A Look at School Buildings with Resilience in Mind

Presented by:

Todd Hanger | AIA, LEED AP BD+C
Megan Saunders | LEEP AP BD+C
Mark Madorsky | P.E., CXA, LEED AP BD+C

April 7, 2018
"A Look at School Buildings with Resilience in Mind"

• Educational Facilities are asked to serve our communities in many ways.

  • Operational 24/7/365
  • Provide Next Generation learning opportunities
  • Provide physical and mental health and well-being
  • Community experiences within the arts, sciences and competition sports
  • Critical Facilities that provide shelter and rescue from natural and man-made disasters
Learning Objectives:

1. Steps towards a threats and hazards assessment
2. Resilient design strategies for building systems
3. Resilient design strategies for site and building design
4. Resilient design strategies for human health and well-being protection
Resources

C3 Living Design Project - RELi
U.S. Green Building Council (USGBC)
ASCE – PRISM Infrastructure Resilience
Envision - Institute for Sustainable Infrastructure
Zofnass Program for Sustainable Infrastructure (Harvard)
Financial System Resilience Index (NEF)
2030 Challenge / SB2030
International Living Future Institute
Living Future
Living Building Challenge
Autodesk
2030 Palette: Design and Planning Strategies
Disaster Safety
TornadoHistoryProject
Illinois State Geological | ISGS
Red Cross

FEMA P-320, Taking Shelter from the Storm: Building a Safe Room
FEMA P-361, Safe Rooms for Tornadoes and Hurricanes
FEMA-428, Design Safe School Projects in Case of Terrorist Attacks and School Shootings
NFPA 909: Code for the Protection of Cultural Resource
NFPA 13: Standard for the Installation of Sprinkler Systems
NIST Special Publication 1190
Community Resilience Planning Guide

ASCE 7-10 American Society of Civil Engineers (ASCE) 2010. Minimum Design Loads For Buildings and Other Structures.
FEMA P-750 NEHRP Recommended Seismic Provisions for New Buildings and Other Structures
FEMA P-908. Mitigation Assessment Team Report
IRC International Residential Code.
NOAA National Weather Service, National Hurricane Center.
Resilient Design & shared attributes

Resilience = a unified preparedness to withstand, adapt and recover from Shocks and Stresses

Shocks = Short-term Threats & Hazards (natural and man-made)
Stresses = Long-term Adversities (generational)

Project viewed as a diverse system of systems

Ability to bounce back from adversities

Ability to thrive forward through
  • Learning
  • Adapting
  • Changing
## Shocks: short-term threats & hazards

<table>
<thead>
<tr>
<th>Natural</th>
<th>Technological</th>
<th>Human-Caused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avalanche</td>
<td>Airplane crash</td>
<td>Biological attack</td>
</tr>
<tr>
<td>Animal disease outbreak</td>
<td>Dam Failure</td>
<td>Chemical attack</td>
</tr>
<tr>
<td>Drought</td>
<td>Levee Failure</td>
<td>Cyber incident</td>
</tr>
<tr>
<td>Earthquake</td>
<td>Mine accident</td>
<td>Explosives attack</td>
</tr>
<tr>
<td>Epidemic</td>
<td>Hazardous materials release</td>
<td>Radiological attack</td>
</tr>
<tr>
<td>Flood/Flash Flooding</td>
<td>Power failure</td>
<td>Sabotage</td>
</tr>
<tr>
<td>Hurricane</td>
<td>Radiological release</td>
<td>Active shooter</td>
</tr>
<tr>
<td>Landslide</td>
<td>Train derailment</td>
<td></td>
</tr>
<tr>
<td>Pandemic</td>
<td>Urban conflagration</td>
<td></td>
</tr>
<tr>
<td>Tornado</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tsunami</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volcanic eruption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wildfire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter storm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Natural** threats are those that occur naturally, without human intervention.
- **Technological** threats involve human-made systems failing or being deliberately attacked.
- **Human-Caused** threats are those initiated by human actions.
## Stresses: Long Term Adversity & Hardship

