KISR

معهد الكويت للأبحاث العلمية
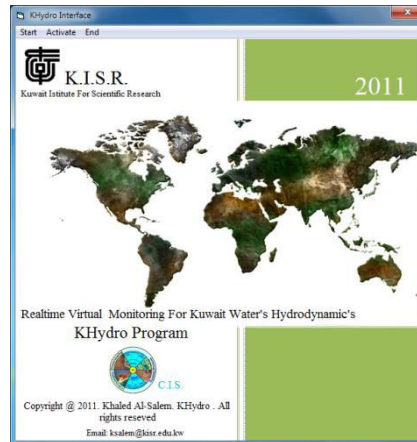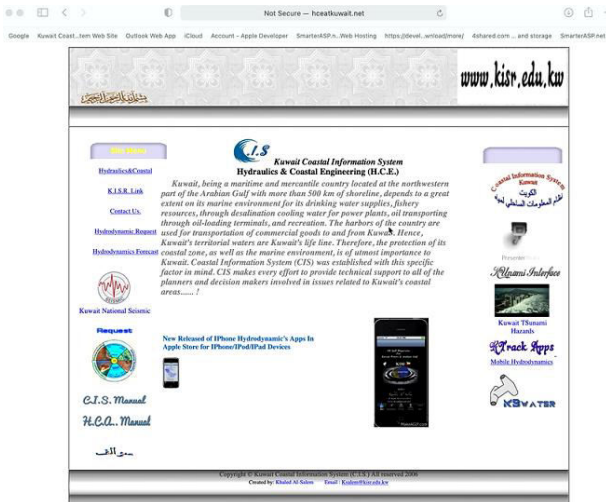KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH

Technical Report

الشبكة الكويتية لرصد الزلازل

Kuwait National Seismic Network
Monitoring seismic activities alerts for GCC cities

KNSN System
Khaled Al-Salem
Kuwait Institute for Scientific Research
2020
www.hceatkuwait.net
Email: ksalem@kisr.edu.kw

Introduction

Kuwait National Seismic Network (KNSN) started in March 1997 with the objectives of recording local, regional and teleseismic events as well as to assess the hazard those seismic events pose to the country. KNSN consists of eight field stations that performed to characterize seismic sources.

Figure 1. KNSN control Center

Objective

Kuwait National Seismic [KNSN], it is a monitoring seismic activities alert for GCC cities the objectives of recording local, regional and teleseismic events as well as to assess the hazard those seismic events pose to the country.

- o KNSN alert operator can setup or broadcast new earthquake events at [http://www.hceatkuwait.net/KNSNset.aspx]
- o KNSN alert system work three operation system:
    - Online Internet website [*http://www.hceatkuwait.net/KNSN.aspx*]
      By [*Active Server Script Page Coding*]
    - Mobile apps [IPhone/Ipad] [*KNSN apps*]
      By [*Objective-C$_{++}$ coding*]
    - Local operation system [Window base] [*Khydro model*]
      By [*Visual Base Coding*]

THEORETICAL ANALYSIS

The information regarding the PGA characteristic caused by earthquake can be obtained from the records of earthquake events in the past. The records of ground acceleration allow to extract the main characteristics from the ground motion recordings such as the peak ground velocity, can be calculated as the acceleration of the ground (ground acceleration) as well as the acceleration of earthquake on the ground surface. The PGA values can be calculated using the attenuation function. The attenuation function is a function that represents the coloration between the intensity of local ground movement (a), the earthquake's magnitude (M), and the distance between one point in the source of the earthquake (r). Experts has formulated Ground-Motion relationships with Earthquakes events can be analysis by data processing in this research consists of six steps which is

- 2D Grid development [up to 400/400 - 2D grids]
- Calculation of distance $D_{i,j}$ from the epicenter to the grid centroid.
- Computer application development.
- $PGA_{i,j}$ value calculation [Peak ground Acceleration]
- Plotting the PGA values in each of the 2D grid centroid on Google map.

- Development of hazard zone map using Kriging Algorithm.

The Earthquake energy is dispersed in waves from the hypocenter, causing ground movement omnidirectional but typically modeled horizontally (in two directions) and vertically. PGA records the acceleration (rate of change of speed) of these movements, while peak ground velocity is the greatest speed (rate of movement) reached by the ground, and peak displacement is the distance moved. These values vary in different earthquakes, and in differing sites within one earthquake event, depending on a number of factors. These include the length of the fault, magnitude, the depth of the quake, the distance from the epicenter, the duration (length of the shake cycle), and the geology of the ground (subsurface). Shallow-focused earthquakes generate stronger shaking (acceleration) than intermediate and deep quakes, since the energy is released closer to the surface. Peak ground acceleration can be expressed in fractions of g (the standard acceleration due to Earth's gravity, equivalent to g-force) as either a decimal or percentage; in m/s2 (1 g = 9.81 m/s2); or in multiples of Gal, where 1 Gal is equal to 0.01 m/s² (1 g = 981 Gal).

Methodology

2D Grids with up to 400 x 400 square with a total of 160000 grids covering all of the area and surroundings the Epicenter of the earthquake , each grid is determined by the centroid. The distance from the epicenter to the grid centroid is calculated by comparing the epicenter coordinate grid centroid and the following equation:

$$D = \sqrt{(A_{long} - B_{long})^2 + (A_{lat} - B_{lat})^2} \qquad [1]$$

Where:

$D_{i,j}$: is the distance from the epicenter earthquake to the centroid of grid (Km).

