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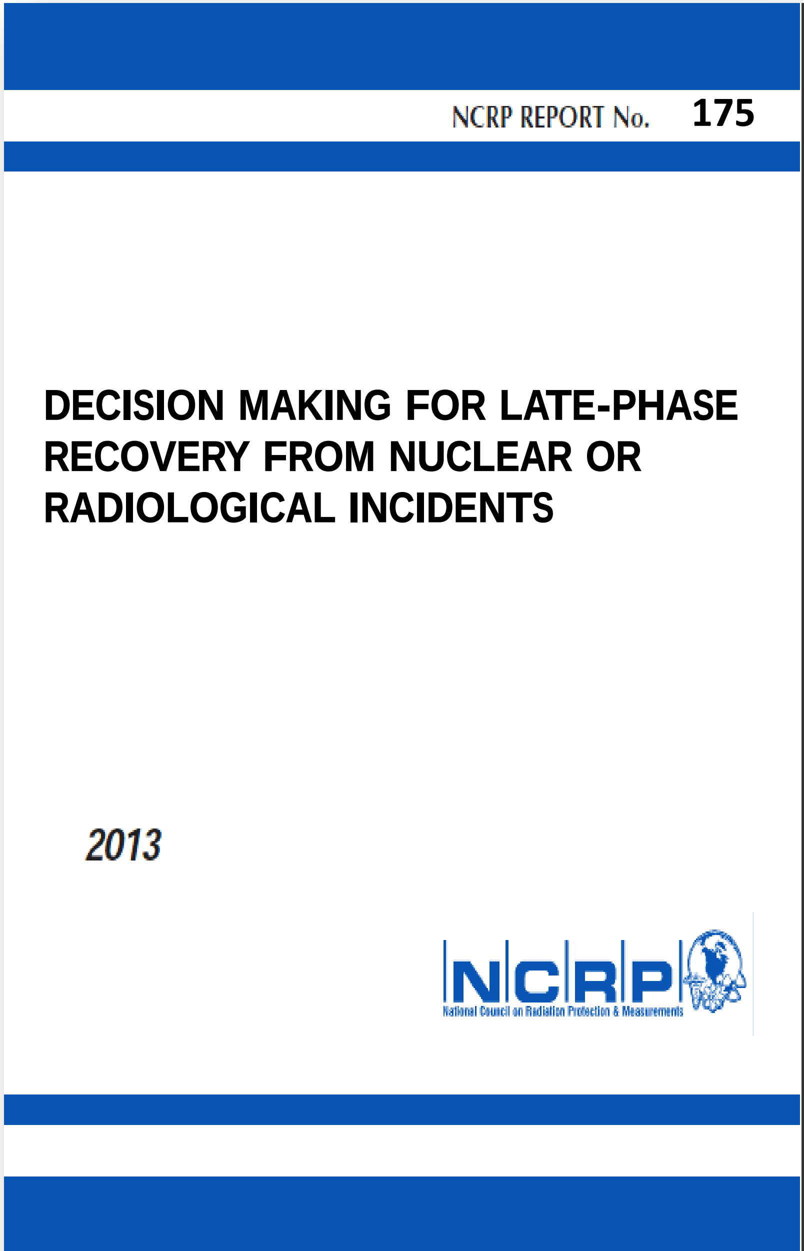

