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Evaluation of Dose and Risk in the Site Release Process for Commercial Power Reactors

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Overview of Site Release Process

- Site release criteria set by the Regulator
  - May be dose or concentration-based
- Future use of the site determined by utility
- If required, development of concentration-based release limits for
  - Land areas (surface and sub-surface)
  - Structures
  - Water (surface and groundwater)
- Development of formal site survey process
  - Survey type
  - Survey methods
  - Sampling protocols
  - Data quality objectives

RESRAD

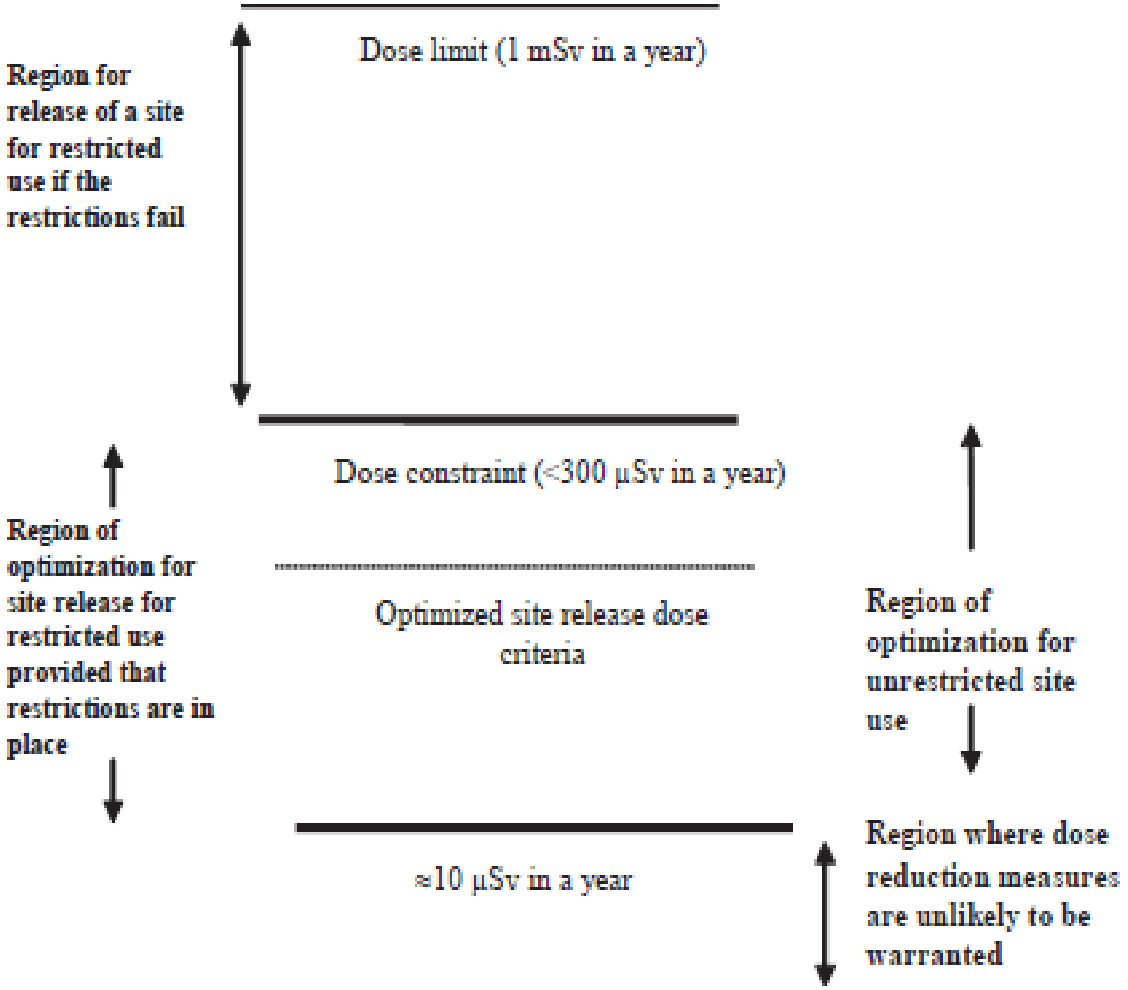
MARSSIM

Site Release Criteria

- Determined by Regulator
- Site Release Criteria may be:
  - Allowable dose to a future user of the site (i.e., mSv/yr)
  - Concentrations for various radionuclides in soil, concrete or groundwater
    - May have originally been determined from dose based criteria
- If the Site Release Criteria are dose based, Site Release Limits (i.e., concentrations) need to be determined by dose modeling