<table>
<thead>
<tr>
<th>Natural</th>
<th>Technological</th>
<th>Human-Caused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>Hazardous materials release</td>
<td>Decreasing population/Unemployment</td>
</tr>
<tr>
<td></td>
<td>Historical power failure</td>
<td>population/Affordable housing</td>
</tr>
<tr>
<td></td>
<td>Radiological release</td>
<td>Increasing population/Affordable</td>
</tr>
<tr>
<td></td>
<td>Aging Infrastructure</td>
<td>housing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socioeconomic divisions</td>
</tr>
</tbody>
</table>
Systems Thinking

• **Multiple Systems** make up the Structure for the whole project.

• **The interactive relationships** between multiple system elements and the holistic system enable a project to achieve resilience.
Integrative Design Approach

• View project as a living-system
• Redundancy and diversity
• Assemble the best team (co-learners)
• Engage the Owner (Goal Setting Session)
• Align around common goals
• Pick a Performance Metric
• Looking at Cost and Schedule
• Research
• Look for synergies
• Maximizing efficiencies and decision making
• How can educational facilities become resilient contributors within their community?

• What are the core concepts for designing a resilient building?
Task #1 – IDENTIFICATION & ASSESSMENT

- Identify relevant **Shocks** – Threats & Hazards (deliberate and natural)
- Identify relevant **Stresses** – Long-term adversities
- Assemble a Threats & Hazards Assessment
Task #1 – IDENTIFICATION & ASSESSMENT

How do we do this? Use your resources:

https://www.fema.gov/national-preparedness-system (national preparedness- CPG 101)
https://www.fema.gov/national-preparedness-system (national preparedness- CPG 201)
www.disastersafety.org (natural shocks)
www.fema.gov (flood risk maps)
http://www.noaa.gov/ (floods, tornados, hurricanes, earthquakes)
https://gacc.nifc.gov/ (USDA – wildfires)
www.airnow.gov (EPA)
http://www.tornadohistoryproject.com/tornado/Texas/2016/map
Discover the risks you face.

Click your state on the map or enter your Zip Code below.

77005  GO

Results highlighted below↓
Tornadoes in Texas in 2016

Year: 2016  Month: all  Day: all  State: Texas  Fujita: all  County: all

100 tornadoes found

Related Searches
- Texas, 2016
- Texas, 2015
- Texas, 2014
- Texas, 2013
- Texas, 2012

Summary
<table>
<thead>
<tr>
<th>Date(s) (yyyy-mm-dd)</th>
<th>Tornadoes</th>
<th>Fatalities</th>
<th>Highest Fatalities</th>
<th>Injuries</th>
<th>Highest Injuries</th>
<th>Longest Path</th>
<th>Widest Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-02-23 - 2016-09-17</td>
<td>100</td>
<td>1 person</td>
<td>1 person</td>
<td>10 people</td>
<td>5 people</td>
<td>25.94 miles</td>
<td>3221 yards</td>
</tr>
</tbody>
</table>
Figure 2. Principal faults in the Houston metropolitan area as observed from 15-foot bare-earth LiDAR-derived digital elevation model (DEM).
Current Conditions

Air Quality Index (AQI) observed at 21:00 CDT

**Moderate**

Health Message: Unusually sensitive people should consider reducing prolonged or heavy exertion outdoors.

AQI - Pollutant Details

- Ozone: **71** (Moderate)
- Particles (PM2.5): **49** (Good)

Air Quality Forecast

**Today**: Moderate

Health Message: Unusually sensitive people should consider reducing prolonged or heavy exertion outdoors.

**Tomorrow**: Moderate

Health Message: Unusually sensitive people should consider reducing prolonged or heavy exertion outdoors.

