earthquakes and commitment to planning are legacies of the Large-Scale Earthquake Countermeasures Act of 1978. The prefecture is large and divided into four areas for coordination of disaster management that would mobilize as crisis management bureaus under the SEWI plan for an advisory or a warning. These crisis management bureaus could request assistance, as needed, from the Self Defense Forces or other response agencies. The prefecture also used its taxation prerogatives to raise and direct funding to municipalities to develop earthquake countermeasures. We were also told that Shizuoka had planned a series of workshops to promote SEWI planning for municipal governments, but the Coronavirus pandemic interfered and the workshops have not yet been held. Our interviewee, a geoscientist as well as a disaster manager, was a member of the Central Disaster Management Council's Disaster Prevention Measures Executive Committee (Cabinet Office) that developed recommended actions for the Nankai Region. Thus, leadership for development of SEWI plans for municipalities has been exercised by this prefecture.

Summary of Factors in Having or Not Having Plans

The great majority (84.4%) of our sample municipalities in the Nankai region reported having plans to respond to an advisory or warning from the JMA that the short-term probability of a major subduction zone earthquake has increased. A total of 73 or 15.6% of the sample reported having no plan for this contingency. Our initial set of statistical tests sought to distinguish between those municipalities with and without plans. We discovered that smaller jurisdictions—villages, towns and smaller cities—up to 49,999 in population --are less likely to have plans for receipt of SEWI alerts than larger cities and prefectural governments. Another significant factor in planning is whether or not the jurisdiction has a dedicated disaster management unit and, the size of that unit. Jurisdictions that have no dedicated unit and those whose disaster management departments are small, particularly those with 4 or fewer staff are at a disadvantage in planning for SEWI alerts. Finally, we determined that jurisdictions without plans are more likely to cite as a major concern resource and staff shortages as impediments to planning. Town and Village governments were significantly more likely to cite staff and resource shortfalls than cities in the sample.

Specific Components of SEWI plans

The survey contained 26 planning actions organized into six related "blocks" that, in the professional judgement of the investigators and based on existing OEF plans, were reasonable in the context of a short-term low probability earthquake warning. The 26 planning actions are displayed below organized by their respective block. The jurisdictions that reported having plans

- Evacuation Block
  - Developed a plan for issuing evacuation instructions to residents in tsunami zones
  - Identified vulnerable populations to be proactively evacuated

- Planned for location and operation of evacuation shelters
- Planned for provision of material needs (stockpiles) for shelters
- Planned for stockpiling and inspecting stockpiles at shelters

- Home Preparedness Block
  - Encourage home preparedness, in general
  - Encouraging storage of emergency water and food
  - Encouraging development of family plan for reuniting in an emergency
  - Reinforcing recommended personal safety actions during an earthquake
  - Taking measures to prevent fires
  - Encouraging the acquisition of emergency items (e.g., flashlight, portable radio, etc.)
  - Become acquainted with evacuation routes and locations of safety

- Communication Block
  -Plan for jurisdiction to communicate with residents regarding an alert during the alert period

- Coordination/Cooperation Block
  - Response actions in cooperation with neighborhood associations and volunteers
  - Response action in coordination with prefectural government and JMA
  - Response in coordination with businesses and industries within jurisdiction
  - Response in cooperation with schools and public facilities
  - Response in cooperation with non-government social welfare facilities
  - Response in coordination with local universities and researchers

- Internal Mobilization Block
  - Plan for assembling senior jurisdiction management at the outset of a SEWI alert
  - Establishment of a disaster management headquarters
  - Conducting drills and exercises of plan and/or plan elements
  - Plan for cancellation or continuation of an alert

- Postponement of Activities Block
  -Provisions to suspend use of roads, bridges and buildings with low earthquake resistance
  -Calls for residents to cancel or postpone non-essential activities
  -Calls for organizations to postpone non-urgent activities (e.g., elective surgery, production of hazardous materials, etc.)

were asked if their plans included these individual planning actions, if their plans differed depending on whether the alert was an advisory or a warning and if their plans were the same for both a warning or an advisory. We discovered that two-thirds of reporting jurisdictions divided their plans between warning and advisory and the remaining third did not distinguish between these two types of alerts. We first wanted to determine the average number of planning actions taken by all jurisdictions and discovered that the mean number of actions for jurisdictions that

distinguished between a warning and an advisory was 8.4 for warnings and 6.8 for an advisory. For jurisdictions that did not distinguish between actions planned for a warning or an advisory, the average number of actions was 8.1. As mentioned earlier, 73 reporting jurisdictions had no plans and 47 jurisdictions (12.7%) had "exceptional" plans, those which contained 16 or more of the planning actions listed in the questionnaire. We will present each "block" of planning items with the frequencies in which they were checked as components of SEWI plans.

Evacuation of vulnerable people: evacuation was one of the specific planning actions mentioned in the national government's 2019 White Paper on the Nankai Trough. This block has 5 items: plans to issue evacuation instructions, identification of those to be evacuated, support for evacuation shelter operation plans, stockpiling shelter necessities for evacuees and for checking and inspection of stockpiles. See Tables 10.1 and 10.2.

Table 10.1: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Evacuation Block	Issued Evac Instructions	ID of Early Evacuees	Shelter Ops	Check/Inspect Stockpiles	Provision of Stockpiles
Advisory N=230	16.5	13.0	15.7	44.3	11.7
Warning N=247	35.2	34.4	41.7	51.4	19.8

Table 10.2: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Evac Block	Issued Evac Instructions	ID of Early Evacuees	Shelter Ops	Check/Inspect Stockpiles	Provision of Stockpiles
N=132	43.2	35.6	7.0	47.7	15.2

In most cases, those municipalities that have separate plans for an advisory and a warning, have implemented more activities for a warning than for an advisory and the jurisdictions that do not distinguish between the two types of alerts more nearly resemble the separate plan group for warnings in having issued instructions and identifying those to be proactively evacuated, but less so in regard to shelter preparations. Overall, the frequencies of implementation on all measures are less than one might expect given that the national government's guideline (2019, Government of Japan, Cabinet Office White Paper) specifically mentioned proactive evacuations of vulnerable populations in its recommendations to local governments that would receive a SEWI alert, if issued.