IAEA Guidance on Site Release Criteria

- The IAEA guidance in Safety Guide WS-G-5.1*
- IAEA Guidance*:
  - Restricted Release: < 1 mSv/yr if restrictions fail
  - Unrestricted Release: < 0.3 mSv/yr
  - "Optimization" performed to determine if lower dose criteria is appropriate
  - Remediation to < 0.01 mSv/yr likely not warranted



***IAEA WS-G-5.1, "Release of Sites from Regulatory Control on Termination of Practices", 2006**

US NRC Site Release Criteria

- 0.25 mSv/yr for Unrestricted and Restricted Release
  - If Restricted Release, also need to demonstrate that if institutional controls fail, dose will be:
    - < 1 mSv/yr, ***or***
    - < 5 mSv/yr if remediation to 1 mSv/yr is:
      - Not technically achievable,
      - Prohibitively expensive ***or***
      - Will result in net public or environmental harm

ALARA evaluation required to evaluate further remediation to satisfy to lower dose criteria

Establish Site Future Assumptions

General Approaches taken in the U.S.

- Land Areas
  - "Greenfield": site assumed to be used by a "Resident Farmer" family
    - Most conservative scenario/lowest release limits
  - Industrial Use: licensee continues to own the site; occupant assumed to be licensee employee (works 2000 hrs/yr)
    - Higher site release limits than "Resident Farmer Scenario"
- Buildings
  - Office worker in concrete structure (2000 hrs/yr)
- Other use scenarios can be assumed such as:
  - Public Park – recreational (less occupancy hours/yr); non-farming use and/or groundwater consumption not allowed

Determine Radionuclides of Concern

- Review plant records to determine radionuclides
  - Radwaste characterization
  - Fuel activation analyses
- Determine radionuclides of concern
  - Decay half-life
  - Quantities projected compared to release limits
  - Dose significance based on abundance and human radiosensitivity

List can be reduced based on site characterization

Typical Radionuclides of Concern At Power Plant Decommissioning

Radionuclide	Half-life (years)	Radionuclide	Half-life (years)
H-3	**12.33**	Cs-134	2.062
C-14	**5,730**	Cs-137	30.17
Mn-54	0.8561	Eu-152	13.3
Fe-55	**2.685**	Eu-154	8.5
Co-60	5.271	Eu-155	4.96
Ni-63	**100**	**Pu-238**	**87.74**
Sr-90	**28.8**	**Pu-239/240**	**2.41×10^{4}**
Nb-94	2.0×10^{4}	**Pu-241**	**14.4**
Tc-99	**2.14×10^{5}**	Am-241	432.2
Ag-108m	1.27×10^{2}	**Cm-243/244**	**28.5**

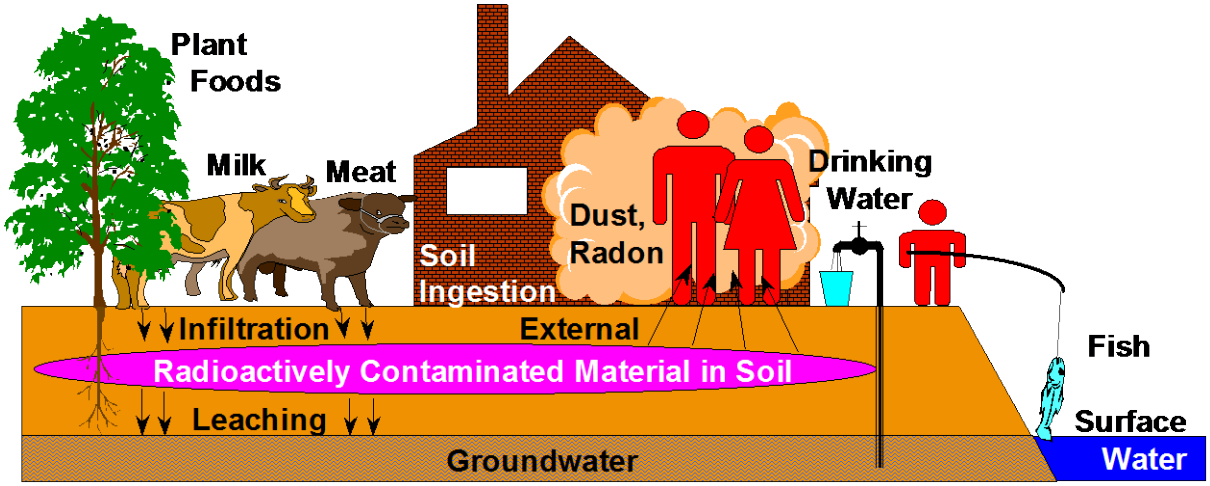
Bold Entries are for Hard to Detect Radionuclides