A_{long} : Longitudinal coordinate of the epicenter earthquake [deg]

B_{long} : Longitudinal coordinate of the grid centroid [deg].

A_{lat} : Latitude of the epicenter earthquake [deg].

B_{lat} : Latitude of the grid centroid.

The Peak Ground Acceleration [PGA] value is calculated using two global attenuation functions which is adopted from [1] and the local attenuation function from [2]. The equation of Youngs' attenuation function can be elaborated as follows:

[For Rock]

$$\ln(PGA)=0.2418+1.414M+C1+C2(10-M)^3+C_3 \ln(r_{rup}+1.7818e0.554M)+0.0060H+ 0.3846Z_r \qquad [2]$$

[For Soil/sand]

$$\ln(PGA) = -0.6687 + 1.438M + C_1 + C_2(10 - M)^3 + C_3 \ln(R + 1.097e^{0.617M}) + 0.00648H + 0.3643Z_r$$

Where

$PGA_{i,j}$: is the peak ground acceleration (gals) value.

M : is the earthquake magnitude value (Richter Scale) [M_w].

$Rup_{i,j}$: is the horizontal distance from the epicenter earthquake to the grid centroid[km]

H: is the depth of the earthquake center [Km].

Zr :is the type of epicenter (0 for interface and 1 for intraslab)

C1,C2, C3 represent the regression coefficient from the function

(C1 and C2 value 0 and C3 = -2.552)

Figure 2 display sample of 2D peak ground acceleration around epicenter with 2D grid [100x100] used by the three operation system.

Correlation with the Mercalli scale

The United States Geological Survey developed an Instrumental Intensity scale, which maps peak ground acceleration and peak ground velocity on an intensity scale similar to the felt Mercalli scale. These values are used to create shake maps by seismologists around earthquake. As shown in Table 1.

Table 1

Instrumental Intensity	Acceleration (g)	Velocity (cm/s)	Perceived shaking	Potential damage
I	**< 0.0017**	< 0.1	Not felt	None
II–III	**0.0017 – 0.014**	0.1 – 1.1	Weak	None
IV	**0.014 – 0.039**	1.1 – 3.4	Light	None
V	**0.039 – 0.092**	3.4 – 8.1	Moderate	Very light
VI	**0.092 – 0.18**	**8.1 – 16**	Strong	Light
VII	0.18 – 0.34	**16 – 31**	Very strong	Moderate
VIII	0.34 – 0.65	**31 – 60**	Severe	Moderate to heavy
IX	0.65 – 1.24	**60 – 116**	Violent	Heavy
X+	> 1.24	**> 116**	Extreme	Very heavy

Figure 2. 2D display on Google map on Khydro model, KNSN website and KNSN apps.

2D Grid System Cover Epicenter Location

No. Of 2D grid [up to 400X400 grids] that cover the epicenter of the earthquake.
Figure 2A display the 2D grid around Epicenter
Each grid resolution in X and Y direction are calculated based on

$$Grid - X = \frac{ABS[Long_{epicenter} - Long(X_{alert\ location}]}{No\ of\ grid}$$

$$Grid - Y = \frac{ABS[Lat_{epicenter} - Lat(Y_{alert\ loation})]}{No\ of\ grid}$$

Where
$Long_{epicenter} - Long(X_{alert\ location}) = 3\ degree$
$Lat_{epicenter} - Lat(Y_{alert\ loation}) = 3$ degree
No of grid from 10 to 200 grids
Total 2D Grid for the simulated domain will be [No of Grid*2 X No of Grid*2]
Approximate Grid resolution if (No of grid=200)
   Grid-x =1470 m
   Grid-y= 1666 m
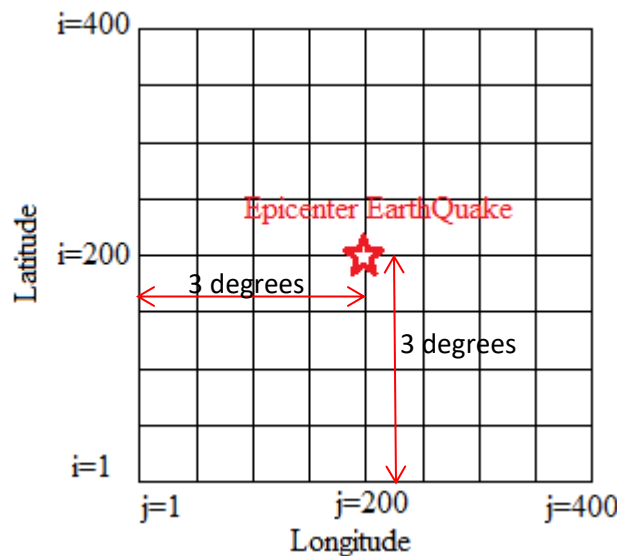
Figure 2A

KNSN alert Operator for setup or broadcast new earthquake events.