AQI - Pollutant Details

- Ozone: Moderate (Today) - Moderate (Tomorrow)
- Particles (PM2.5): Good (Today) - Good (Tomorrow)
### NFPA Threats Assessment

#### POTENTIAL THREATS ASSESSMENT

<table>
<thead>
<tr>
<th>Unintentional Act</th>
<th>Likelihood of Occurrence</th>
<th>Potential Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire/explosion</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Health emergency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazardous material spill or release</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation accident</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intentional Act</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terrorism</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Cyber attack</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Arson</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Theft</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Vandalism</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Sabotage</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Civil disturbances, public unrest, mass hysteria, riot</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Strike</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>System Failure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of electricity</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Water leak</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Building collapse/structural failure</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Fuel shortage</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Communications system interruption</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Air/water pollution contamination</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Water control structure, dam, or levee failure</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>HVAC system failure</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Loss of protection systems</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Geological</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earthquake</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tsunami</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Volcano</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Landslide/mudslide</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Biological</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pandemic disease</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Animal or insect infestation</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Meteorological</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood, flash flood, seiche, tidal surge</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Drought</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Wild fire (forest, range, urban)</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Snow, ice, hail, sleet, avalanche</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Windstorm, tropical cyclone, hurricane, tornado, water spout, dust/sand storm</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Extreme heat/cold</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Lightning</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>

#### NFPA 909, Code for the Protection of Cultural Resource Properties
- Museums, Libraries, and Places of Worship
Task #2 – CONTEXT & EFFECTS

- Describe Threats & Hazards of concern, showing how they may affect the community
- What are the different impacts depending on the time, place, and conditions?
- What have been past experiences with threats and hazards?
- How might future experiences with threats & hazards differ due to changes in demographics, climate, and the built environment?

What is the estimated recovery time?
- Past experiences
- Recovery sequence

What is the estimated cost?
- Materials to restore & adapt
- Manpower
## Assessment Matrix

<table>
<thead>
<tr>
<th>SHOCK</th>
<th>STRESS</th>
<th>LIKELIHOOD (1-3)</th>
<th>IMPACT (1-3)</th>
<th>RECOVER TIME (hrs-days)</th>
<th>COST (1-3)</th>
<th>IMPORTANCE FACTOR (1-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td></td>
<td>3</td>
<td>3</td>
<td>14 days</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Earthquake</td>
<td></td>
<td>1</td>
<td>1</td>
<td>~</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tornado</td>
<td></td>
<td>1</td>
<td>2</td>
<td>30 days</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Air Pollution</td>
<td></td>
<td>2</td>
<td>2</td>
<td>~</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Electricity Loss</td>
<td></td>
<td>1</td>
<td>1</td>
<td>4 hrs</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cyber Terrorism</td>
<td></td>
<td>1</td>
<td>2</td>
<td>24 hrs</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Intruder</td>
<td></td>
<td>1</td>
<td>3</td>
<td>8 hrs</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Social Division</td>
<td></td>
<td>3</td>
<td>3</td>
<td>~</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
Task #3 – TAKE ACTION

- Strategies for Existing Buildings
- Strategies for New Construction

Prevention, Protection, and Mitigation / Response and Recovery
Emergency Preparedness Planning

For Common Hazards and Extreme Events

• Develop **Emergency Operations Plan (EOP)** that outlines actions to be taken in the event of a crisis
  • Fire/Evacuation
  • Lockdown during acts of violence
  • Tornado/Severe Weather
  • Shelter in Place
  • Reverse Evacuation
• Communications
  • Emergency alert systems & Tornado sirens
  • Wi-Fi & Cellular networks
  • Radio
  • P.O.T.S. Phone
  • Satellite Phone

(The ability of a community to accelerate the recovery process begins with its efforts in pre-disaster preparedness)
Preferred Sites

Flood plain
- Avoid sites located in the 100-year flood plain
- Protect critical structures from the 500-year flood elevation
- Provide flood protection for existing buildings below 500-year flood elevation
- Avoid Coastal Zones inundated by 2’-6” of sea level rise or greater
- Locate electrical and mechanical equipment above the 500-year flood plain