Development of Concentration-Based Release Limits

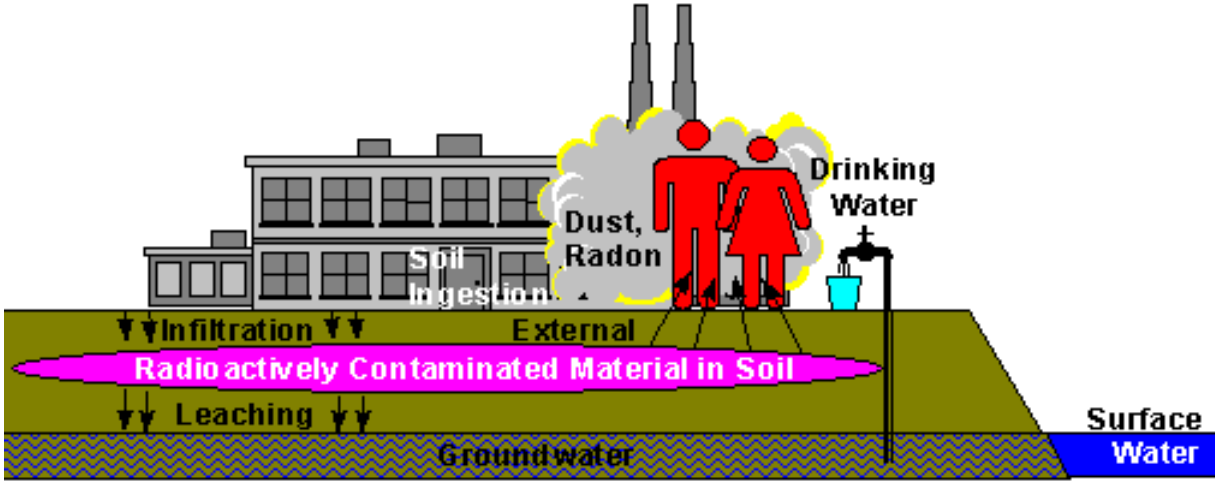
- Dose after site release too low to measure directly – release limits (i.e., Derived Concentration Guideline Levels or DCGLs) determined using dose modeling computer codes
- Computer codes typically used developed by Argonne National Labs:
  - Land areas – RESRAD
    - Allows modeling of soil, material used as backfill and groundwater
  - Buildings - RESRAD-Build
  - Input parameters can be adjusted to match site use scenario

NRC has developed conservative "Screening DCGLs" that use default input parameters and a dose criteria of 0.25 mSv/yr