KNSN system Demonstration
Internet Website Version
[http://www.hceatkuwait.net/KNSNset.aspx
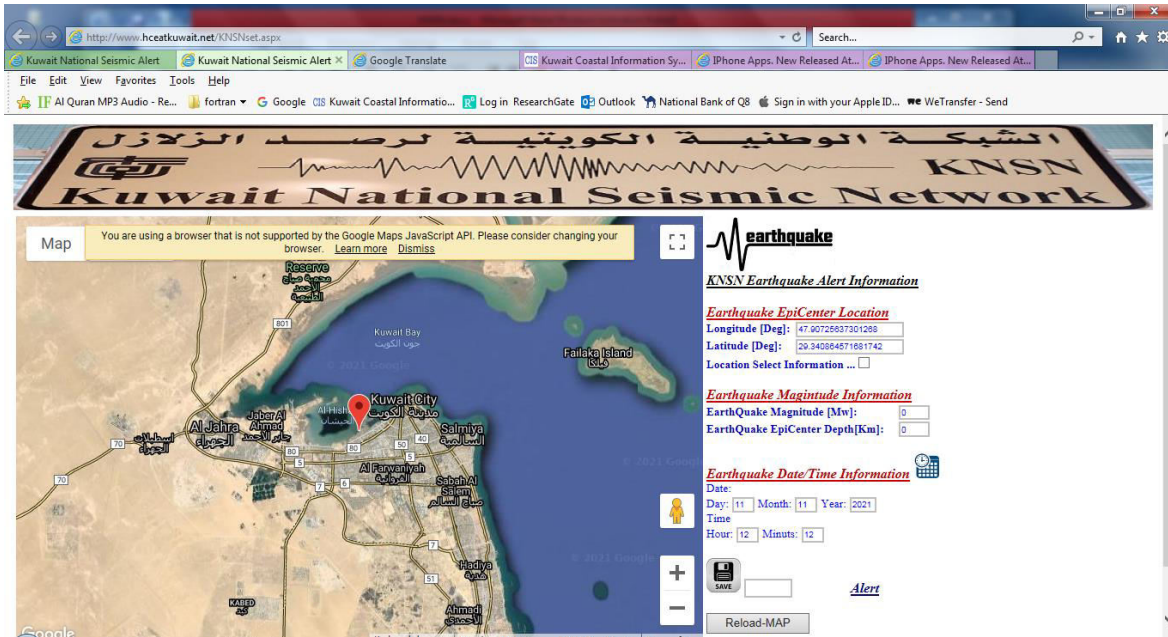
Figure 3. Operator control website main page for setting up new events.

This section is for KNSN system Operator for broadcast earthquake event .
 From [hcatkuwait.net] as shown in Figure 4. Then must select [⊙] to redirect to KNSN system as shown in Figure 5.
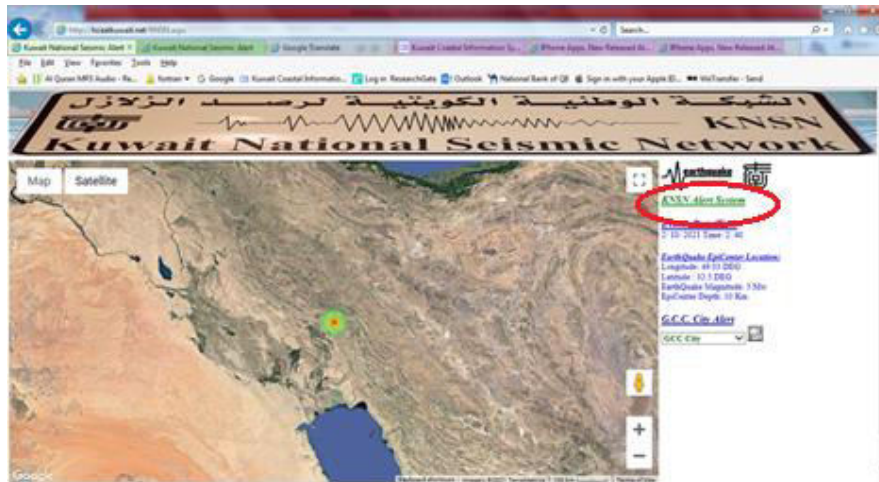

Figure 4

Figure 5

Then from Figure 5 user must select [*KNSN Alert System*] to redirect to KNSN setup page for operator as shown in Figure 3.

To setup new earthquake events operator must enter the following earthquake information as:

- Earthquake Epicenter Location in [Longitude/Latitude] deg.

  To enter location user must **Check** [Location Select Information ... ☐]

  Then select location by two ways as:
  - (1) Manually enter Longitude/Latitude in deg.
  - (2) By click on Google map as shown in Figure 6

  Then to set the selected location use must **Un-Check** [Location Select Information ... ☐]

  To check select location by [Reload-MAP]

- Earthquake Magnitude [Mw]
- Date [day/month/year]
- Time [hour/minutes]
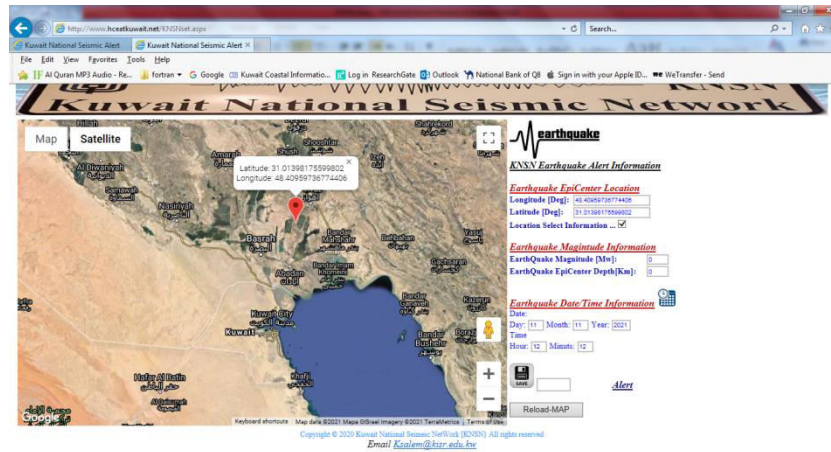
Figure 6

Then user must enter the password to save and broadcast the Earthquake events for Public Alert

at [SAVE _____] as shown in Figure 6.