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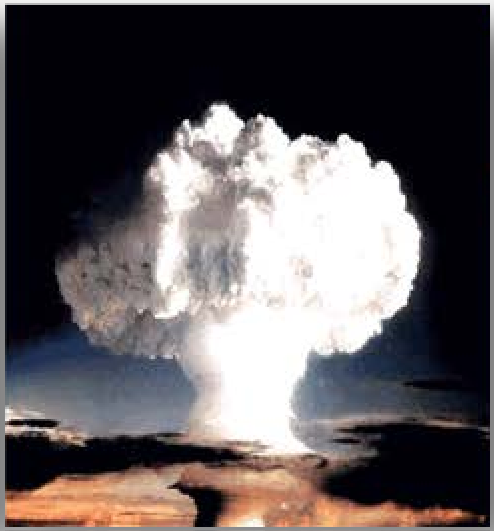
In 2008, DHS issued Protective Action Guides (PAGs) for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) incidents, providing recommendations for protection of public health in the early, intermediate, and late phases of response to an RDD or IND incident. IN 2013, the Environmental Protection Agency (EPA) also issued a draft Protective Action Manual (PAG) for comment and interim use.
The NCRP Report provides **framework and approach to implementing and optimizing decision making during late stage recovery for large-scale nuclear incidents**

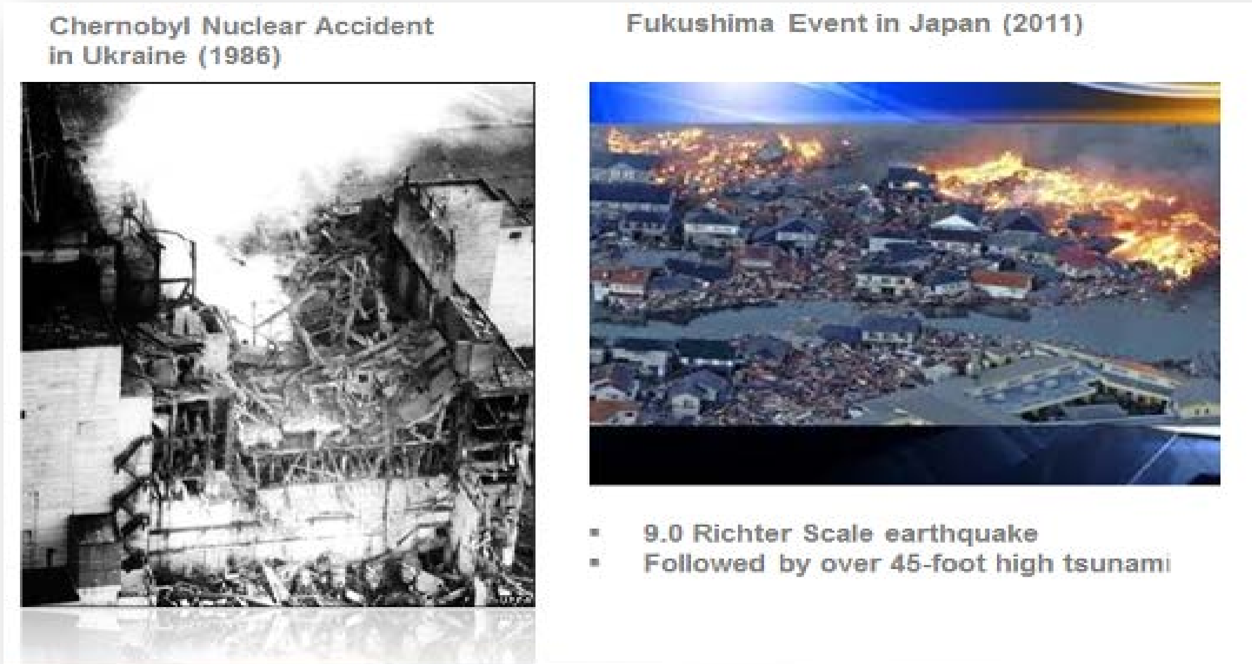
Radiological and nuclear incidents from terrorism RDDs and INDs

Potential Sources:

- **Radiological Dispersal Device** (RDD) refers to any method used to deliberately disperse radioactive material in the environment in order to cause harm.
- **Improvised Nuclear Device** (IND) refers to any device incorporating radioactive materials designed to result in a nuclear explosion.