Home Preparedness: communicating preparedness information to residents should be an ongoing activity of municipal governments in areas with earthquake risk, but periods of enhanced earthquake potential associated with SEWI may offer an opportunity to do so during which residents are more acutely risk aware. This block has 7 items: promoting preparedness in general, calls for stockpiling food and water, establishing family communication and meeting places,

considering earthquake response strategies (e.g., Drop, Cover and Hold On), measures to prevent fire, having emergency supplies and knowing evacuation routes and sites. In response to the general question regarding the promotion of home preparedness for SEWI 60.9% of all jurisdictions that had separate plans for a SEWI warning and advisory response reported that they had done so and 53% of those with combined plans. See tables 11.1 and 11.2.

Table 11.1: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Home Prep Block	Home prep	Food & H2O	Comm/Mtn Place	Safe Acts in EQ	Fire Prevention	Emergency Supplies	Evac Routes/ Sites
Advisory N=230	60.9	40.0	40.4	21.3	22.2	31.3	44.8
Warning N=247	59.5	42.1	43.7	21.9	23.1	35.6	51.8

Table 11.2: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Home Prep Block	Home Prep	Food & H2O	Comm/Mtn Place	Safe Acts in EQ	Fire Prevention	Emergency Supplies	Evac Routes/Sites
N=132	53.0	49.2	41.7	29.5	22.0	35.6	48.5

While majorities of jurisdictions, whether plans are separate or combined regarding advisories and warnings, have emphasized home preparedness in their SEWI plans, inclusion of specific elements of home preparedness fall off in number of plan inclusions. An important paper by Field and colleagues (Field et al., 2017) identified specific home preparedness measures as an important opportunity in operational earthquake forecasts. The small number of jurisdictions that mentioned having included recommendations regarding how to respond when an earthquake occurs and fire prevention is particularly disappointing.

Emergency Public Information: this one item "block" sought to determine whether local jurisdictions had planned for communicating with residents about SEWI during an advisory or a warning, assuming the public demand for information would intensify during this period. See Tables 12.1 and 12.2.

Table 12.1: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Public Information Block	Emergency Public Information Plan
Advisory N=230	30.4
Warning N =247	33.2

Table 12.2: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Public Info Block	Emergency Public Information Plan
N=132	25.8

From a disaster management perspective, effective communication between government and residents regarding a possible impending hazard is a critical necessity. The small number of inclusions of this component in jurisdictional plans is both surprising and disappointing. The assumption being made here is that residents, once an advisory or warning is issued, will look to local government for response recommendations, an explanation of what to expect during an alert and, of equal importance, what the jurisdiction is going to do to protect residents from the hazard. The lack of planning for this contingency is a major omission on the part of jurisdictions that have not included this action in their plans.

Cooperation/Coordination: these 6 items sought to identify points of cooperation and coordination between jurisdictions and organizations in the community. They included: with neighborhood associations and voluntary disaster prevention organizations, prefectural offices and the JMA, businesses and industry, schools and other public facilities, non-governmental welfare facilities and local universities. See Tables 13.1 and 13.2.

Table 13.1: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Cooperation Block	NH & Vol Orgs	Pref & JMA	Bus & Ind	Sch &Pub Facilities	Welfare Facilities	Local Universities
Advisory N=230	21.3	32.2	17.8	25.7	15.2	1.7
Warning N=247	28.7	36.0	25.5	39.3	23.1	2.0

Table 13.2: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Cooperation Block	NH & Vol Orgs	Pref & JMA	Bus & Ind	Sch & Pub Facilities	Welfare Facilities	Local Universities
N=132	33.3	36.4	31.8	41.7	27.3	3.0

Another assumption is that coordination and cooperation between the local government and various organizations and institutions within government agencies and between local government and community organizations is a useful and vital component of disaster planning. In nearly every type of organizational coordination, fewer than half of the jurisdictions in the sample have identified these groups as points of outreach and coordination. For smaller jurisdictions, one might argue that coordination with community organizations is a means of overcoming staffing and resource shortfalls necessary for effective planning. One notable difference between jurisdictions with separate vs. unified plans is the somewhat greater likelihood that unified plans have included these measures in their plans.

Disaster Management Mobilization: this block is associated with plans to mobilize a response to receipt of an advisory or warning from the JMA for the Nankai region. It includes 4 items: mobilizing senior jurisdiction management, establishing a disaster management headquarters, drills or exercises of mobilization plans prior to receipt of SEWI and provisions to cancel an expired alert (in coordination with the prefecture and JMA scientists). See Tables 14.1 and 14.2.

Table 14.1: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Internal Disaster Mngt Block	Mobilize Senior Management	Establish Disaster HQ	Advance Drills	Provision to Cancel Alert
Advisory N=230	52.6	63.0	15.7	20.9
Warning N=247	55.9	74.9	16.2	21.1

Table 14.2: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Internal Disaster Mngt Block	Mobilize Senior Management	Establish Disaster HQ	Advance Drills	Provision to Cancel Alert
N=132	47.0	61.4	22.7	14.4

Majorities of jurisdictions in the sample have included in their plans the mobilization of senior personnel and establishing a disaster management headquarters. The exception is unified plan jurisdictions which fell slightly below 50%. Surprising is the small number of municipalities that have conducted drills of their plans and have considered the cancellation of an alert. Although alert cancellation or continuation is not a measure left to local governments (the JMA would handle this detail), local jurisdictions should plan to communicate what measures implemented during an alert can be suspended and what might be continued for safety reasons.