Site Geology, Ecology, Biodiversity
- Avoid developing on green field sites
- Avoid sites located in environmentally sensitive areas
- Avoid sites with fault zones
- Prevent surface/ground water contamination (reduce pesticide/fertilizer reliance)
- Protect or Restore native habitats
- Protect or Restore/Create species biodiversity

Quality access to essential community operations and amenities
- First response
- Multiple points of access
- Multi-modal transportation
# Site Selection

## Site Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Cost</th>
<th>Cost/Acre</th>
<th>Facilities</th>
<th>Curriculum</th>
<th>Neighbors</th>
<th>Distance</th>
<th>Access</th>
<th>Electric</th>
<th>Gas</th>
<th>Data</th>
<th>Sewer</th>
<th>Water</th>
<th>Project Fit</th>
<th>Topography</th>
<th>Flood Plain</th>
<th>Features</th>
<th>Score</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. Bishop Rd.</td>
<td>$1,566,700</td>
<td>$25,269</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>3</td>
<td>Tertiary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Flat</td>
<td>None</td>
<td>Stream</td>
<td>1.10</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Veterans Dr.</td>
<td>$3,500,000</td>
<td>$50,000</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>2</td>
<td>Primary</td>
<td>3-ph</td>
<td>4H</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Flat</td>
<td>None</td>
<td>None</td>
<td>1.88</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>N Cactus Lane</td>
<td>$2,030,000</td>
<td>$35,000</td>
<td>Ball &amp; Park Hospital</td>
<td>Highway / Hospital</td>
<td>3</td>
<td>Second</td>
<td>3-ph</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>Slight</td>
<td>Adjacent</td>
<td>None</td>
<td>1.61</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11255 N Sparrow Lane</td>
<td>$2,000,000</td>
<td>$16,807</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>4</td>
<td>Tertiary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Slight</td>
<td>Adjacent</td>
<td>River</td>
<td>0.90</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>O Tolle Lane</td>
<td>$340,000</td>
<td>$6,071</td>
<td>None</td>
<td>Rail/Airport</td>
<td>2</td>
<td>Primary</td>
<td>3-ph</td>
<td>4H</td>
<td>cable</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>Flat</td>
<td>Adjacent</td>
<td>Stream</td>
<td>2.06</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>11251 E Ambassador</td>
<td>$1,700,000</td>
<td>$35,052</td>
<td>None</td>
<td>Rail /Highway</td>
<td>3</td>
<td>Primary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Flat</td>
<td>None</td>
<td>Lake</td>
<td>0.86</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>22 Fairway Drive</td>
<td>$950,000</td>
<td>$12,179</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>2</td>
<td>Tertiary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Rolling</td>
<td>Flood Way</td>
<td>Lake</td>
<td>0.98</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>42n &amp; richview Rd</td>
<td>$700,000</td>
<td>$9,859</td>
<td>None</td>
<td>Rail /Highway</td>
<td>2</td>
<td>Primary</td>
<td>3-ph</td>
<td>1OL</td>
<td>cable</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>Slight</td>
<td>Adjacent</td>
<td>None</td>
<td>2.25</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Wells By Pass</td>
<td>$1,364,760</td>
<td>$35,915</td>
<td>None</td>
<td>Rail /Highway</td>
<td>3</td>
<td>Primary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Slight</td>
<td>None</td>
<td>None</td>
<td>0.98</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>E Violet Rd.</td>
<td>$138,525</td>
<td>$3,744</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>6</td>
<td>Tertiary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Slight</td>
<td>Adjacent</td>
<td>None</td>
<td>1.12</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>County Farm Rd</td>
<td>$246,400</td>
<td>$3,200</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>4</td>
<td>Tertiary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Rolling</td>
<td>Adjacent</td>
<td>None</td>
<td>1.14</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Robin &amp; Stratford</td>
<td>$132,050</td>
<td>$3,773</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>7</td>
<td>Tertiary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Flat</td>
<td>None</td>
<td>None</td>
<td>1.06</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>13235 E Oakton</td>
<td>$120,000</td>
<td>$3,000</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>4</td>
<td>Tertiary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Hilly</td>
<td>Adjacent</td>
<td>None</td>
<td>0.94</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>N McCauley Lane</td>
<td>$110,000</td>
<td>$4,400</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>3</td>
<td>Tertiary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Hilly</td>
<td>None</td>
<td>None</td>
<td>0.92</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Veterans Dr.</td>
<td>$1,200,000</td>
<td>$30,000</td>
<td>Ball &amp; Park Hospital</td>
<td>None</td>
<td>3</td>
<td>Primary</td>
<td>3-ph</td>
<td>4H</td>
<td>fiber</td>
<td>12</td>
<td>8</td>
<td>2</td>
<td>Flat</td>
<td>Adjacent</td>
<td>None</td>
<td>1.96</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Wells By Pass</td>
<td>$1,500,000</td>
<td>$25,000</td>
<td>None</td>
<td>Rail /Highway</td>
<td>3</td>
<td>Primary</td>
<td>3-ph</td>
<td>4H</td>
<td>fiber</td>
<td>12</td>
<td>8</td>
<td>2</td>
<td>Slight</td>
<td>None</td>
<td>None</td>
<td>2.41</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Veterans Dr.</td>
<td>$1,750,000</td>
<td>$35,000</td>
<td>None</td>
<td>Hospital</td>
<td>None</td>
<td>3</td>
<td>Primary</td>
<td>3-ph</td>
<td>4H</td>
<td>fiber</td>
<td>12</td>
<td>8</td>
<td>2</td>
<td>Flat</td>
<td>Adjacent</td>
<td>None</td>
<td>1.98</td>
<td>4</td>
</tr>
</tbody>
</table>