Late-phase responses to nuclear incidents



- ❑ Long-term recovery
- ❑ Wide-area contamination
- ❑ Risk communication and management
- ❑ Huge volume of radioactive waste generation
- ❑ Long-term management

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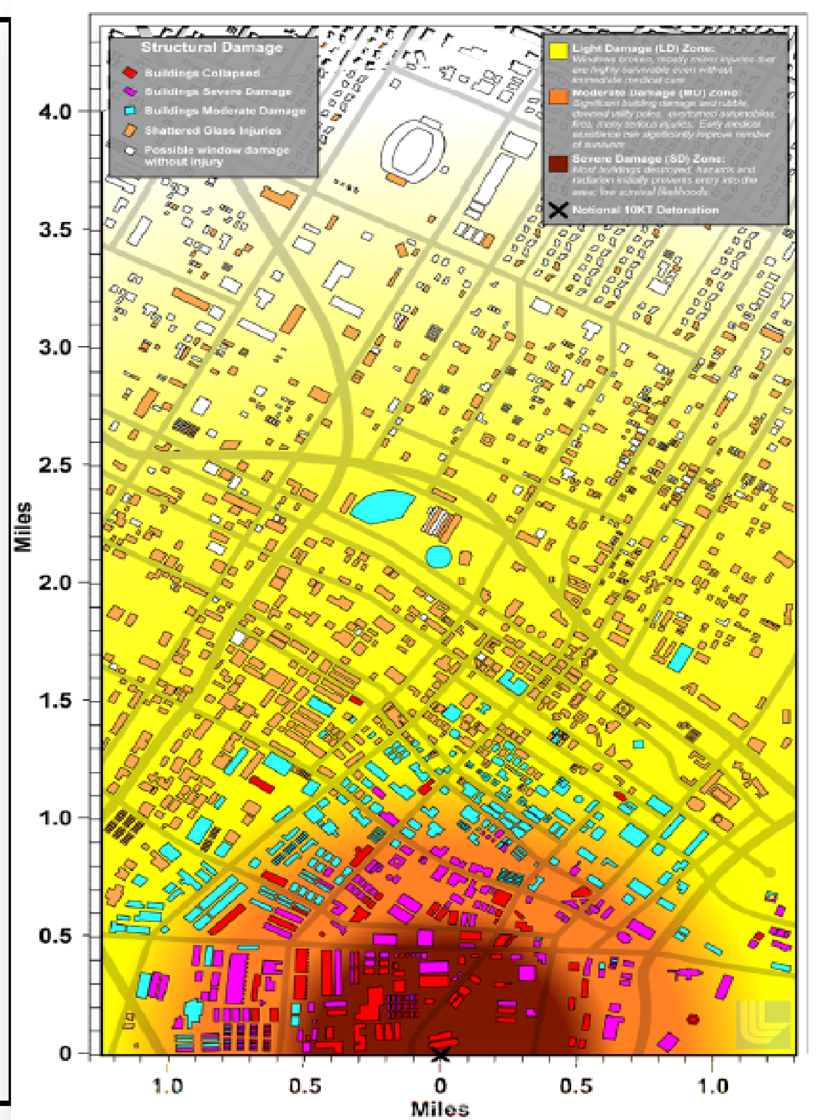
The damage zones from IND Impact may extend for several miles in an affected urban area

