Preparedness and Response Lessons -- *3.11 East Japan Earthquake Disaster*

2012 EERI Annual Meeting
National Earthquake Conference

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Critical Elements of Preparedness and Response

- Functioning Government, NGO & Community Sectors
- Integrated Preparedness, Mitigation, Response and Recovery Cycle
- Local Capacity to Respond and Coordinate Sectors
- Integrated Business, NGOs, Volunteer Resources
- Humanitarian Logistics Capacity
- Ability to Adapt to Unexpected / Rapid Onset Events

Drawing on the Lessons from Tohoku

- Many Parallels to the US in Economic Development, Engineering, Public Education, Earthquake Science
- Some Divergent Aspects in Government Organization, Response Structures, Support for Infrastructure, NGO Sectors, Application of Technology
- On-going Dialogue on Public Education, Emergency Management, EEW, Engineering

Some Lessons

- Mitigation and Preparedness Work
  - Limited Structural Damage From Earthquake Shaking
  - A Culture of Earthquakes and Tsunamis
  - Robust Seismic Network & Warning System
- Continuous and Visible Public Education About Hazards
  - Works if it is Correct Information
  - Works if it is Reinforced by Mitigation, Alert and Warning Messages
  - Can Create False Sense of Security Behind Flood Walls, in Refuge Areas and Above Inundation Hazard Zones
  - Requires Robust Pre-event Education, Delivery Mechanism, and Correct Content

Four Storey Earthquake Retrofit Hospital/Tsunami Evacuation Refuge Was Overtopped

Science Assumptions That Impacted Emergency Response in Tohoku

- Assumptions on Fault Segmentation & Multiple Segment Rupture
- Impact of Multiple Near Simultaneous Events on Warning System Function
- Probabilistic Hazard Assessments
  - Time Frame
  - Outliers
- Utilization of Probabilistic Hazard Assessments in Emergency Management
  - Being Prepared for the Probable and the Possible
  - "The Event Exceeded Our Expectations"

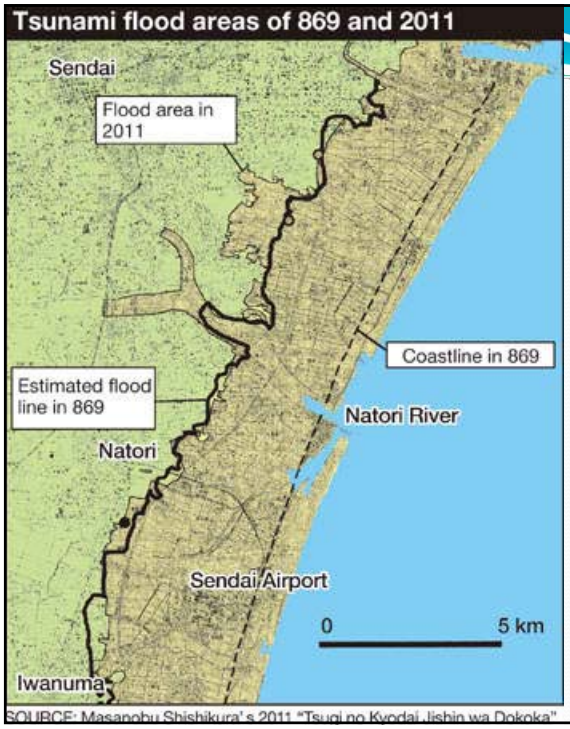
Tohoku Planned for the Probable

- Plan A: Mitigate the Risk
  - Structural Design for Earthquakes
  - Sea Walls and Tsunami Evacuation Structures
  - Flood Gates
- Plan B: Educate the Population
  - Warning System
  - Signs of Historic Wave Height
  - Refuge Areas Designated
  - Evacuation Plans and Signs and Drills
  - "Tsunami Tendenko"
- What if the Tsunami Exceeds Expectations? What is Plan C?