Suspension/Postponement of Non-Essential Activities: this block of 3 items sought to identify any activities that jurisdictions considered non-essential and that could be postponed during an advisory or warning for safety reasons. These items included: suspended use of buildings, roads and bridges with low earthquake resistance, recommendations to residents to postpone non-essential activities, and recommendations to all organizations to postpone non-essential activities. See tables 15.1 and 15.2.

Table 15.1: Percentage (%) of Respondent Jurisdictions Reporting that Actions are Part of Plan

Suspension of Activities Block	Suspend Use of EQ Vulnerable Structures	Residents to Susp Non-essential Activities	Organizations to Susp Non-Essential Activities
Advisory N=230	5.2	8.3	3.9
Warning N=247	10.5	8.1	3.6

Table 15.2: Percentage (%) of Respondent Jurisdictions Reporting that Actions are part of Plan

Suspension of Activities Block	Suspend Use of EQ Vulnerable Structures	Residents to Susp Non-Essential Activities	Organizations to Susp Non-Essential Activities
N=132	7.6	6.8	3.8

Our expectations were that these measures would not be widely implemented as a low probability forecast may not justify significant disruption of social and economic activities within a jurisdiction. Whether high risk activities such as the processing of hazardous materials, high-

rise building construction or occupation of known earthquake vulnerable structures should be suspended was an issue that our research group considered in our in-depth interviews. The prevailing view in nearly all in-depth interviews was that these activities were inconsistent with a low probability earthquake forecast.

Hierarchical Cluster Analysis of "Divided" Plans

In the previous section we presented frequencies and percentages of actions as "blocks" or as they were grouped in the survey questionnaire and reported by jurisdictions as having been included or not in plans. A more analytical display of actions by jurisdictions with divided plans is based on a statistical procedure called Hierarchical Cluster Analysis (IBM, 2023) that identifies relatively homogeneous groups of cases based on selected characteristics. In the case of divided plans, those which distinguish between actions for a warning and an advisory, there are four possible combinations of responses which are clustered based on frequency as reported by jurisdictions from most frequent to least frequently included in plans. The four possible responses are displayed in Table 16. Like the "blocks" in the previous section, the resulting analysis produced

Table 16: Four Types of Actions in Divided Plans

Warning	Advisory	Name
Yes	Yes	Type 1
Yes	No	Type 2
No	Yes	Type 3
No	No	Type 4

six clusters, but the order in which they are displayed in Table 17 below is based on the frequency in which specific combinations occur providing a clearer picture of divided plans. The "cluster" that reveals the SEWI planning action that a significant majority (73%) of jurisdictions have included in their plans is the establishment of a disaster response headquarters upon receipt of a warning or an advisory. This basic measure was recommended in the Cabinet Office guidance and constitutes a fundamental step in executing additional actions in an emergency.

The second tier or cluster is comprised of actions in which Types 1,2 and 3 combinations of actions constitute a majority, though not overwhelmingly so, varying from 50.3% to 61%. These actions included checking stockpiles of shelter supplies for evacuations, promotion of home preparedness (in general), calls for residents to be aware of evacuation routes and sites of safety and actions to mobilize senior jurisdiction management upon receipt of a SEWI alert. Also, note that the rare Type 3 action combination in which an action is planned for an advisory but not a warning is most prevalent for promoting home preparedness, a basic and typical action in lower-level alerts. The third cluster includes actions in which Types 1-3 combinations vary from 33% to

Table 17: Hierarchical Clusters Reflecting Actions Taken based on Four Types of Actions (N=256)

Type 1 (Y/Y)		Type 2 (Y/N)	Type 3 (N/Y)	Type 4 (N/N)	Action
1	143	42	2	69	Establish Disaster HQ
2	96	31	6	123	Ck Shelter Stockpiles

	129	18	11	98	Promo Home Prep
	102	26	1	127	Ck Evac Routes/Sites
	119	19	2	116	Mobilize Senior Mngt
3	89	15	3	149	Home Prep Food/H2O
	93	15	0	148	Home Com/Meet Plc
	69	19	3	165	Home Emerg Supplies
	68	14	2	172	Pub Info During SEWI
	74	15	0	167	Coop w/JMA & Pref
	58	39	1	158	Coop w/sch & Pub Fac
4	27	22	0	207	Stockpiles for evacs
	48	6	1	201	Prom Safe Acts in EQ
	49	8	2	197	Home Fire Protection
	47	24	2	183	Coop w/comm groups
	40	23	1	192	Coop w/Bus & Indus
	33	24	2	197	Coop w/Soc Welfare
	36	4	0	216	Adv Drills for SEWI
	48	4	0	204	Act for post SEWI
5	37	50	1	168	Issue Evac Instructions
	27	58	3	168	Identify Vuln Groups
	34	69	2	151	Support for Pro Evacs
6	4	1	0	251	Coop w/Universities
	12	14	0	236	Avoid Use of Vuln Infra
	19	1	0	236	Res Cancel Activities
	8	1	1	246	Orgs Cancel Activities

42% and include three household preparedness measures, storing emergency food and water, having a plan for family members to communicate and reunite during a warning or advisory and having emergency items for use if there is an earthquake (e.g., flashlight, gloves, first aid manual, extra medication etc.). Also, among this third cluster are planning for jurisdictions to provide public information to residents during a SEWI alert and two actions involving coordination with other organizations including organizations external to the jurisdiction (e.g., prefecture or JMA) and internal (e.g., schools and public facilities).