KNSN alert Display new broadcast earthquake event by remote internet website

KNSN system Demonstration
Internet Website Version
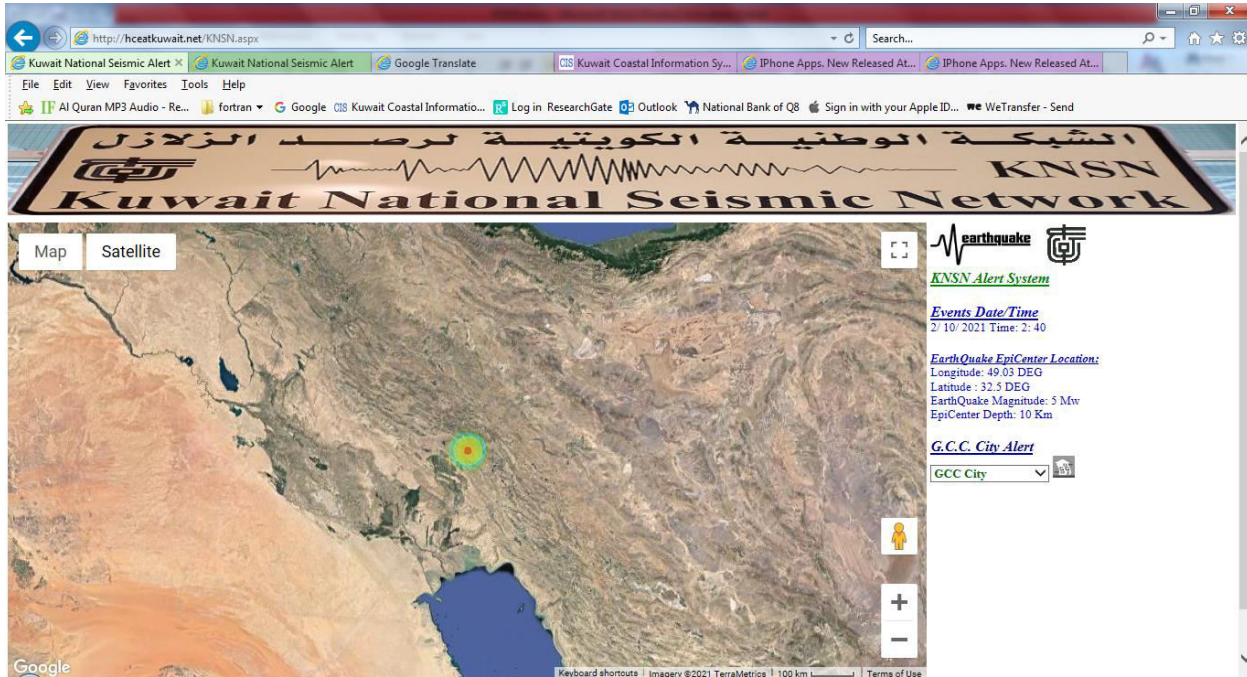[http://www.hceatkuwait.net/KNSN.aspx]

Figure 7

This section is for KNSN system to display earthquake event .
From [hcatkuwait.net] as shown in Figure 8. Then must select [⟩⟨] to redirect to KNSN system as shown in Figure 7.
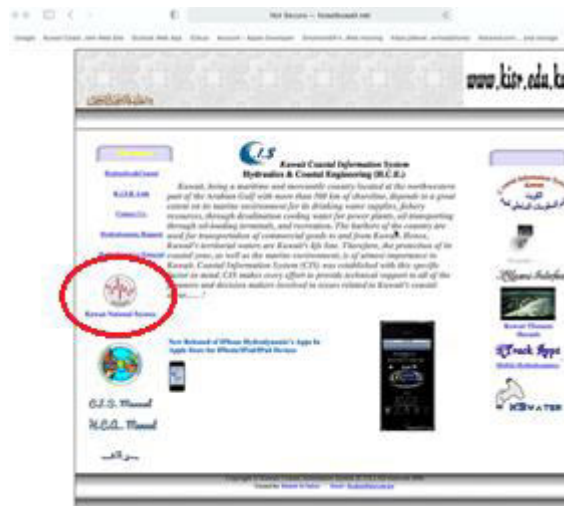

Figure 8

Figure 7 display through the internet any newly broadcast Earthquake event published by the KNSN operator. It display the following event parameters as follows:

- Event Date and Time
- Event Epicenter Location
- Event Magnitude
- Event Epicenter Depth

Figure 7 display 2D hazard shake maps from event around earthquake on Google map.
Map will be updated every certain time.
To analysis GCC cities from hazard shake due to earthquake events. From Figure 7 user must

select from Dropdown list as shown in Figure 9 a city to hazard analysis then click on [ ]

Figure 9

Figure 10 display earthquake hazard analyses based on table 1 as follows:

- Epicenter Earthquake Distance: km
- Mercalli scale Intensity:
- Peak Ground Acceleration: gal
- Velocity: cm/s
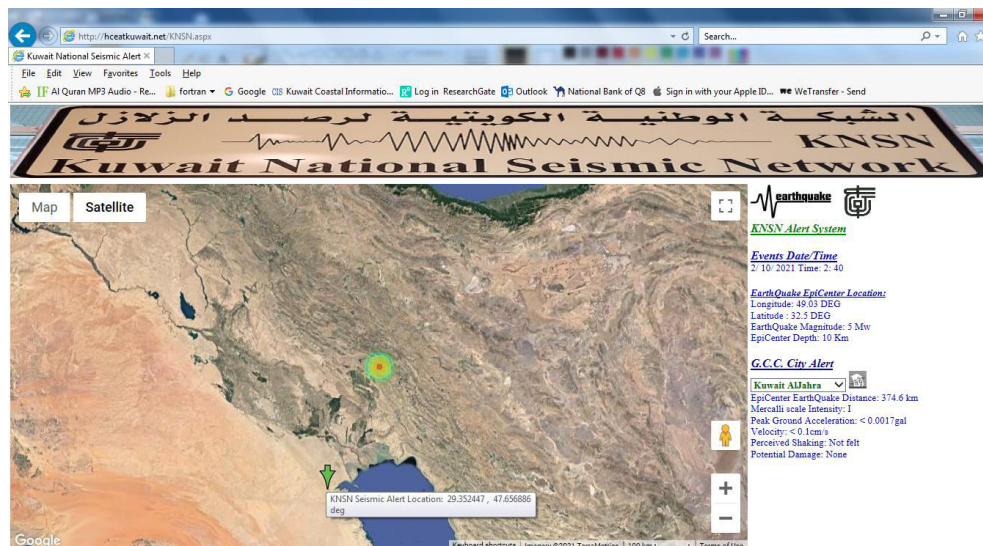- Perceived Shaking:
- Potential Damage:

Figure 10

KNSN alert Display New Broadcast Earthquake Event on Local Window system

KNSN system Demonstration
P.C. Version
[*Khydro model*]

KNSN Alert system display earthquake event by local window operation system using Khydro model for Virtual Mentoring system as shown in Figure 11. KHydro model consist of monitoring system for the following:

- Online Monitoring System for Hydrodynamics' parameters
- Online Monitoring System for Seismic events activies
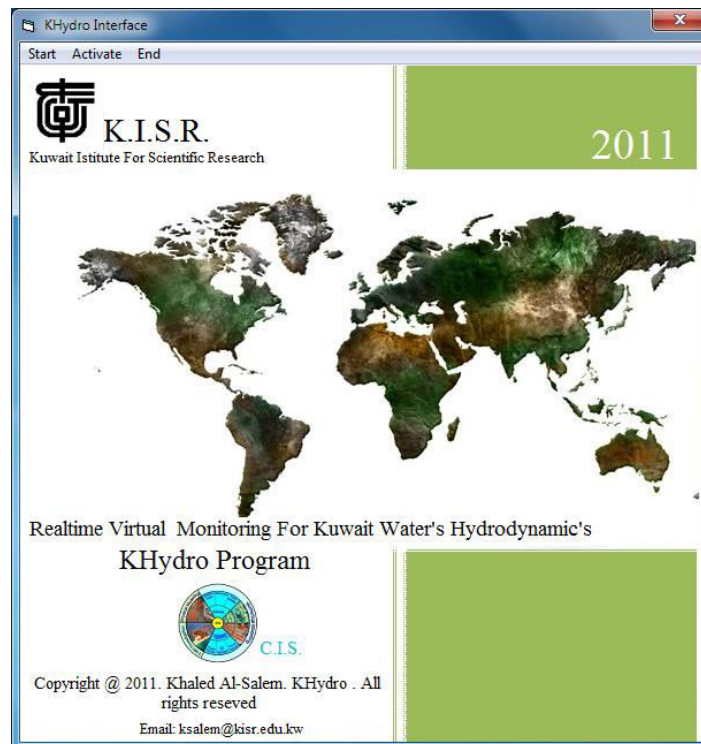
Figure 11

From Figure 11 user must select [**START**] then dropdown list will show for user to select. User select [**SEISMIC**]. Then Figure 12 will display the following:

- 2D hazard Google map at epicenter
- Events Information
    - o Event Date and time
    - o Epicenter [Longitude and Latitude] deg
    - o Earthquake Magnitude
    - o Epicenter Depth
- BY default [Kuwait City Monitoring]
    - o Distance from Epicenter Earthquake to select location
    - o Mercalli scale Intensity [As shown in table 1]
    - o Peak Ground Acceleration at select alert location

- o Velocity
- o Perceived Shaking
- o Potential Damage

Figure 12

To analysis the event hazard of different location from hazard shake due to earthquake events. From Figure 12 at the red circle user must check-in the square box.
Then new information will display as shown in Figure 13

Figure 13

Figure 13 displays [***KNSN Alert Monitoring Location***] to setup new location and a number input parameter as follow:

- Monitoring Location [Longitude / Latitude] deg.
  To enter the new alert location by
    - Manually enter location
    - Click on Google map to Longitude and Latitude data
- Type of Epicenter
  From dropdown list there are two type for calculation the hazard as:
    - Intraslab
    - Interface
- No. Of 2D grid [up to 400X400 grids]
  Figure 14 display the 2D grid around Epicenter
  Each grid resolution in X and Y direction are calculated based on

$$Grid - X = \frac{ABS\left[Long_{epicenter} - Long(X_{alert\ location}\right]}{No\ of\ grid}$$

$$Grid - Y = \frac{ABS\left[Lat_{epicenter} - Lat(Y_{alert\ loation})\right]}{No\ of\ grid}$$