Historic Tsunamis in Tohuku

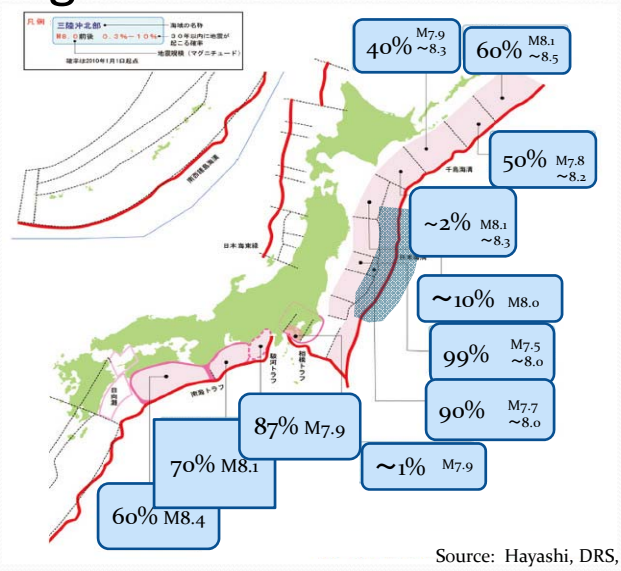
Date	Earthquake	Size / Tsunami Wave Heights	Deaths
869	Jogan	M 8.3 / 20+m	~1,000
1611	Keiho-Sanriku	M8.1 / 20m	2,000 – 5,000
1896*	Meiji Sanriku	M8.5 / 38m	21,959
1933	Showa Sanriku	M8.1 / 28m	3,046
1960*	Chile	M9.5 / 5.3m	142
2011*	Great East Japan	Mw9.0 / 38m-40m	22,626** (including missing)

*Tsunamis that Devastated Ofunato
** 7/5/2011, National Police Agency



Jogan 869 and the 11 March 2011 Tohoku Tsunami

Estimated Earthquake Probabilities by Segment



Source: Hayashi, DRS, Kyoto University

What Did They Plan For?

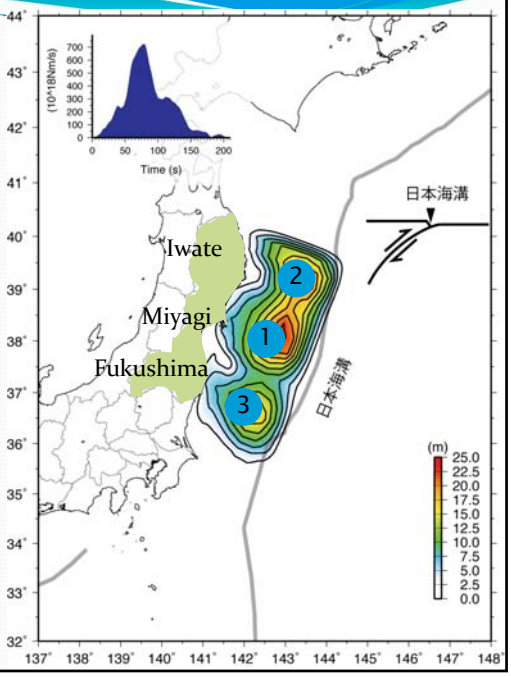
- The Maximum Probable Disaster, Not the Maximum Possible Disaster or Historic "Great Event"
- Expectations Built on What They Had Experienced
  - 1896, 1933, 1960* Tsunamis
- Post Great Hanshin-Awaji Earthquake (1985) Changes in Response Plans and Structure Not
  - Multi-Prefecture Disaster
- National Focus on Tokaii-Tonankai-Nanka Planning
- They did Not Plan for Cascading Failures of Infrastructure

* Chilean Tele-tsunami

Facts about the Earthquakes

- Inter-plate boundary earthquake between North American Plate and Pacific Plate
- Three consecutive earthquakes occurred
  1. Miyagi
  2. Iwate
  3. Fukushima
- North American Plate was raised by 25 meters
- Strong Shaking lasted for 200+ seconds

Yuji Yagai et al. 2011



How Big Was the EQ? How Big Will the Tsunami Be?