A fourth cluster is the largest including eight actions, but this cluster represents much less frequently included actions in plans ranging in frequency of Type 1-3 combinations of 15.6% to 25%. The actions included in this cluster are two household preparedness measures, promotion of personal safety actions during an earthquake and fire suppression techniques. It also includes SEWI response actions in coordination with several groups or organizations including non-governmental and welfare entities, neighborhood or community-based groups and business and industry. It includes actions to stockpile supplies for SEWI alert proactive evacuations, conducting drills or exercises of plan elements before an alert is issued and actions to be recommended if a major earthquake does not occur within the time widow of an alert. Cluster 5 is unique in that Type 2 actions (Y/N) outnumber those of type 1 (Y/Y) though the combinations range between 34% and 41% in plan inclusion. These actions all entail evacuations which are more prevalent in warnings than for advisories. They include identification of vulnerable groups that are advised to

evacuate, issuance of evacuation instructions, and support for evacuees who will require shelter. Finally, cluster six consists of actions we identified in the survey as postponements or cancellations of non-essential activities, avoidance of non-earthquake resistant structures (e.g., buildings, bridges and roads) and closures of some facilities for safety reasons. There were also actions in cooperation with local colleges and universities which may not be present in most cities in the region. These actions ranged in frequency from 2% to 10%.

The analytical technique of hierarchical cluster analysis provided us an opportunity to regroup planning actions according to their frequency of adoption rather than a simple grouping according to what seemed to be their similarity. It clearly identified actions that will require emphasis in our planned Year 2 activities as well as those that are already well-established. It also reveals an understandable tendency for local jurisdictions to more readily include actions over which they have control than to seek cooperation and coordination with non-governmental actors within the community. These more challenging planning elements; however, are particularly important for small jurisdictions with limited resources and small numbers of employees who can be mobilized in an emergency. For example, our in-depth interviews as well as the survey suggest that very small jurisdictions have considerable difficulty with proactive evacuations due to limited facilities that can be set aside as shelters and an inadequate number of staff to manage them, even for a short period of time. In these situations, the cooperation from and coordination with community-based groups and volunteers is of great importance. A related issue is the apparent low priority given to drills and exercises. If local jurisdictions are to mount a rapid and efficient response to a warning or advisory, they must assure through practice that planned activities can be effectively implemented. This is particularly so when local jurisdictions must rely on non-governmental entities to carry out their assigned roles in a coordinated manner.

VI. Discussion

Although the trajectory of earthquake forecasting in Japan spans some four and a half decades, the Nankai earthquake forecasting system is relatively new and we must acknowledge that local jurisdictions in the likely impact region are struggling to meet the need for comprehensive planning in advance of an alert that the short-term risk of a major earthquake has increased. On the positive side, 84.4% of jurisdictions in our sample reported having plans and while some plans are minimal and reveal deficiencies, a small number of jurisdictions have formulated exceptional plans that, if fully implemented, will serve them well in responding to an advisory or warning from the JMA. There were, however, very few measures that a majority of jurisdictions had implemented. These few included: promotion of home preparedness, mobilization of senior jurisdictional management, establishing a disaster management headquarters upon the issue of a SEWI message, and recommending that residents understand evacuation routes and sites following a warning and checking and inspecting stockpiles of shelter supplies. What was surprising (at least to one of the co-authors who spent most of his career as a disaster manager) was that so few jurisdictions had considered in their plans: how to communicate with residents during an advisory or warning; the importance of reiterating individual home preparedness messages during an advisory or warning, particularly what to do if they experienced ground motion from an earthquake; that few had planned for a coordinated

response with community groups and other organizations within the jurisdictions boundaries; and, that so few municipalities had conducted drills or exercises for receipt of SEWI messages.

In the judgement of our research team, the OEP program itself as it currently exists in Japan, contains flaws that should be addressed to optimize response on the part of local jurisdictions. As discovered in our in-depth interviews, the JMA will announce an advisory or warning by conducting a nationwide news conference. There appears to be no provision in the announcement protocol for prefectural and municipal governments to be notified of a SEWI alert significantly in advance of the news conference through secure disaster management communication channels. This flaw could result in an uneven distribution of vital information and delays in the implementation of response plans in the affected jurisdictions. Further, the national government, as stated in the Cabinet Office White Paper of 2019, will provide specific recommendations for disaster management actions at the point of release of a SEWI alert, and though commendable, recommendations issued at this stage are unlikely to be effectively implemented if planning in advance of issuance of a warning or advisory has not taken place. Finally, while the guidance provided by the national government for local planning for a SEWI alert has been appropriate, it has not been sufficient to develop comprehensive response plans or provide an adequate understanding of the science behind an OEF among disaster managers or the residents of the local governments.

Given the state of planning, as revealed in our survey and in-depth interviews, what we see as significant factors in the future preparedness of the Nankai region include: 1) having both an adequate understanding of OEF and appropriate guidance to develop comprehensive SEWI response plans that are consistent with the level of short-term hazard implied in an alert; 2) for smaller jurisdictions, acquiring the resources or developing compensatory strategies to improve existing plans or develop plans where plans do not exist; 3) for all jurisdictions (as revealed in the hierarchical cluster analysis), adopting countermeasures which can be done independently and internally, but neglecting countermeasures requiring negotiation and cooperation with other stakeholders (reflecting the mindset of municipal disaster managers to adopt measures over which they have full control, but also reflecting a weakness in planning); and 4) addressing the planning deficits as identified in our study to achieve comprehensive SEWI plans that provide optimal protection for life and property. These will be the objectives of our research group as we transition into the second year and seek to address each as we develop both planning guidance materials and conduct local government-oriented planning workshops in the Nankai region.