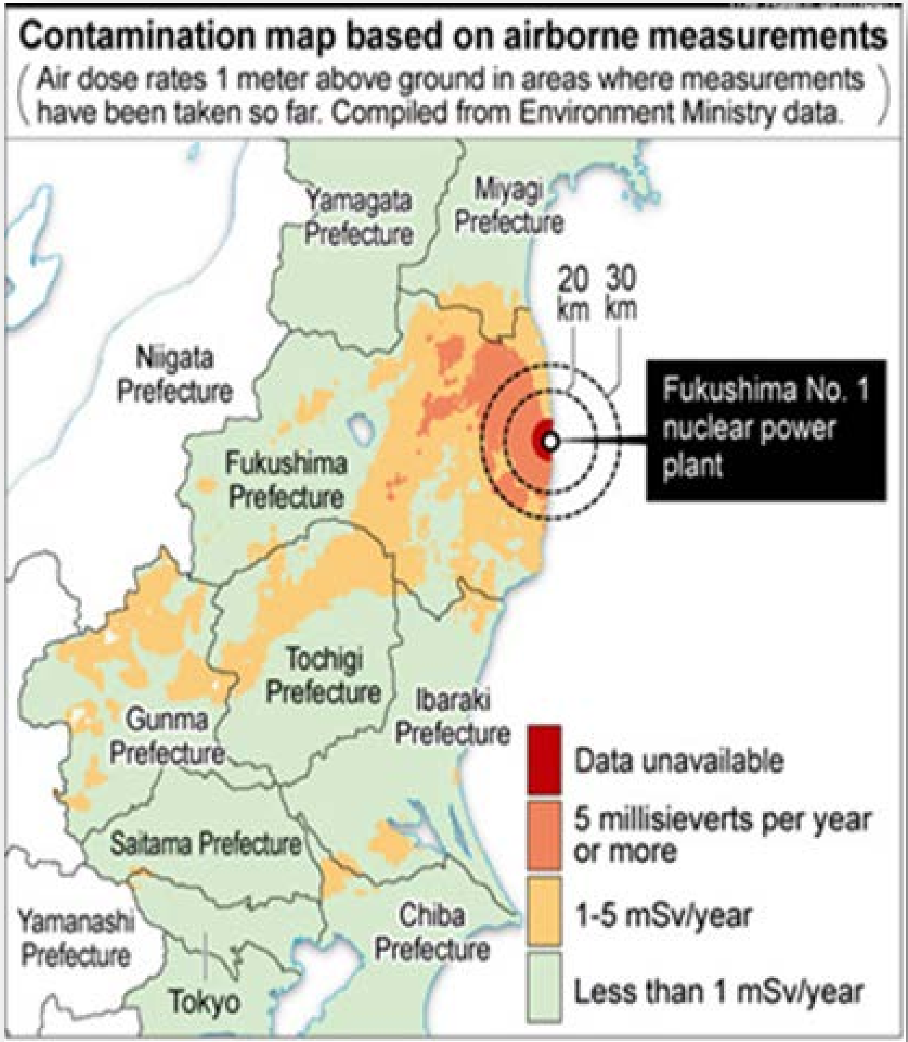
Blast Pressures on Buildings:

- ❑ **<u>Low Damage Zone:</u>**
  0.5 psi at the outer boundary and 2-3 psi at the inner boundary (light building damages; blown windows, etc.)
- ❑ **<u>Medium Damage Zone:</u>**
  2-3 psi at the outer boundary and 5-8 psi at the inner boundary (substantial building damages)
- ❑ **<u>Severe Damage Zone:</u>**
  > 5-8 psi (severe building damages; area flattened)



(DHS 2010)

Addressing wide-area contamination and the unprecedented impact



Cleanup level at 1 mSv/y:

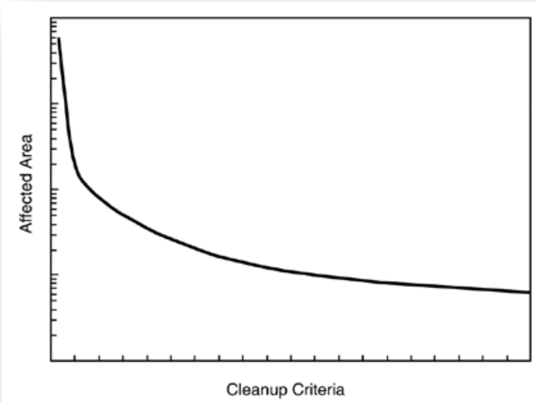
- **13,000 km², or**
- **3% of Japan's land mass**
- **Costs several $B**

Contaminated area is about the size of State of Connecticut

Radioactive waste is a priority issue in recovery

Estimated radioactive waste volume from cleanup of nearby prefectures surrounding Fukushima NPP is 29×10^6 m^3, or about 1 billion ft^3. This *has exceeded* the US commercial LLW disposal capacities combined. Some *adaptive management strategy* is needed.