- Tsunami-genesis is Inferred From Earthquake Magnitude (Mw)
- JMA Tsunami Bulletins

Bulletin #	Time (Local)		Mw	Wave Height
Nucleation	1446			
1	1450	EQ + 4 Min.	7.9	3 M
6	1514	EQ + 28 Min.	7.9	6 M
10	1531	EQ + 45 Min.	7.9	>10 M
16	1609	EQ + 83 Min.	8.4	>10 M
31	1847	EQ + 241 Min.	8.8 (32 x More Energy than #1)	>10 M

Source: JMA

Peak Tsunami Heights

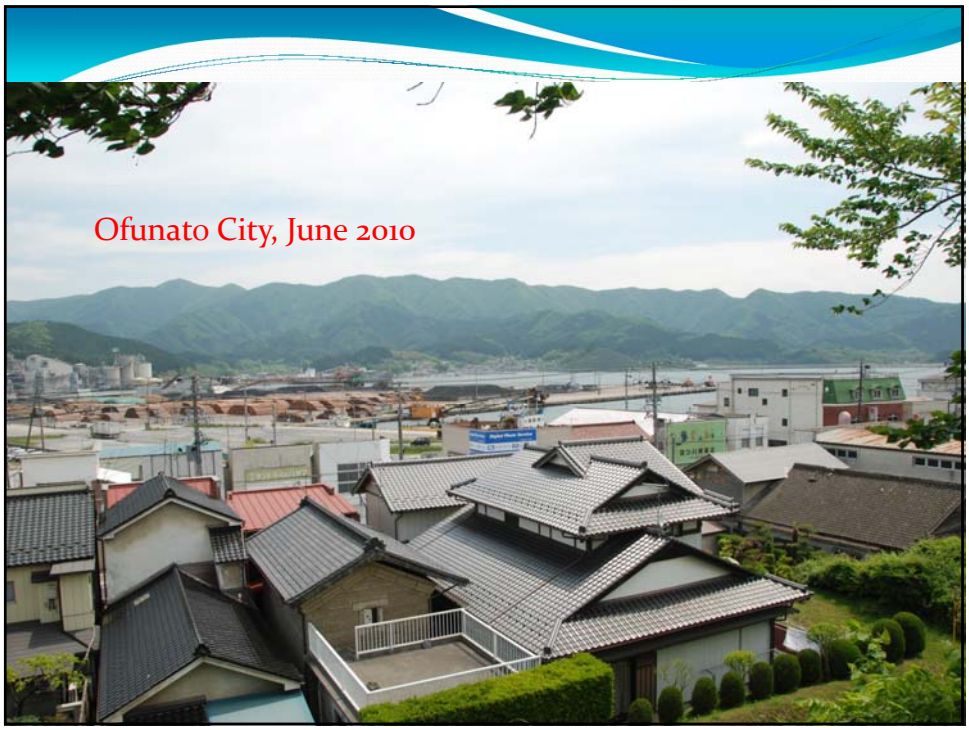
- Kuji 19m
- Fudai Village 28m
- Taro/Miyako 38m
- Otsuchi Town 19m
- Ofunato City 24m
- Rikuzentakata City 12m
- Minamisanriku Town 16m
- Sendai/Natori 12m
- Maximum Estimated Height ~42m (~136 Ft)

Source: IOC/UNESCO Bulletins

Flooding in Unosumai Town

Red Line -- 1896/1933 Tsunami Inundation Line
Orange Line -- Evacuation Zone [The Probable]
Blue Line -- 2011 Tsunami Inundation [The Possible]

Source: Mainichi Shinbun



Ofunato City, June 2010


スミレ
cafe de cur
Kojik
Kojika


西
災害は忘れた頃にやってくる
5.3M
チリ地震津波水位表
大船渡市
TOKYO
引き出物
物
承ります
にしや


100 m
津波避難場所
Tsunami Emergency Place of Refuge
台町高台
Daimachi Hill


Daily Siren Tests
0700 Edelweiss
1200 Traditional
1700 Yesterday


MAIYA
SANDWICH &
YA


MAIYA
~2.5 m

When the Possible Occurred: Ofunato City on March 15, 2011 (T.D. Flack, Stars and Stripes)

Brief Time History

- Strong Ground Shaking Lasted for 4 Minutes
- First Tsunami Waves Arrived within 15 Minutes of Nucleation
- Tsunami Inundation Lasted for Approximately 8 Hours
- 600 km if Tohoku Coast were Inundated and Isolated for Up To 3 Days
- First Response Was Local. First Responders Were Surviving Residents