*Estimated

## Weighting of Criteria

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Size</th>
<th>Cost/Acre</th>
<th>Facilities</th>
<th>Curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>55</td>
<td>$10,000</td>
<td>Ball &amp; Park Hospital</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>70</td>
<td>$20,000</td>
<td>Ball Fields</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>50</td>
<td>$30,000</td>
<td>Parking</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>45</td>
<td>$35,000</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dist. Access</th>
<th>Electric</th>
<th>Gas</th>
<th>Data</th>
<th>Sewer</th>
<th>Water</th>
<th>Topography</th>
<th>Flood Plain</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Primary</td>
<td>4H</td>
<td>fiber</td>
<td>12</td>
<td>12</td>
<td>Slight</td>
<td>None</td>
<td>Adjacent</td>
</tr>
<tr>
<td>2</td>
<td>Second</td>
<td>3-ph</td>
<td>10L</td>
<td>T1</td>
<td>8</td>
<td>Rolling</td>
<td>Adjacent</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>Tertiary</td>
<td>DSL</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>Flat</td>
<td>Flood Way</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>None</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>hills</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
Plan the Site

Building Orientation
Passive/Active Solar Strategies

Renewable Energy
Solar

Carbon Neutrality
Low Impact Development

- Protect/Restore natural features & native habitats
- Protect/Restore natural drainage patterns
- Protect prime farmland and floodplains
- Provide native plantings to minimize pesticides and surface/groundwater contamination
- Storm Water Pollution Prevention Plan (SWPPP)

- Minimize site disturbances
- Minimize total impervious area
- Disconnect impervious surfaces
- Bioretention and engineered soils
- Bioswales
- Rainwater harvesting
Low Impact Development

62 ACRES

natural waterway
Low Impact Development

2009

82 ACRES
Low Impact Development

- Practice
- Practice
- Practice
- Detention
- Competition
Elevated new building so that finish floor is 2’ above 500-yr BFE (100-yr flood plain)

Proposed flood wall to protect the existing science wing

Provide artificial turf in the central courtyard
Elevated electrical and mechanical equipment so that they are 2’ above 500-yr BFE
Proposed underground detention under the building and under the football field is designed to flood.

Parking garage is designed to flood.