RESRAD Potential Dose Pathways



Resident Farmer Scenario

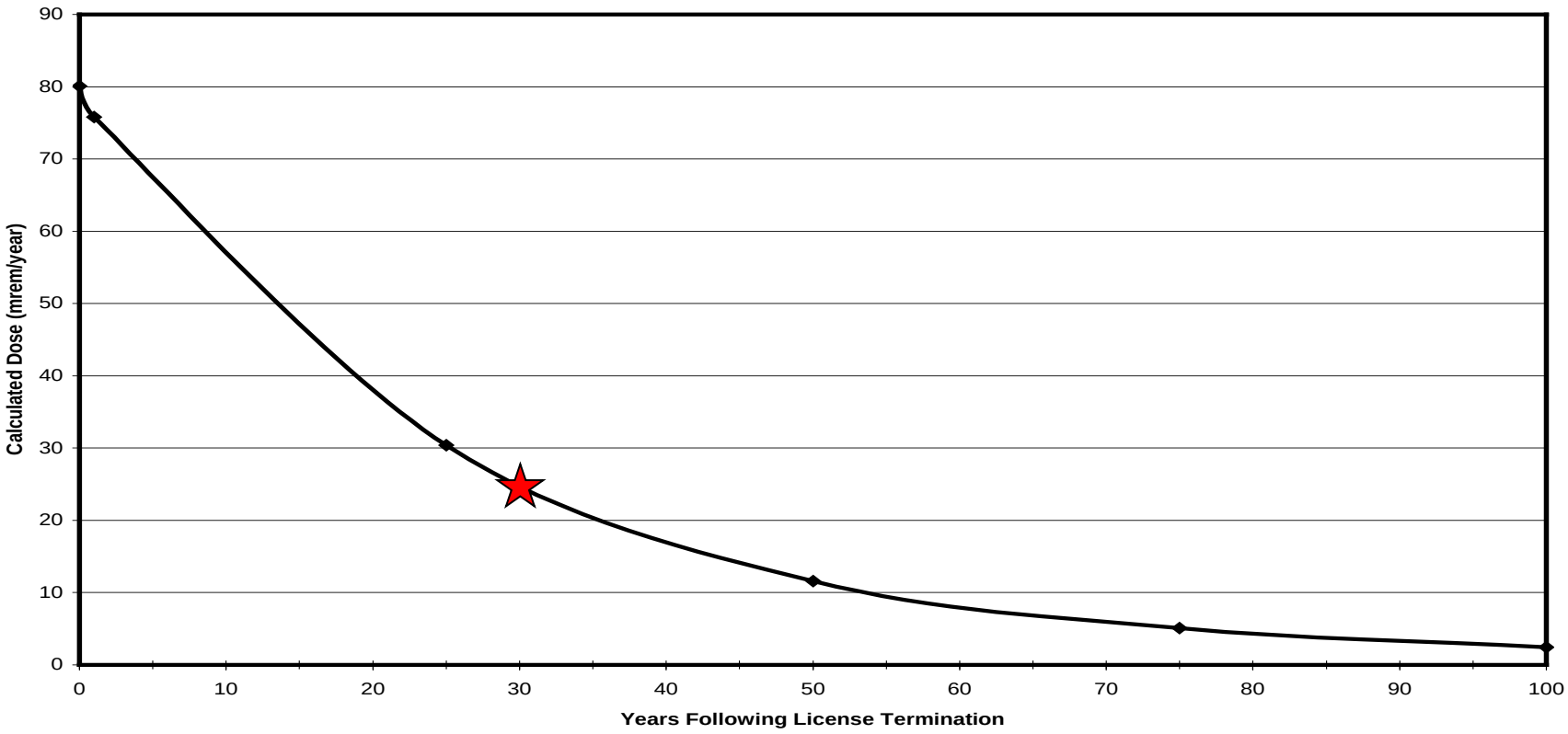


Industrial Use Scenario

Exposure Scenario Where Site to be Retained by the Utility (Ranch Seco Experience)

- Site to be re-powered and reused
  - Applied “Industrial Worker Scenario”
  - Control by the Utility allows:
    - Limitation of assumed worker time on site (hours/year)
    - Groundwater table is 40 meters below the site
    - Dose pathways modified or eliminated:
      - Plant ingestion
      - Meat ingestion
      - Ingestion of aquatic foods (fish, etc)

Reduction in “Resident Farmer Scenario ” Dose Over Time at Rancho Seco “Industrial Worker” Remediation Limits



Site owner demonstrated that residual radioactivity for “Industrial Worker Scenario” dropped to “Resident Farmer” levels after 30 Years due to decay and “weathering”

Soil DCGLs for Selected Scenarios in U.S. (Release Criteria 0.25 mSv/yr)

Radio-nuclide	CY: RESRAD Resident Farmer (Bq/g)	Rancho Seco Industrial Worker (Bq/g)	Ratio of Rancho Seco to Connecticut Yankee (Times Higher)
H-3	15.2	Not Significant at Rancho Seco* (N/S)	N/A
Fe-55	1,014	N/S*	N/A
Co-60	0.14	0.47	3.4
Ni-63	26.8	581,000	21,700
Sr-90	0.057	240	4,200
Cs-137	0.29	1.95	6.7
Pu-241	32.2	N/S*	N/A
Am-241	0.95	N/S*	N/A