The First Hours

Date	Time	Action
11 March	14:46	M_w 9.0 earthquake nucleation offshore of Sanriku. Three prefectures impacted simultaneously
	14:50	Response Office established in Prime Minister's Office. Emergency Response Team convened
	15:14	Established "Extreme Disaster Management Headquarters" headed by the Prime Minister (first establishment of function since passage of Basic Law)
	15:37	Convening of Extreme Disasters Management Headquarters (adopted basic policy on response to the disaster and Disaster Relief Act)
	18:42	Dispatched government inspection team to Miyagi Prefecture
	19:23	Extreme Disaster Management Headquarters meeting on relief measures for stranded commuters
12 March	06:00	Established Local Headquarters for Extreme Disaster Management in Miyagi Prefecture
		Designation of event as an Extremely Severe Disaster
13 March		Designation of event as a Specified Major Disaster
14 March		Decision to liquidate reserve fund to purchase relief supplies

Source: Cabinet Office, Government of Japan, 2011

Observations on Care and Shelter

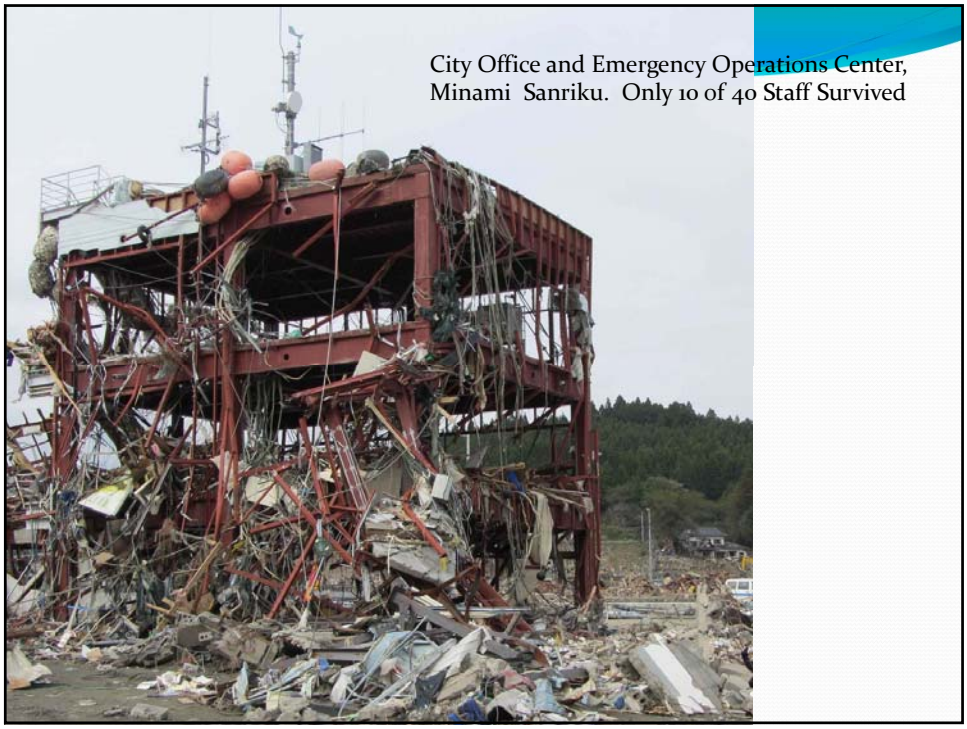
- Initial Sheltering Was Ad Hoc by Residents
- Many Designated Shelters were Flooded
- Local Governments were Responsible for Care and Sheltering, but Food and Water Were Initially Provided by Surviving Neighbors. Many Shelters Had Neither Food or Water.
- Logistic Support was Constrained by Rail & Road Damage, Debris, Lack of Fuel, Damage to Communications and Utilities, & Loss of Local Government Capacity

- By Day 5, Self Defense Force Provided Food and Water
- Shelters Were Organized and Managed by Residents
- But Shelters Had Limited Capacity to Respond to Those With Functional and Access Needs
- Logistics Continued to be Challenging

Minato School Shelter
Ishinomaki

Unexpected Issues

- In Many Towns, Senior Management Staff Perished in Tsunami
- Tsunami Evacuation Structures Were Overtopped by Waves
- 5 Million Temporary Homeless Commuters in Tokyo
- After Day 5, Logistics Still Constrained by Lack of Fuel, Power, Communications


City Office and Emergency Operations Center,
Minami Sanriku. Only 10 of 40 Staff Survived


Four Storey Apartment/Tsunami
Shelter Was Overtopped by Waves

Causes of Deaths

Cause	Number	% of Total
Drowning	14,353	92.4
Crushing	683	4.4
Burns	170	1.1
Unknown	310	2.0
Est. TOTAL	15,534	
Missing	7,092	

Source: National Police Agency (As of July 5, 2011)

Who Were the Casualties?