In conducting our assessment of SEWI planning among municipal governments in the Nankai region, we identified 26 separate planning actions that we believe are consistent with a low probability high consequence alert in the form of an earthquake advisory or warning. In having done so, one might legitimately ask: are some of these actions more important than others? We would respond yes. We consider the national government's special emphasis on proactive evacuations of vulnerable populations in mapped tsunami inundation zone the highest priority in local planning. Yet, only about a third of the jurisdictions in our sample have addressed this set of actions in their plans. Another high priority action is having a plan to provide ongoing

communication with residents during an alert. Experience and social science research have confirmed the importance of providing accurate and authoritative information during hazard warnings and our survey revealed that only one-fourth to one-third of our sample jurisdictions have addressed this planning need. For small jurisdictions with limited resources and few staff for planning and the execution of plans in an alert, mobilization and cooperative engagement with community-based groups may be the best strategy for overcoming the challenges these jurisdictions face.

Just below the high priority of evacuation, public communication planning and coordination with community-based groups, we would place the reinforcement of ongoing efforts to promote home preparedness by residents of the Nankai region. Of particular importance is for people to know how to protect themselves during earthquake shaking and, for those in tsunami inundation areas, to promptly evacuate to higher ground following a major earthquake. Japan has the world's only nationwide earthquake early warning system (Kinkyu Shishin Sokuho) and while research indicates that most Japanese people are familiar with this system, reminders that residents may receive a few seconds to a few tens of seconds warning that an earthquake has occurred and that they may soon feel shaking, would be wise public policy in the Nankai region. Other measures such as having a family communication and reunification plan, storing emergency food, water and supplies and knowing tsunami evacuation routes and safe areas are also well advised. Finally, we were surprised that so few local governments had conducted drills and exercises of planning elements; fewer than one-quarter had done so. We feel that these drills are vital for orderly and practiced evacuation in locations where timely movement of people to safety is critical.

We also consider it important to identify the characteristics of jurisdictions with exceptional plans and there were 19 combined plans and among divided plans, 28 for warning and 20 for advisory that had accomplished a great majority of the actions we identified as best practices. The survey, however, provided us few, if any, clues as to the factors that made these plans exceptional. The variables that allowed us to differentiate those with plans from those without, proved to be non-significant. The in-depth interviews suggested that having an advocate for SEWI planning was one important factor in the development of comprehensive SEWI plans. Shizuoka prefecture and Toyohashi City, for example, have well-informed and articulate disaster managers who are very familiar with SEWI and have affiliations that reinforce their understanding of planning for this contingency and commitment to mitigating the hazards posed by a Nankai Trough earthquake. In Shizuoka, the recently retired disaster manager is also a geoscientist and member of national government committees that developed guidelines for local jurisdiction SEWI planning. The disaster manager from Toyohashi City is affiliated with Nagoya University's Disaster Mitigation Research Center and has worked with center faculty in holding workshops to promote planning for SEWI.

VII. Conclusions and Planned Interventions

Japan's scenario driven OEF system for the Nankai region is relatively new having been implemented between 2015 and 2021, but the effort to forecast earthquakes dates back to the

late 1970's with passage of the Large-Scale Earthquake Countermeasures Act and the Tokai earthquake prediction. So, we regard the present system as a result of evolutionary development rather than an abrupt change following the Great East Japan Earthquake and Tsunami of March 11, 2011. Of course, hindsight is always 20/20, but had the current OEF system been in place in 2011, the JMA would have issued an advisory, or perhaps a warning, based on the occurrence of a magnitude 7.3 earthquake, three magnitude 6 events and multiple slow slip events in the eventual rupture zone beginning on March 9, 2011. Would it have saved lives? We conclude that it would have had there been plans in place to respond based on an advisory or warning. Prefectural and municipal governments in the Nankai region have, since that time done much in preparing for such a contingency, but based on our study, more can and must be done.

We would first recommend some modifications in the OEF system. In addition to a nationwide news conference at which the JMA announces the release of a warning or advisory, prefectural and municipal governments in the defined Nankai region will be notified in advance of a general announcement through prefectural JMA offices in the 29 prefectures in the Nankai region. We encourage the JMA to give sufficient advance notification through secure disaster management communication channels that will facilitate a mobilization of personnel and initiation of planned measures within Nankai jurisdictions prior to both external and internal demands for information and local action. Second, we recommend that the national government provide more detailed planning guidance materials that are likely to result in comprehensive plans for response to a JMA issued advisory or warning for Nankai and simple non-technical information designed for residents of the region to help them understand the warning systems and the events that may increase the probability of a large damaging earthquake in the region. Finally, given that the JMA will convene scientists to evaluate the occurrence of potential earthquake precursors in the Nankai Trough which will require about two hours, the JMA should consider implementing a system similar to the US Geological Survey's Earthquake Notification System (ENS). This system provides real-time notification of the occurrence of earthquakes that can be tailored to a specific region and range of earthquake magnitudes. With such a system, disaster managers and residents could become aware of earthquakes that may conform to the scenario earthquakes for advisories or warnings and begin responding before a formal announcement.

Recommendation: That our research group prepare a memorandum to the Secretary General for Seismology and Volcanology of the JMA suggesting that the measures identified above be considered. We would like to place special emphasis on real-time notification of local jurisdictions in the Nankai region of earthquakes or other seismic activity that may trigger a warning or advisory for the region, possibly through a modification of the J -Alert system (*Zenkoku Shunji Keihō Shisutemu*).