***Not Detected in Characterization Samples**

Comparison of Rancho Seco Soil DCGLs to IAEA Clearance Levels

Radio-nuclide	Rancho Seco Industrial Worker DCGLs (Dose Criteria 0.25 mSv/yr) (Bq/g)	IAEA Clearance Levels (Dose Criteria 0.01 mSv/yr) (Bq/g)	Ratio of Rancho Seco Industrial Worker DCGLs to IAEA Clearance Levels (Times Higher)
Co-60	0.47	0.1	4.7 Times
Ni-63	581,000	100	5,810 Times
Sr-90	240	1	240 Times
Cs-137	1.95	0.1	19.5 Times

Groundwater Related Site Release Limits

- Groundwater dose pathway not applicable if:
  - Site owner prohibits use of groundwater
  - Groundwater quality precludes ingestion (for example, brackish water)
- Run RESRAD to determine groundwater DCGLs
  - Gives groundwater DCGLs (in Bq/Liter) at the dose Limit
  - Use DCGLs to calculate dose from monitoring well concentrations

Comparison of Groundwater Release Limits for Connecticut Yankee (CY)

Release Limit for Key Radionuclides	NRC 0.25 mSv/yr Groundwater DCGLs (For CY using RESRAD)	EPA Maximum Contaminant Levels: Required by EPA/NRC MOU and State of Connecticut
H-3	24,124 Bq/L	740 Bq/L
Sr-90	9.3 Bq/L	0.3 Bq/L
Cs-137	16 Bq/L	7.4 Bq/L

Input to Decommissioning release limits from other stakeholders can have a major effect on amount of remediation required

RESRAD-Build (for Buildings) Overview

- RESRAD-BUILD also allows scenario-based inputs
- Typical building exposure scenarios:
  - Long-term occupancy (Resident or Office Worker)
  - Short-term occupancy (Renovation Worker)
- Calculated dose is normally to a single receptor (center of room)
- The RESRAD-BUILD code considers exposure pathways:
  - Direct exposure from material on surfaces or in air
  - Inhalation of airborne radioactive particulates and tritiated water vapor
  - Ingestion of radioactive material

Rancho Seco Plant Experience

- Rancho Seco building decommissioning strategy:
  - Building to remain standing after license termination
  - All interior components and exposed piping removed
  - Remove all concrete inside containment liner
    - Other concrete decontaminated as required
  - Decontaminate/survey embedded piping (1600 meters)
- Due to repowering/reuse of site:
  - Used Realistic Scenario for certain areas of plant
    - Access into Containment Building considered restricted
    - Building Renovation Scenario used for area inside Containment Building
- Higher release limits due to lower exposure time

Rancho Seco Realistic Concrete Scenario (Release Criteria 0.25 mSv/yr)

Key Radio-nuclide	Concrete Surface DCGLs using Building Occupancy Scenario Bq/cm2	Concrete Surface DCGLs using "Realistic" Renovation Scenario Bq/cm2	Increase in DCGL using Realistic Scenario
H-3	5.3 E+04	2.0 E+05	4 Times
Co-60	2.5 E+00	6.7 E+00	3 Times
Sr-90	2.0 E+01	3.4 E+02	17 Times
Cs-137	9.3 E+00	3.0 E+01	3 Times
Am-241	5.0 E-01	3.6 E+00	7 Times
Pu-241	3.0 E+01	1.9 E+02	6 Times

Summary

- The choice of the future use of the site greatly affects dose/risk assessment
  - Applicable exposure pathways
  - Rate of occupancy of the site in the future
  - Site release limits and resulting remediation required
- Use of “Realistic Scenarios” more closely represents future use of the site
  - Manages future risks
  - Reduces current costs
- Dose modeling computer codes are available for use by decommissioning sites

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Back-Up Slides

Site Release Criteria by Country

Site Release Criteria (1/4)

- European Union guidance contained in RP 113*
  - Clearance Levels based on 0.01 mSv/yr
  - Levels defined for different cases:
    - Reuse of the building
    - Demolition of the building
    - Demolition and recycle or conventional disposal of concrete
- France
  - For buildings: After remediation to a predetermined depth based on concrete characterization results, no detectable contamination can be measured in post-remediation survey