Where
$Long_{epicenter} - Long(X_{alert\ location}) = 3\ degree$
$Lat_{epicenter} - Lat(Y_{alert\ loation}) = 3$ degree
No of grid from 10 to 200 grids
Total 2D Grid for the simulated domain will be [No of Grid*2 X No of Grid*2]
Approximate Grid resolution if (No of grid=200)
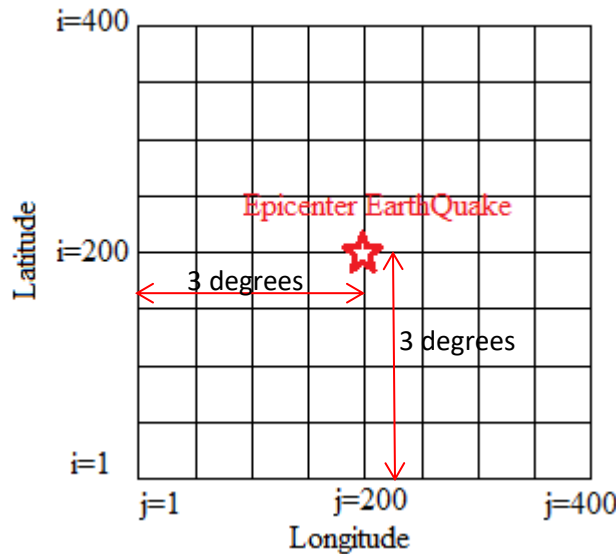   Grid-x =1470 m
   Grid-y= 1666 m

Figure 14

- Google map Zoom Factor
- Monitoring Time Interval [in minutes up 60 minutes]
- Online Monitoring ON/OFF [Check-in]
- Line Contour map ON/OFF [Check-in]

To create HTML file for 2D hazard map on Google user must select [Save HTML].
Figure 15 shows sample of snap script code of HTML file created by the model and Google map

```
<!DOCTYPE html>
<html>
 <head>
  <meta http-equiv='content-type' content='text/html;charset=utf-8'/>
  <meta http-equiv='X-UA-Compatible' content='IE=edge'>

   <title>Kuwait National Seismic NetWork</title>
   <style>
    #map {
      height: 100%;
    }
    html, body {
      height: 100%;
      margin: 0;
      padding: 0;
    }
    #floating-panel {
      background-color: #ffff;
      border: 1px solid #999;
      left: 1%;
      padding: 5px;
      position: absolute;
      top: 45px;
      z-index: 5;
    }
    #floating-panel2 {
      background-color: #ffff;
      border: 1px solid #999;
      left: 5%;
      padding: 5px;
      position: absolute;
      top: 60px;
      z-index: 5;
    }
    #tv2 {
      background-color: #ACE1AF;
    }
    #tv4 {
      background-color: #ffa812;
    }
    #tv6 {
      background-color: #c41e3a;
```
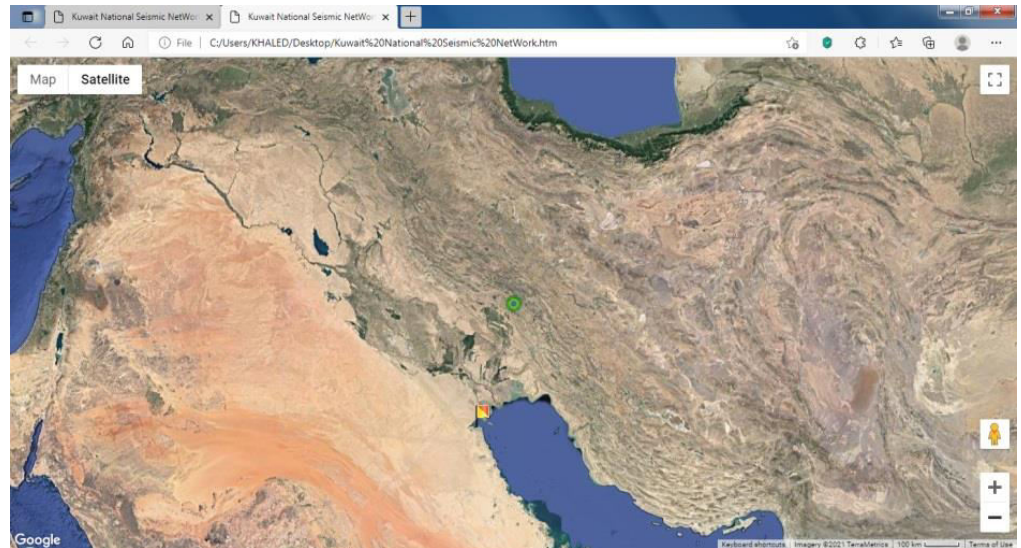

Figure 15

KNSN Alert Display New Broadcast Earthquake Event by Smart Device.

KNSN system Demonstration
Mobile Version
[KNSN Apps]
http://hceatkuwait.net/request/Data_iphone.htm

KNSN Alert system display earthquake event by Smart Mobile Operation System [IPhone/IPad] for Virtual Mentoring system as shown in Figure 16. KNSN Apps consist of monitoring system for new broadcast Earthquake events by KNSN operator.

Figure 16

Figure 16 display for user to select type of monitoring display [English / Arabic display] as shown in Figure 17.

User select [***Alert or*** أنذار] at [earthquake] To start Event mentoring then Figure 17 will display. Figure 17 display a number of information which are:
- 2D hazard Google map at epicenter
- Events Information
  - Event Date and time
  - Epicenter [Longitude and Latitude] deg.