Resilient Strategies
The Keys to a Resilient Building

- Mark Madorsky, P.E., CxA, LEED AP BD+C
- President
- LEAF Engineers
Impact

- 623,967 square feet affected
- Sports Fields Inundated
- +$50,000,000 repair contract
- Closed 8 months, portions 1 year
- Priceless Legacy Loss (trophies, banners, etc.)
- Disruption of Community Spirit
Resilient Strategies

**HARDENING**
- Strengthening Structure
- High Wind Loading
- Redundant Power Services
- Withstand the Storm
- Maintain Operations Without Interruption

**RESILIENCY**
- Potable water storage
- Elevate Critical Infrastructure
- Civil Defense Response Site
- Recover Operational Status Quickly
- Preventative Maintenance

$-$$ - $$$-$$$$
Site Selection is Everything

- Review Aerials and FEMA Maps
- Review Wind Maps (DFW in 250 MPH Zone Per IBC)
- Assume the Worst Case Asset Protection
  - Life Expectancy
  - Operational Criticality
  - Risk of Flood/Wind Damage
Extended Site Parameters

- Storm Event Performance
- Major Roadway Impacts
- Residential Risks
- Staff Transportation
- Utility Interruptions

Ground Elevations in Addicks Reservoir Area
Best Practices Water Protection

- 1’ / 500 year flood elevation (2’ in Harris County, Texas)
- Padmount Equipment 1’ AFF
- Electrical/MDF/NOC on 2nd Floor
- Drains at Doors, drains in Vestibules
- Durable Flooring Selections
Best Practices Water Protection

- CMU walls on 1st Floor
- Cementitious wall board on 1st Floor
- Sanitary Check Valves
- Curbs for Ground Floor Glazing
- Flood Barriers, Site Berms, Levees
Best Practices Wind

- Shelter Design Wind Speeds For Tornadoes
  - Resist 100 mph stud
  - Resist 67 mph roof impact
Best Practices Wind

- HVAC Restraints Roof/Site
- Landscaping Away From Building
- Interior Shelter Room
- Wind Loading of Canopies/Roofs
- Impact Resistant Glass/Frames
- Indoor Generator Room
- Indoor Water Cooled Chillers
Best Practices Operations

- Detailed Weather Reports
- Operations Center (EOC)
- Coordinate Response with Regional EOC’s
- Business Continuity Plans
- Colocation for Technology Infrastructure
After the Storm

- Assessment, Photographs and Video
- Contact Insurance Agent, FEMA, State
- Hygienist, Architects, Engineers
- Mitigate/Restore/Replace Infrastructure
- Disaster recovery consultant (Federal Funding Process Expert)
Some Hidden Risks

- Mold
- Desks, Chairs, Books, Supplies
- Contaminated Duct Systems
- Exposure of Building Materials and Systems to High Humidity Levels
- Toxic Hydrocarbons and Fecal Matter in Flood Waters
Trending Now…

- Elevated Substation
Trending Now…

- Emergency generator
  - Lighting
  - auditorium house lights
  - exist signs
  - Communications
  - Command center
  - fire alarm equipment
  - Coolers and freezers

- Manual transfer switch
  - Portable generator
  - Lights and heating at gyms, locker rooms kitchen, cafeteria maintenance
  - Kitchen equipment
Trending Now…

- Demountable Flood Barriers
Trending Now…

- Aqua dams
Trending Now…

- High Strength Glazing
Photovoltaic Design
Solar Panel Layout – Roof, Ground, Canopy
Net Metered Photovoltaic (PV) System Proforma

**Facility Size – 240,000 sq. ft.**

- Projected Annual Electric Consumption: 2,104,000 kWh
- Projected Annual Electric Bill Summary: $195,876
- Utility Rate Structure: LGS with Net Metering Agreement for Interconnection and Parallel Operation of Grid-Connected On-Site Solar Generation