Temporary storage of contaminated material – examples from clean-up demonstration tests



Waste volume is *directly proportional* to the rigor in cleanup.

(Source: ICRP 2012)

Considerations of Radioactive Waste Management

(1) The approach to waste characterization and volume estimation
(2) The establishment of temporary waste storage criteria and treatment strategies
(3) Considerations for final disposal site(s) selection, and
(4) Waste packaging and transport decisions
(5) Strategy toward risk-informed waste disposition approach

Issues affecting the waste characterization and management

- Ownership of LLRW would be in question (waste such as generated by RDDs or INDs)
- Waste volume could range in the order from a few 1,000 m^3 to a few million m^3. By comparison Class A waste has been generated at around 900 m^3/y in routine operations (NA/NRC 2006)
- LLRW disposal capacity (commercial) will be seriously constrained
- Information on alternative disposal options (hazardous or municipal landfilled) is hampered by lack of open information (over 8,300 sites with “proprietary” information) (***Directory of Waste Processing and Disposal Sites***)

Low-Level Radioactive Waste (LLRW)
Waste Characterization and Volume Estimation

Definition by **exclusion** - LLRW is defined (10 CFR 61.55) **not by *what it is***, but rather by ***what it is not***. LLRW is radioactive waste that is **not *high-level radioactive waste, transuranic waste, spent nuclear fuel, or 11e(2) byproduct material (uranium and thorium mill tailings and wastes)***.

LLRW consists of a wide range of wastes having various physical and chemical characteristics and concentrations of radioactive isotopes. Disposal of commercially generated LLRW is regulated by the U.S. Nuclear Regulatory Commission (NRC), and must be done in a controlled manner to protect human health and the environment.

The U.S. radioactive waste system is *origin-based* but *not risk-based* *(NA/NRC 2006)*.

Examples for Determining the Waste Classification

Radionuclide	Concentration, curies per cubic meter		
	Col. 1	Col. 2	Col. 3
Total of all nuclides with less than 5 year half-life	700	([1])	([1])
H-3	40	([1])	([1])
Co-60	700	([1])	([1])
Ni-63	3.5	70	700
Ni-63 in activated metal	35	700	7000
Sr-90	0.04	150	7000
Cs-137	1	44	4600

(i) If the concentration does not exceed the value in Column 1, the waste is Class A.
(ii) If the concentration exceeds the value in Column 1, but does not exceed the value in Column 2, the waste is Class B.
(iii) If the concentration exceeds the value in Column 2, but does not exceed the value in Column 3, the waste is Class C.
(iv) If the concentration exceeds the value in Column 3, the waste is not generally acceptable for near-surface disposal.
(v) For wastes containing mixtures of the nuclides listed in Table 2, the total concentration shall be determined by the sum of fractions rule

U.S. Commercial low-level radioactive waste disposal facilities

Disposal Facility	Wastes Allowed	Various States Access	Capacity
Energy Solutions--Barnwell, SC	Class A, B, C	Atlantic Compact (CT, NJ, SC)	15,000 $ft^3\ y^{-1}$
Energy Solutions--Clive, UT	Class A, and mixed LLRW	Open to all states	41 million ft^3 with plans to more than double capacity
U.S. Ecology--Richland, WA	Class A, B, C	Northwest and Rocky Mountain Compacts (11 states)	25 million ft^3
Waste Control Specialists--Andrews, TX, west Texas near NM border	Class A, B, C, and mixed LLRW	Texas Compact (VT, TX; Texas Compact Commission considering providing access to out-of-compact states)[a]	2.3 million ft^3 for commercial use and 26 million ft^3 for Federal (DOE) use

[a] Waste Control Specialists intends to construct and operate a separate federal (DOE) disposal capacity in conjunction with its commercial facility.