***European Commission RP 113, "Recommended radiological protection criteria for the clearance of buildings and building rubble from the dismantling of nuclear installations"**

Site Release Criteria (2/4)

- Germany
  - Clearance Levels published in German Radiation Protection Ordinance for buildings, soil and metals
  - Based on a Dose of 0.01 mSv/yr
  - Levels defined for different cases:
    - Soil in Land Areas
    - Reuse of buildings
    - Demolition of buildings
    - Demolition and Recycle or Conventional Disposal of Solids
- Spain
  - Buildings to be remediated to the RP 113 Clearance Levels
  - For land areas, total dose from surface and subsurface soil, surface water and groundwater : < 0.1 mSv/yr
  - Dose must be < 1 mSv/yr if land use restrictions fail

Site Release Criteria (3/4)

- Sweden
  - Dose Criteria “on the order of 0.01 mSv/yr”
  - Buildings to be remediated to the RP 113 Clearance Levels
- United Kingdom
  - Buildings and land areas: approval of the IAEA Clearance Levels has been obtained at some sites
  - Alternately, a Site Specific Analysis can be performed:
    - Based on maintaining the maximum dose <0.01 mSv/yr
    - Trend in the UK is to use the IAEA Clearance Levels

Site Release Criteria (4/4)

- United States (other stakeholders)
  - State Regulations
    - Maine:
      - 0.1 mSv/yr including < 0.04 mSv/yr from Groundwater
    - Connecticut
      - 0.19 mSv/yr TEDE
      - Groundwater Criteria – Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs)
  - EPA/NRC Memorandum of Understanding (MOU)
    - MCLs for Groundwater
    - Soil Screening Levels Defined
    - Exceeding these levels may result in EPA involvement in site release process