- o Earthquake Magnitude
- o Epicenter Depth
- • BY default [Kuwait City Monitoring]
  - o Distance from Epicenter Earthquake to select location
  - o Mercalli scale Intensity [As shown in table 1]
  - o Peak Ground Acceleration at select alert location
  - o Velocity
  - o Perceived Shaking
  - o Potential Damage
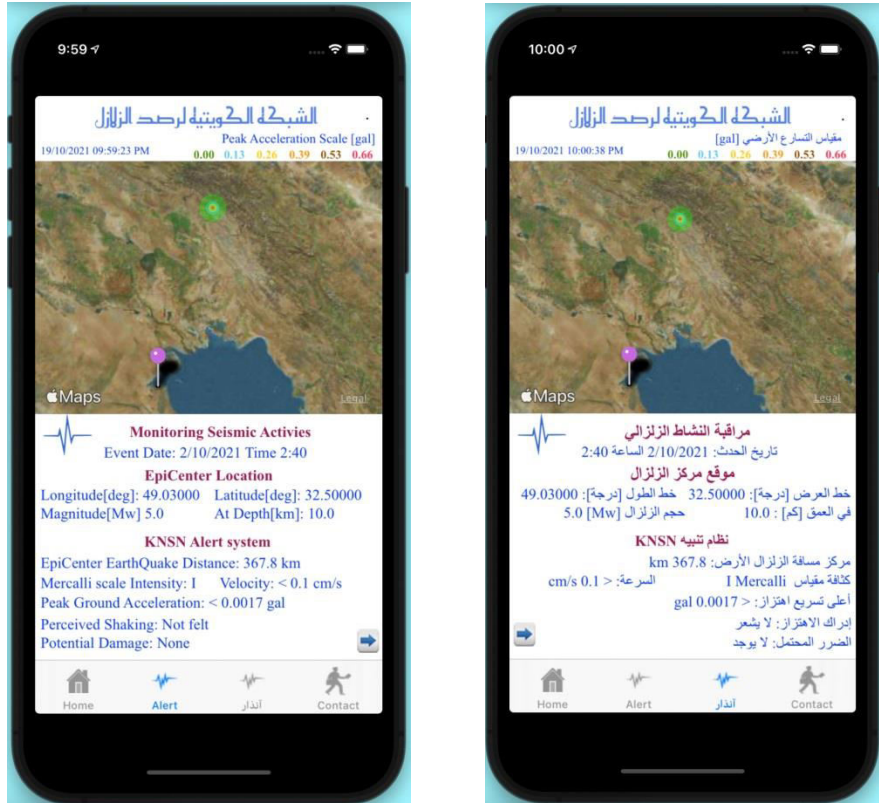
Figure 17

To analysis the event hazard of different location from hazard shake due to earthquake events.

From Figure 17 user must select [ ] to display new setup information as shown in Figure 18 For the following parameters:

- • Monitoring Location [Longitude / Latitude] deg.
  To enter the new alert location by
  - o Manually enter location
  - o Click on Google map to Longitude and Latitude data
- • Type of Epicenter
  From dropdown list there are two type for calculation the hazard as:
  - o Intraslab

- o Interface
- No. Of 2D grid [up to 400X400 grids]
  Figure 14 display the 2D grid around Epicenter
  Each grid resolution in X and Y direction are calculated based on

$$Grid - X = \frac{ABS\left[Long_{epicenter} - Long(X_{alert\ location}\right]}{No\ of\ grid}$$

$$Grid - Y = \frac{ABS\left[Lat_{epicenter} - Lat(Y_{alert\ loation})\right]}{No\ of\ grid}$$

Where

$Long_{epicenter} - Long(X_{alert\ location}) = 3\ degree$
$Lat_{epicenter} - Lat(Y_{alert\ loation}) = 3$ degree
No of grid from 10 to 200 grids
Total 2D Grid for the simulated domain will be [No of Grid*2 X No of Grid*2]
Approximate Grid resolution if (No of grid=200)
  Grid-x =1470 m
  Grid-y= 1666 m

Figure 14

- Google map Zoom Factor [⊖ or   manually   or   ⊕]
- Line Contour map ON/OFF [Check-in]
- Take snap shot of Google map for Sending data [Email or Whatsapp]
- Create HTML file for 2D events plot on Google map for send data [Email or Whatsapp]
- Clean Google map from all PINS drop
- Current Location ON/OFF [Check-in]

- Change ALPHA Color of the Contour on Google map [⊖   ⊕]

Figure 19 display an example for check the new hazard location close to Epicenter.

Figure 18

Figure 19

User can send data by :
  o Email with and attachment [Google map image and HTML file created]
  o Whatapps can only send [Google map Image]

From 19 user can select [ ] to display the data transfer page as shown in Figure 20.