Waste Treatment and Staging

- Large volumes of waste with varying levels of contamination (mostly Class A or lower but higher level wastes may be generated such as by neuron activation in an IND event): building materials, soils, asphalt, concrete, trees/shrubs, decontamination residues, thus treatment strategies will need to be closely coordinated
- Methods of treatment may include: stabilization, removing contaminants, volume reduction (evaporation, grinding, crushing, shredding)
- Meet waste acceptance criteria (e.g., RCRA land disposal restrictions)
- Waste staging areas to be chosen, preferably close to the incident site
- Staging criteria to be developed during planning process

Issues with the Current LLRW System

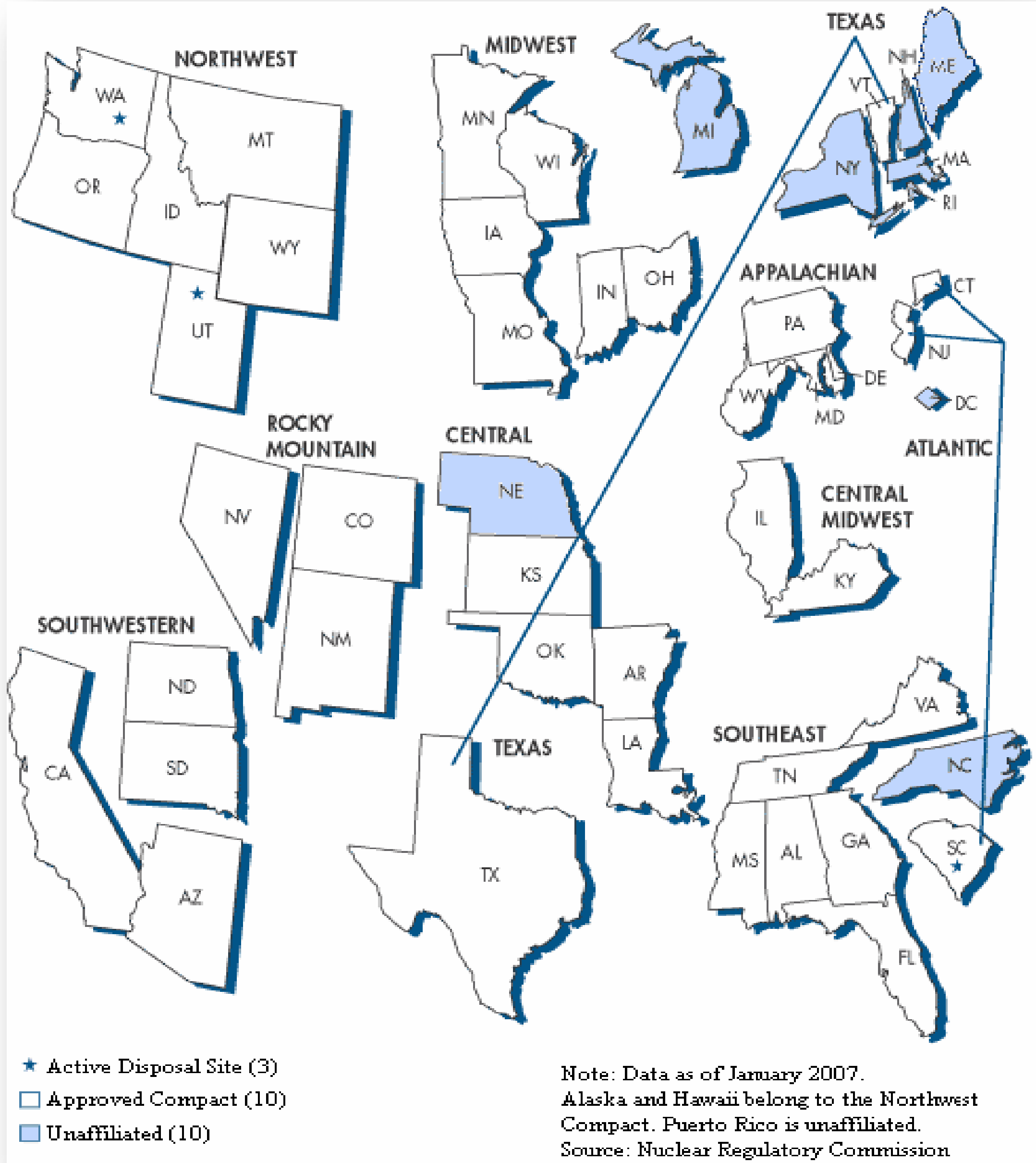
- ❑ Difficult to assign ownership of the waste generated in an incident (the current system that is based on the origin does not help)
- ❑ Without explicit exempt levels huge amounts of LLRW will be generated by the very definition (most will likely be the innocuous, low activity waste)
- ❑ Uncertainty about how the current regulatory definition might apply to a terrorist situation (outside of the current regulatory statutory framework as stipulated by AEA.