**1 MW Solar Array Performance**

- Area: 198,924 sq. ft. (4.6 acres)
- Annual Production: 1,702,000 kWh
- Initial Capital Cost: $2,000,000
- Annual Electric Savings: $165,500
- Simple Payback: 11.6 Years
- 20 Year Life Cycle M&O Savings: $3,310,000
- Total Energy to Grid: 34,040 MWh
Safe and Secure Schools - Layering

Physical Security

- 6’ Iron Fencing Around Entire Perimeter
- Bollards, Speed Bumps, Vehicular Barriers
- Dedicated First Responders Access Drive
- Secure Entry Vestibule with Ballistic Hardening
- Window Sill Heights Elevated (5’)
- Access Controlled Doors
Safe and Secure Schools - Layering

Surveillance, Messaging, Intelligence

- PTZ Surveillance Cameras with Facial Recognition Software
- Gunshot Detection & Weapons Radar
- Incident Response Room
  - Master Keys/Proximity Cards
  - Floor Plans
  - Access to Cameras
  - Access to Public Address
Community Resilience – Health & Wellbeing

- Reducing Environmental Impact
- Human Performance and Productivity
- Community Engagement & Connectivity
Reducing Environmental impact

- Reduce air pollutant emissions
- Facility recycling program & waste management planning
- Material selection/Material effectiveness
Facility recycling program & waste management planning

• Trash Compactor
  • Reduced disposal costs
  • Landfill Reduction
Water efficiency

- Reduce potable water consumption
- Provide landscaping that does not require permanent irrigation systems
- Reduce runoff
- Improve water quality
- Provide on-site food production for a % of the building footprint
- Rainwater harvesting for facility use and crisis use
Human Performance and Productivity

- Indoor Air Quality Performance: Mechanically, Naturally, Mixed-mode
- Environmental Tobacco Smoke Control
- Low-Emitting Materials
- Reinforced natural daylighting
- Quality Views to Exterior for 25% of Occupied Space
- High-Quality Interior Lighting
- Provide effective acoustic design

Daylight and Views
Fresh Air
Human Productivity
Community Engagement & Connectivity

**Community Access**

**Improve quality of life**
Has identified, assessed, and incorporated community needs, goals, and objectives into the project

**Knowledge and society**
- Meeting space
- Shared library
- Civic space
- Shared Athletics

**Incorporate Community Views & Local Character**

**Community production**
- Plant nursery
- Organic food
- Auto repair
- News and radio
Local Investments

Deep rooted community attachment to school, willing to come together after crisis

- Expand Citizen Participation:
  - Councils, Organizations, Communication

- Resilient Organizations:
  - Develop a resilient organization
  - Social equity: community, supply chain, project team

- Develop or Expand Local Skills
  - Project delivery
  - Hire locally
  - Skills outreach
  - Local development and competitiveness
Community Engagement & Connectivity

Surrounding density and diverse uses

- Crisis and Health Services
- Walkability
- Non-motorized Transit
- Public Transit
<table>
<thead>
<tr>
<th>Elements</th>
<th>Measures</th>
</tr>
</thead>
</table>
| Organizations                 | • Distribution of community groups across the region  
• Number of active interfaith organizations  
• Diversity and number of community organizations |
| Communications and social media | • Speed with which messages travel through official and unofficial channels  
• Number of people who have or do not have access to social media |
| Connectedness                 | • Number and type of organizations in which people are engaged  
• Number of people registered to vote  
• Knowledge of what resources are available during and after a disaster  
• Network analysis to map social connectedness |
| Trust                         | • Amount of connection and communication between local officials  
• Public confidence in leadership  
• Public trust in leadership |
| Volunteerism                  | • Number of people who participate on neighborhood teams (e.g., Community Emergency Response Teams)  
• Number of volunteer hours per capita  
• Number of active disaster response teams in a neighborhood/community  
• Number of people who attend neighborhood meetings  
• Number of people who attend community resilience training |
| Other                         | • Number of people with access to transportation  
• Types of transportation available  
• Connection of residents who do not use social media with other community providers |