Our plan for a second year of US-Japan Foundation funding is to develop planning guidelines based on best practices of exemplary OEF planning efforts in Japan and other nations and conduct workshops in the Nankai region to assist jurisdictions in constructing comprehensive OEF plans. These guidelines will be based on information obtained in our survey, in-depth interviews and documents containing response measures specific to a low probability/high

consequence situation. The guidelines will be distributed via multiple channels to prefectural and municipal governments in the Nankai region and form the basis for presentations and exercises that comprise our regional planning workshops. Smaller jurisdictions are struggling to develop plans and we will focus on the needs of smaller jurisdictions in both our guidelines and our workshops.

Recommendation: Upon conclusion of the first-year assessment of planning among municipal governments in the Nankai region, develop a set of planning guidelines and model plans, with special (though not exclusive) emphasis on the needs, concerns and challenges experienced by smaller jurisdictions. Distribute the guidelines as published documents to all local jurisdictions in the Nankai region and utilize them in the workshops that will be conducted to promote planning for a SEWI alert.

Our assessment identified a number of neglected areas of planning that merit emphasis and incorporation in SEWI plans. They are: proactive evacuation planning for jurisdictions with mapped tsunami inundation zones including the identification of categories of persons to be evacuated, shelters or other alternate safe locations where these evacuees will be housed during a warning or advisory and how these evacuees will be provided with food and other necessities during the period of evacuation; household preparedness measures, particularly how to protect oneself in an earthquake, to secure furnishings to avoid injury from non-structural hazards, and plans for family reunification after an earthquake; public communication between local government and residents during a SEWI alert; coordination and cooperative planning that involves the prefecture in which the municipality resides, private sector organizations, organized community-based groups, volunteers and other stakeholders; conducting drills and exercises to test and refine plans, particularly evacuation procedures and internal mobilization of municipal response personnel and consideration of non-essential activities during a warning, in particular.

Recommendation: Highlight these relatively neglected actions in the guidelines, model plans and workshops that will be held in the region. Within each category, identify specific actions that should be considered in planning and provide special emphasis on actions and strategies for jurisdictions challenged by resource and personnel shortfalls in capacity.

We realize that not all jurisdictions will be reached through workshops, so the guidance material and workshop videos will be distributed to every jurisdiction in the Nankai region and be maintained on the webpages of the Disaster Prevention Research Institute for on-going reference. In addition, the national government in December 2022 expanded the OEF system to include virtually all the Pacific Coast of Japan by adding seven prefectures from Chiba to Hokkaido citing the high probability that a large tsunami-genic earthquake could occur in this region. This expansion of the OEF system will add 182 municipal governments in Hokkaido, Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Chiba prefectures.

Recommendation: Consider the possibility of proposing future workshops and planning activities in the newly designated areas covered by the OEF system. Respond to individual jurisdictional requests for advice and assistance as we are able.

The OEF planning assessment conducted by our research team identified a number of deficits in planning for a warning or advisory from the JMA indicating that the short-term probability of a major earthquake in the Nankai region has increased. It also identified some extraordinary levels of planning for this contingency carried out by dedicated disaster managers at the municipal government level. There remain challenges that must be overcome if all local jurisdictions in the Nankai region are to secure an optimal level of seismic safety for their residents. We have, to the best of our ability identified the challenges and feel qualified to address deficits and challenges in the months ahead and to spread best practices to all municipal governments in the Nankai as well as new jurisdictions added to the OEF system by Japan's national government. The government has set a goal of significantly reducing catastrophic levels of damage and the loss of life along the dangerous Japan Trough which in 2011 claimed the lives of 18,000 people, displaced millions and caused one of the world's worst nuclear accidents. It is to this task we now turn.

VIII. Limitations of the Study

Our methods included multiple sources of data collection from documents, in-depth interviews and a survey of jurisdictions in the Nankai region. One might reasonably ask, do surveys really capture the true picture of planning as it will actually be carried out? Is there a gap between reporting planned actions and the actual implementation of actions when the occasion arises to implement a plan? We must admit that this is a possibility, though there are constraints on organizations, particularly government entities that limit, if not prevent, failures to perform actions that have been established as policies and commitments, particularly for acts that affect public safety. These constraints are both legal and normative, thus we have reasonable confidence that the answers received in our survey are accurate and reflect the intent of the jurisdictions that are represented in the sample.

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Appendix: Survey Questionnaire

Questionnaire Survey on Response Plans Regarding "Nankai Trough Earthquake Extra Information"

1. What is the name of your jurisdiction?
   name of your prefecture _____
   name of your city/town/village _____ (if you are a prefectural government, please leave here blank)

2. Are there mapped tsunami inundation zones in this jurisdiction that include areas that may be affected by the largest possible Nankai Trough earthquake (*Level 2)? (*Level 2: the largest class of earthquake scientifically assumed that is Mw [moment magnitude] 9.1)

   ___ Yes
   ___ No

3. Does your jurisdiction have a plan specifically for response to receipt from the JMA of "**Nankai Trough Earthquake Extra Information**" (hereinafter referred to as "Extra Information")? In this survey, the "Response Plan" for "Extra Information" includes the description of the response to "Extra Information" in the local disaster prevention plan. (Multiple choices allowed.)

   ___ Yes (We have the "Response Plan" as an independent plan.)
   ___ Yes (We have the "Response Plan" in our local disaster prevention plan.)
   ___ No

4. What are your main concerns regarding planning for receipt of "Extra Information" from the JMA? Please select top 3 important items.
   - Please enter "1" for the most important item, enter "2" for the second most important item and "3" for the third one.
   (Example)
   _2_ The likelihood of a larger earthquake within a few days is low
   __ We do not wish to disrupt the economy and business activity
   _1_ We do not want to trigger panic and disturb people's lives
   _3_ Scientists do not have sufficient skill to tell whether there will be another large

earthquake

- If you have only one or two most important item(s), please enter “1” and “2” for those items. If you don’t have any most important item, please enter “1” for “We have or had no concerns”.