Back-Up Slides

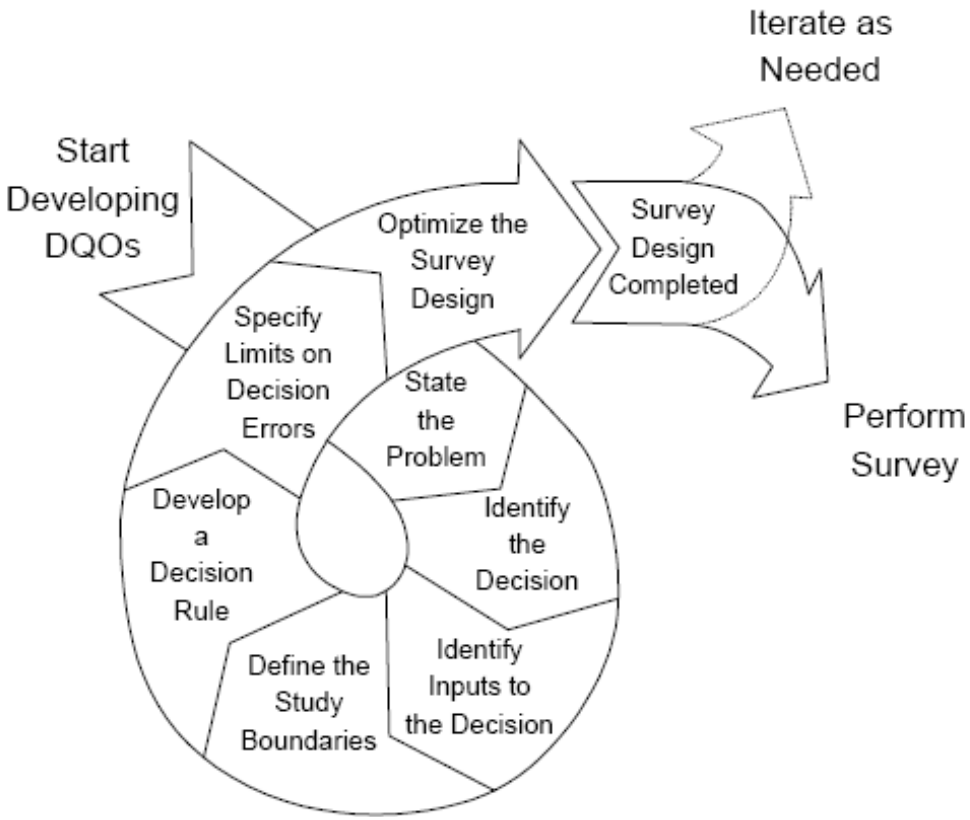
MARSSIM Overview

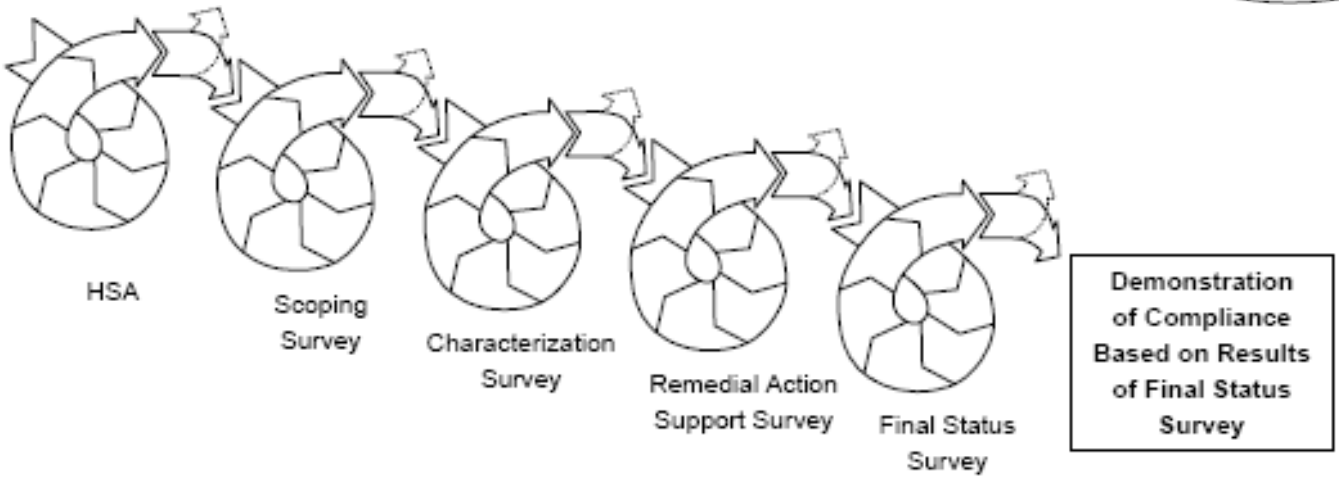
Purpose and Scope of MARSSIM

- Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) - a nationally consistent consensus approach to conducting radiation surveys for site release
- Does not address all situations (i.e., groundwater, subsurface soil, underwater sediments)
- Does not provide guidance on developing Site Release Limits (NRC Guidance on Site Release Limits in NUREG 1757)
- Not specific to nuclear power plants

MARSSIM Is An Iterative Process

MARSSIM is an Iterative Process: Based on information gathered, the next step in the process is designed





The Steps of MARSSIM Process (1/2)

- Historical Site Assessment (HSA)
  - Identify potentially contaminated areas from existing Information
- Scoping Survey
  - Initial investigation based on results of HSA
    - Biased sampling of potentially contaminated areas
    - Sampling of other areas to determine if contaminated
    - Determines radionuclides present
  - Results in MARSSIM Classification of areas by contamination levels present:
    - Class 1 (Potentially > DCGLs)
    - Class 2 (Likely < DCGLs)
    - Class 3 (Likely << DCGLs)
    - Non-Impacted (No radioactivity other than background)

The Steps of MARSSIM Process (2/2)

- Characterization Survey
  - Based on HSA, scoping survey, initial area classification
  - More detailed survey intended to:
    - Bound areas of contamination (defines remediation)
    - Confirm survey area classification
    - Results needed to design the Final Verification Survey
- Remedial Action Survey
  - Determines if remediation is complete
  - Generally performed as remediation is being conducted
  - Can be designed to serve as a Final Status Survey

Final MARSSIM Surveys

Final Verification Survey (Final Status Survey [FSS])

- Shows compliance with site release limits
- Performed to statistically-based protocol
- Survey must be performed to an established Quality Assurance Plan
- Document results in FSS Report
- Regulator follows FSS with their own Verification Survey