Where Figure 21 display the data transfer methods [Email or Whatsapps]
Figure 22 show sample of snap script code of HTML file created by the model and Google map

Figure 20

Figure 21. Data Transfer by Whatsapp and Email

```html
<!DOCTYPE html>
<html>
 <head>
 <meta http-equiv='content-type' content='text/html;charset=utf-8'/>
 <meta http-equiv='X-UA-Compatible' content='IE=edge'>

  <title>Kuwait National Seismic NetWork</title>
  <style>
   #map {
     height: 100%;
    }
   html, body {
     height: 100%;
     margin: 0;
     padding: 0;
    }
   #floating-panel {
     background-color: #ffff;
     border: 1px solid #999;
     left: 1%;
     padding: 5px;
     position: absolute;
     top: 45px;
     z-index: 5;
    }
   #floating-panel2 {
     background-color: #ffff;
     border: 1px solid #999;
     left: 5%;
     padding: 5px;
     position: absolute;
     top: 60px;
     z-index: 5;
    }
   #tv2 {
     background-color: #ACE1AF;
    }
   #tv4 {
     background-color: #ffa812;
    }
   #tv6 {
     background-color: #c41e3a;
```
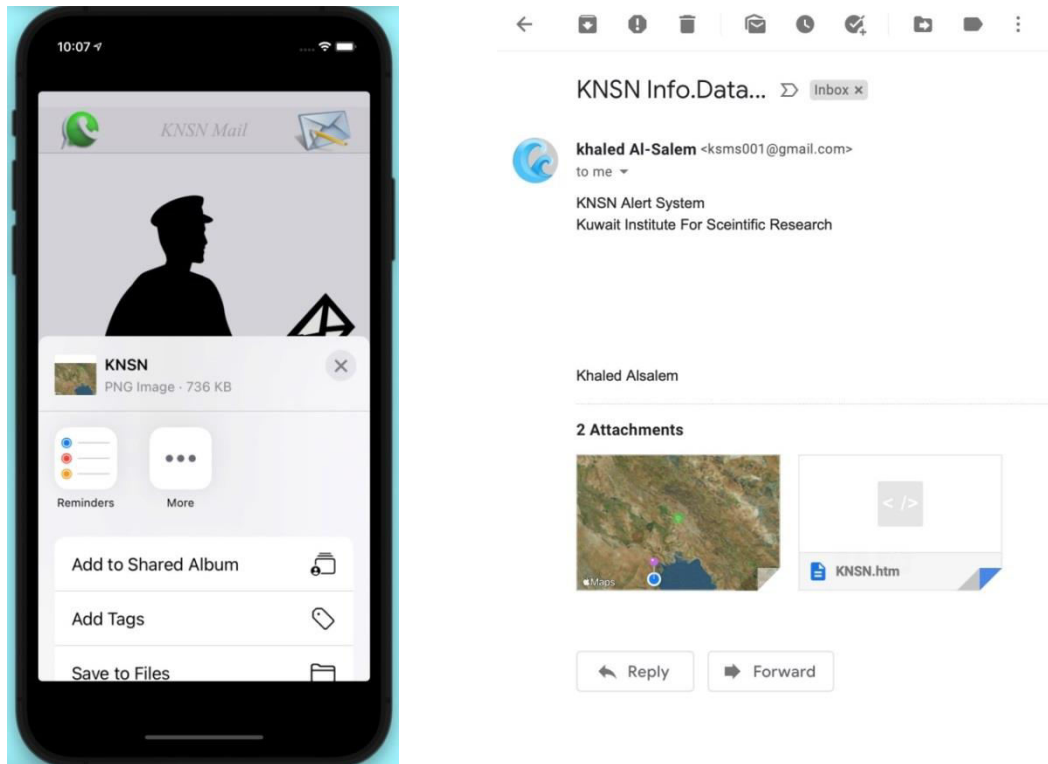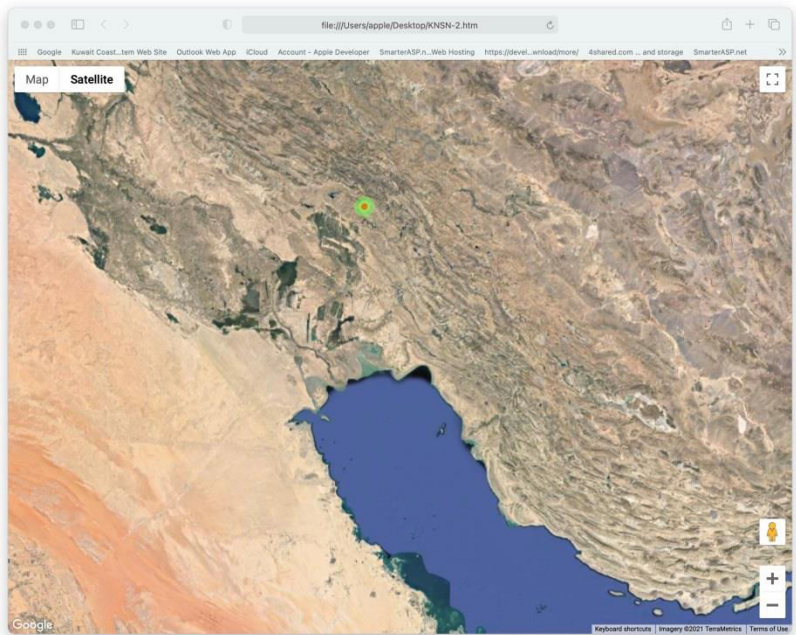

Figure 22

From Figure 16 user can display a description of KNSN control section by click of KISR image at [🔲]. Then Figure 23 will display in [English and Arabic description display].

Figure 23

Reference

[1] Youngs et al 1997 Strong Ground Motion Attenuation Relationship For Subduction Zone Earthquake.pdf. (n.d.).

[2] Megawati K, Pan TC, Koketsu K 2005 Response spectral attenuation relationships for Sumatran-subduction earthquakes and the seismic hazard implications to Singapore and Kuala Lumpur. *Soil Dynamics and Earthquake Engineering,* vol.25, no.1, pp11-25.