___ The likelihood of a larger earthquake within a few days is low
___ We do not wish to disrupt the economy and business activity
___ We do not want to trigger panic and disturb people’s lives
___ Scientists do not have sufficient skill to tell whether there will be another large earthquake
___ We do not consider our jurisdiction at risk of damage or casualties in a Nankai earthquake
___ We have not yet had time to complete a plan to respond to “Extra Information”
___ We do not have adequate resources and staff to implement a plan
___ We have or had no concerns
___ Other, please specify:
_____
_____
_____
_____

5. Do you feel that the national government has provided adequate support, both information and resources, to prefectural and municipal government to prepare and implement “Response Plans” for receipt of “Extra Information”?

___ Yes
___ Somewhat agree
___ I can’t say either way
___ Not so much
___ Not at all

6. What kind of support does your municipality need or have needed from the government in order to prepare a “Response Plan” for “Extra Information”? Please select top 3 important items.
   - Please enter "1" for the most important item, enter “2” for the second most important item and “3” for the third one.
   - If you have only one or two most important item(s), please enter “1” and “2” for those items. If you don’t have any most important item, please enter “1” for “We don’t or didn’t need any additional support”.

___ More detailed guidelines from the national government for municipal governments to plan

___ Training for municipal officials on “Extra Information”
___ Development and dissemination of planning strategies for small municipalities
___ Help from other jurisdictions in securing facilities for proactive evacuation
___ Explanatory materials for residents regarding “Extra Information”
___ Subsidies for the preparation of “Response Plans”
___ More active publicity and dissemination of the “Extra Information” System by the government and mass media
___ Establishment of a platform for sharing the issues that each municipality faces in the proactive evacuation measures, etc.
___ Compensation for financial losses due to disruption of business and commerce
___ Create a leave system to encourage evacuation from proactive evacuation areas
___ Subsidies for proactive evacuation and living in shelters when “Extra Information” is announced
___ We don’t or didn’t need any additional support
___ Other, please specify; _____
_____
_____

7. If the JMA issues “Extra Information (Major Earthquake Warning)” for an earthquake or seismic activity that may be a foreshock to a major earthquake and tsunami in the Nankai region, how likely do you think a large earthquake and tsunami will follow receipt of this information?

___ Extremely likely
___ Somewhat likely
___ Unsure
___ Somewhat unlikely
___ Extremely unlikely

8. Do you think development of a “Response Plan” will reduce injuries and damage if a large earthquake occurs following receipt of “Extra Information” from the JMA?

___ Will definitely reduce injuries and damage
___ Will probably reduce injuries and damage
___ Unsure
___ Will have no impact on injuries and damage
___ Will probably not reduce injuries and damage

The following Q.9 to Q.14 are for those who answered Yes in Q.3 (Does your jurisdiction have a plan specifically for response to receipt from the JMA of “Nankai Trough Earth quake Extra

Information” (hereinafter referred to as “Extra Information")?
If you answered "No" in Q.3, please go to Q.15.

9. Is your “Response plan” based on information received from the Government of Japan and/or the prefecture in which your jurisdiction is located? Would you say that your plan contains:

___ Only national government recommended actions
___ In addition to recommendations from national government, we have included actions specific to our jurisdiction
___ Both national and prefectural recommended actions
___ In addition to recommendations from other levels of government, we have included actions specific to our jurisdiction
___ Neither national nor prefectural recommended actions
___ Unclear

10. Does your “Response Plan” distinguish between the two cases that are “Extra Information (Major Earthquake Warning)" and “Extra Information (Major Earthquake Advisory)"?

___ Yes
___ No

11. If your municipality's “Response Plan” has established “proactive evacuation areas", what criteria did you use to establish these areas? Please select the one that best applies to your situation.
___ The entire tsunami inundation area of the largest possible Nankai Trough earthquake is designated as “proactive evacuation areas".
___ Areas where a tsunami of 30 cm or more in depth is expected to reach within 30 minutes of the largest possible Nankai Trough earthquake are designated as “proactive evacuation areas".
___ Other than the above (please specify below;
_____)
___ No “proactive evacuation areas" have been established.
___ Unclear

12. Does your “Response Plan” address any of the following actions? In the table below, please select all the contents described in the “Response Plan”. Please divide your answer into two categories: (1) as for the case of “Extra Information (Major Earthquake Warning)" and (2) as for the case of “Extra Information (Major Earthquake Advisory)". If both cases are included, please check both (1) and (2).

	(1) Major Earthquake Warning	(2) Major Earthquake Advisory
Description regarding the issuance of "Evacuation Instruction"	☐	☐
Description regarding the issuance of "Evacuation of the Elderly, Etc."	☐	☐
Description regarding support for operation of evacuation shelters for residents who evacuated proactively	☐	☐
Description regarding checking and inspecting stockpiles	☐	☐
Description regarding provision of stockpiles for proactive evacuees	☐	☐
Description regarding promotion of home preparedness	☐	☐
(The following six items are questions about the existence of specific individual items regarding home preparedness.)	-	-
Call for stockpiling of water and food in each household	☐	☐
Call for households to reconfirm communication methods and meeting places	☐	☐
Call for households to reconfirm safety actions in the event of an earthquake (e.g., hiding under a desk, getting down, etc.)	☐	☐
Call for households to take measures to prevent fires from starting and spreading	☐	☐
Call for households to prepare emergency items (food, water, medicine, flashlights, portable radios, etc.)	☐	☐
Call for households to check evacuation sites and routes	☐	☐
Description regarding providing information on “Extra Information" and promotion of communication with residents (appointment of a spokesperson, explanation of information from the JMA, explanation of the situation and provision of the latest information to the mass media, counteracting false information, etc.)	☐	☐
Description regarding response actions in cooperation with neighborhood associations and voluntary disaster prevention organizations	☐	☐