- 30% of the Population Were Over 60 Years Old
- 60% of those Who Perished Were Over 60 Years Old

Observations on Emergency Preparedness & Response in Japan

- Preparedness is a Local Government Function
- The Population was Educated About Hazards
- Initial Response was Local, by Survivors and Neighbors
- JMA Detection and Warning Systems Worked, But Initial Message Inaccurate. Without Local Power, Telephony, They Could Not Communicate Updates
- Probabilistic Hazard Assessments Proved Inaccurate, But Reinforced by Sea Walls, Signs, Location of Refuge Area, Warning Message [More Perished Outside of the Mapped Inundation Zone]

- No NGO to Back Fill for Overwhelmed Local Government
- No Structured Volunteer Function
- New National Multi-Prefectural Disaster Plan Issued but Not Tested or Exercised. First Multi-Prefectural Disaster (Level 3 Disaster)
- First Use of GIS Mapping and Situation Awareness Tools at Cabinet Level in Tokyo
- Top down Hierarchal Structure (Local and Prefectural Governments Awaiting National Decisions)Without Access and Communications, Constrained Response
- No Initial Logistics Function, Dependence on Donations

- New Management Structure Implemented in the Midst of Disaster
- Inter-Prefectural Mutual Aid Initiated
- Operation Tomodachi (US Military/SDF Partnership) Provided Logistic Support
- Need for Unified Command to Set Priorities for Limited Resources (Aircraft, Ground Transportation, Access, Debris Movement)

Extraordinary Resources Committed to Response

- 100,000 Japan Self Defense Force (SDF) Personnel
  - Search / Victim Recovery
  - Clearing Debris and Opening Roads
  - Logistic Support
  - Communications
  - Feeding at Shelters
- 28 International Search & Rescue Task Forces (USAR)
  - Search / Victim Recovery
- Operation Tomodachi – Logistics, Operations, Support
  - 24,000 US Military Personnel (Incl. USS Ronald Reagan)
  - 189 Aircraft, 24 Naval Ships
- DoD, DoE, NRC, Training and PPE at Fukushima Daiichi

Challenges to Emergency Management

- Two Separate Disasters: Earthquake and Tsunami; and, Fukushima Daiichi
- Two Command Structures: One for Earthquake & Tsunami and a Second for Fukushima Daiichi Nuclear Disaster. Prime Minister In-charge of Both
- No Initial System for Tsunami Victim Registration and Tracking
- Lost Capability at Local Government Level
- Debris

Lessons From Earthquake Early Warning System

- The System Worked to Stop 88 Shinkansen Trains and Notify Public
- Challenged by Multi-Segment Event
- EEW Must Survive and Continue to Function During Event and Aftershock Sequence
- More Than Hardware & Analysis Algorithms, Message Content Is Critical to Reinforce Education
- Most Effective at Distant Locations and for Aftershocks
- Many Post 3-11 "False Alarms"

Preparedness & Response Lessons

- Some Lessons About Tsunami History Forgotten Over Time
- Loss of Telephone, Internet Communication and Overload of Satellite Phones. SDF Eventually Provided Radio Com
- First Response, as in Most Disasters, was Local, By Survivors
- Need to Test and Exercise Priority Setting and Unified Command
- Need to Build Partnerships with NGO Sector Organizations and Community

- Expand and Formalize Local and Prefecture Mutual Aid Systems
- Develop Volunteer Recruitment and Credential Verification Systems
- Develop Donations Management Systems
- Need to Build a Culture of Preparedness
- Majority of Victims Were Communities' Most Vulnerable Residents
- Need to Plan for the Possible, Not Just the Probable. How to Quantify Outliers & Uncertainty in Determining Risk?
- …and If You Can't Clear and Process Debris, You Can't Respond or Recover


Photos: T. Norton, S. Chang