In advising on the Fukushima nuclear accident, the IAEA (2011) urged, "***It is important to avoid classifying as 'radioactive waste' waste materials that do not cause exposures that would warrant special radiation protection measures***."

LLW Compacts

Low-Level Radioactive Waste Policy Act (LLRWPA) of 1980 and subsequent amendments direct states to take care of their own LLW either individually or through regional groupings, referred to as compacts. The states are now in the process of selecting new LLW disposal sites to take care of their own waste. The selection process for these new sites is complex and varies because of many factors including the regulations for site selection. This selection process will be affected by EPA's new LLW standard.

The Regional Compacts for LLRW



Waste Transportation and Packaging

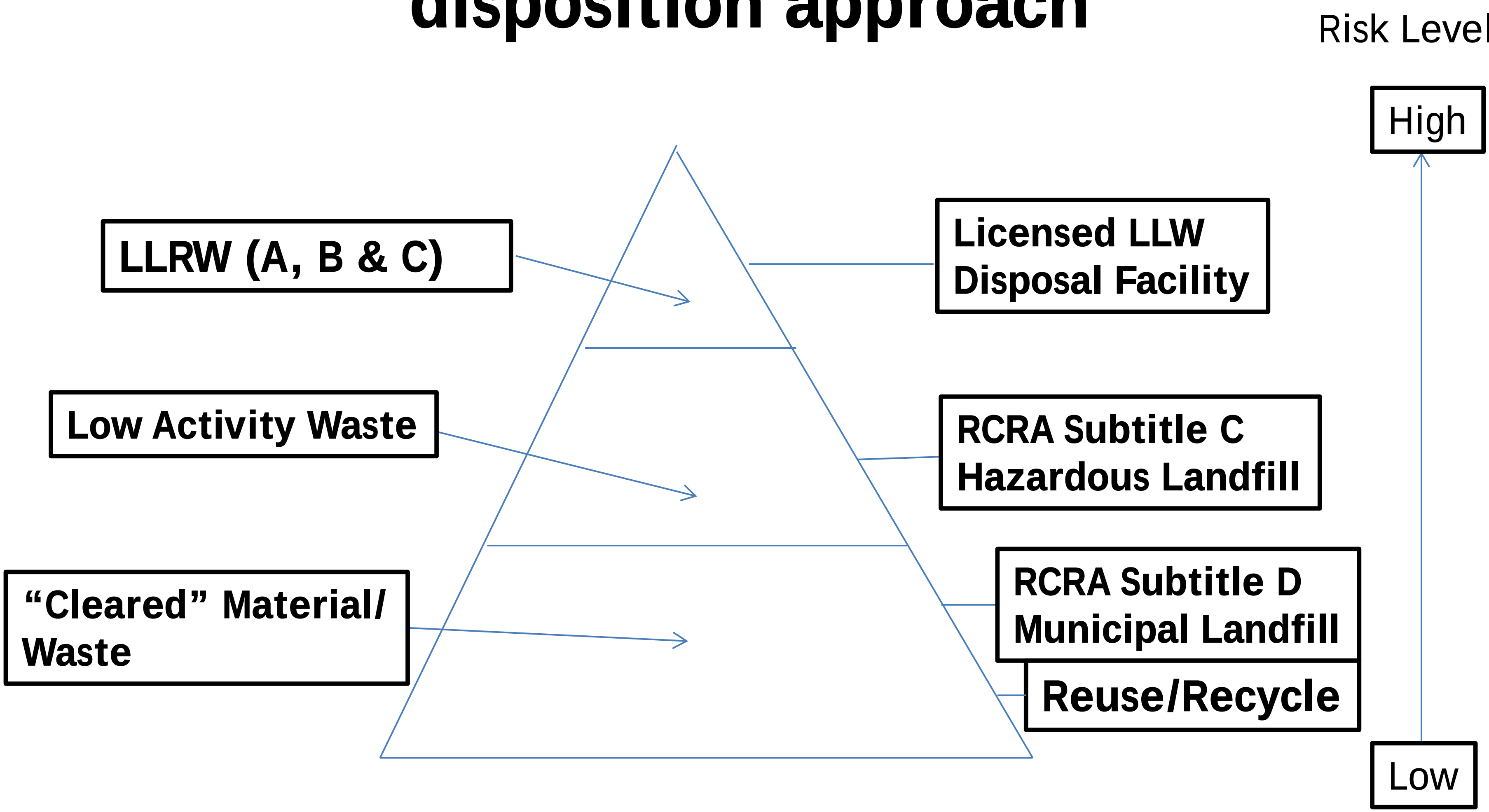
Given the large quantities of wastes, transportation effort may turn into a major campaign both locally to the staging areas and regionally to the final disposal sites. For planning purposes, one must ensure:

- Sufficient quantity of waste containers (appropriate type, size, and integrity specifications)
- Appropriate packaging requirements for transportation through various transportation routes and modes (highways, railways and waterways)

Disposal Options

- **Commercial disposal sites**
  - Commercial LLRW disposal sites
    - Limited disposal capacity
  - RCRA Subtitle C (hazardous) landfills
    - Possibility of accepting “low activity” wastes (EPA 2003)
  - RCRA Subtitle D (municipal) landfills
    - Possibility of accepting wastes with “clearance”
- **Government disposal sites**
  - Possibility of disposal at DOE sites may require Executive Orders

Concept of graded (risk-informed) disposition approach



Final Disposal

Because much of the waste may have very low activities with extremely minimal radioactive contamination, it may be possible to use waste facilities regulated under RCRA, specifically RCRA Subtitle C and Subtitle D landfills. However, site-specific determinations to use a particular landfill would likely need to be rigorously supported, those for Subtitle D landfills even above those allowing use of Subtitle C landfills. EPA has examined many of the issues associated with using Subtitle C landfills for disposal of “low-activity” radioactive wastes under a more routine, risk-based framework (EPA, 2003).

Summary and Conclusions

- Radioactive waste characterization and management is one key issue in planning and managing recovery from nuclear or radiological incidents
- Current policy and regulatory provisions are ill equipped to properly respond to a large scale incident
- Response planning needs to accommodate the large quantities of waste with miniscule radioactivity
- Current system requires a risk-informed radioactive waste management approach in order to achieve an expedient cleanup effort in recovery following a major nuclear or radiological incident

Thank You!