Description regarding response actions in cooperation with the JMA, prefectural governments, etc.	☐	☐
Description regarding response actions in cooperation with business and industry	☐	☐
Description regarding response actions in cooperation with schools and other public facilities	☐	☐
Description regarding response actions in cooperation with nongovernmental social welfare facilities	☐	☐
Description regarding the gathering system of senior management	☐	☐
Description regarding the establishment of disaster response headquarters	☐	☐
Description regarding countermeasures in cooperation with local universities and researchers	☐	☐
Description regarding advance drills regarding response to “Extra Information"	☐	☐
Description regarding suspension of use of roads, bridges and buildings with low earthquake resistance	☐	☐
Calls for residents to cancel or postpone non-essential activities	☐	☐
Description regarding calls for the postponement of non-essential and non-urgent socioeconomic activities (e.g., postponement of non-urgent surgery or temporary suspension of the production of hazardous materials)	☐	☐
Description regarding actions to be taken if no earthquake occurs after a certain period of time after the announcement of the "Extra Information"	☐	☐
Other descriptions, please specify. _____	☐	☐
Other descriptions, please specify. _____	☐	☐
Other descriptions, please specify. _____	☐	☐

13. Did your municipality obtain the advice of a consulting firm in developing a “Response Plan"?

___ Yes
___ No
___ Don't know

14. If your “Response plan” is available on your municipality's web page, what is the URL? (If your local disaster prevention plan includes a “Response Plan”, please provide the URL where the local disaster prevention plan is posted.)

    Please add the link here _____

15. Do you have any additional thoughts or comments about planning for “Extra Information” that your jurisdiction may receive from the JMA?
    _____
    _____
    _____
    _____
    _____
    _____
    _____
    _____

16. What is your agency and position?

    Agency or department: _____
    (Crisis Management Division, Disaster Prevention Division, General Affairs Division, etc.)

    Position: _____
    (Department Manager, Section Chief, Assistant Section Chief etc. Your name is not required)

17-1. Does your municipality have a department dedicated only to disaster prevention and crisis management? Please select "No" if your municipality does not have a department specializing in disaster prevention and crisis management, but has a general affairs section staff member in charge of disaster prevention in addition to other duties.

    ___ Yes
    ___ No

17-2. We would like to ask municipalities that answered "yes" to Q.17-1. Please indicate the number of full-time employees in the department specializing in disaster prevention/crisis management.
    If there is more than one department in charge of disaster prevention/crisis management, please enter the total number of staff in all departments. Please enter the

number of employees at the time of your response. If you do not know the exact number, please give an approximate number.

Number of full-time employees: _____ persons

18. Would you be willing to meet with us for a brief interview if we have additional questions about planning for receipt of “Extra Information”?

__ Yes
__ No

If yes, please also fill out the following
Your name: _____
Email address: _____
Phone number: _____

19. Would you like to receive a report summarizing the information provided by each municipality? (The Disaster Prevention Research Institute of Kyoto University will send this report to those municipalities that have requested it via email at a later date.)

__ Yes (Please enter your email address below)
_____
__ No

Please feel free to write any comments you may have about this survey.
_____
_____
_____
_____
_____

Thank you for your time and attention, this concludes the survey.

Note: If a respondent answers “No” to Q.10, Q12 becomes as below.

12. Does your “Response Plan” address any of the following actions? In the table below, please select all the contents described in the “Response Plan”.

Description regarding the issuance of "Evacuation Instruction"	□

Description regarding the issuance of "Evacuation of the Elderly, etc."	☐
Description regarding support for operation of evacuation shelters for residents who evacuated proactively	☐
Description regarding checking and inspecting stockpiles	☐
Description regarding provision of stockpiles for proactive evacuees	☐
Description regarding promotion of home preparedness	☐
(The following six items are questions about the existence of specific individual items regarding home preparedness.)	-
Call for stockpiling of water and food in each household	☐
Call for households to reconfirm communication methods and meeting places	☐
Call for households to reconfirm safety actions in the event of an earthquake (e.g., hiding under a desk, getting down, etc.)	☐
Call for households to take measures to prevent fires from starting and spreading	☐
Call for households to prepare emergency items (food, water, medicine, flashlights, portable radios, etc.)	☐
Call for households to check evacuation sites and routes	☐
Description regarding providing information on “Extra Information" and promotion of communication with residents (appointment of a spokesperson, explanation of information from the JMA, explanation of the situation and provision of the latest information to the mass media, counteracting false information, etc.)	☐
Description regarding response actions in cooperation with neighborhood associations and voluntary disaster prevention organizations	☐
Description regarding response actions in cooperation with the JMA, prefectural governments, etc.	☐
Description regarding response actions in cooperation with business and industry	☐
Description regarding response actions in cooperation with schools and other public facilities	☐
Description regarding response actions in cooperation with nongovernmental social welfare facilities	☐

Description regarding the gathering system of senior management	☐
Description regarding the establishment of disaster response headquarters	☐
Description regarding countermeasures in cooperation with local universities and researchers	☐
Description regarding advance drills regarding response to “Extra Information"	☐
Description regarding suspension of use of roads, bridges and buildings with low earthquake resistance	☐
Calls for residents to cancel or postpone non-essential activities	☐
Description regarding calls for the postponement of non-essential and non-urgent socioeconomic activities (e.g., postponement of non-urgent surgery or temporary suspension of the production of hazardous materials)	☐
Description regarding actions to be taken if no earthquake occurs after a certain period of time after the announcement of the "Extra Information"	☐
Other descriptions, please specify. _____	☐
Other descriptions, please specify. _____	☐
Other descriptions, please specify. _____	☐