Hazards from Spent Nuclear Fuel at Andreeva Bay

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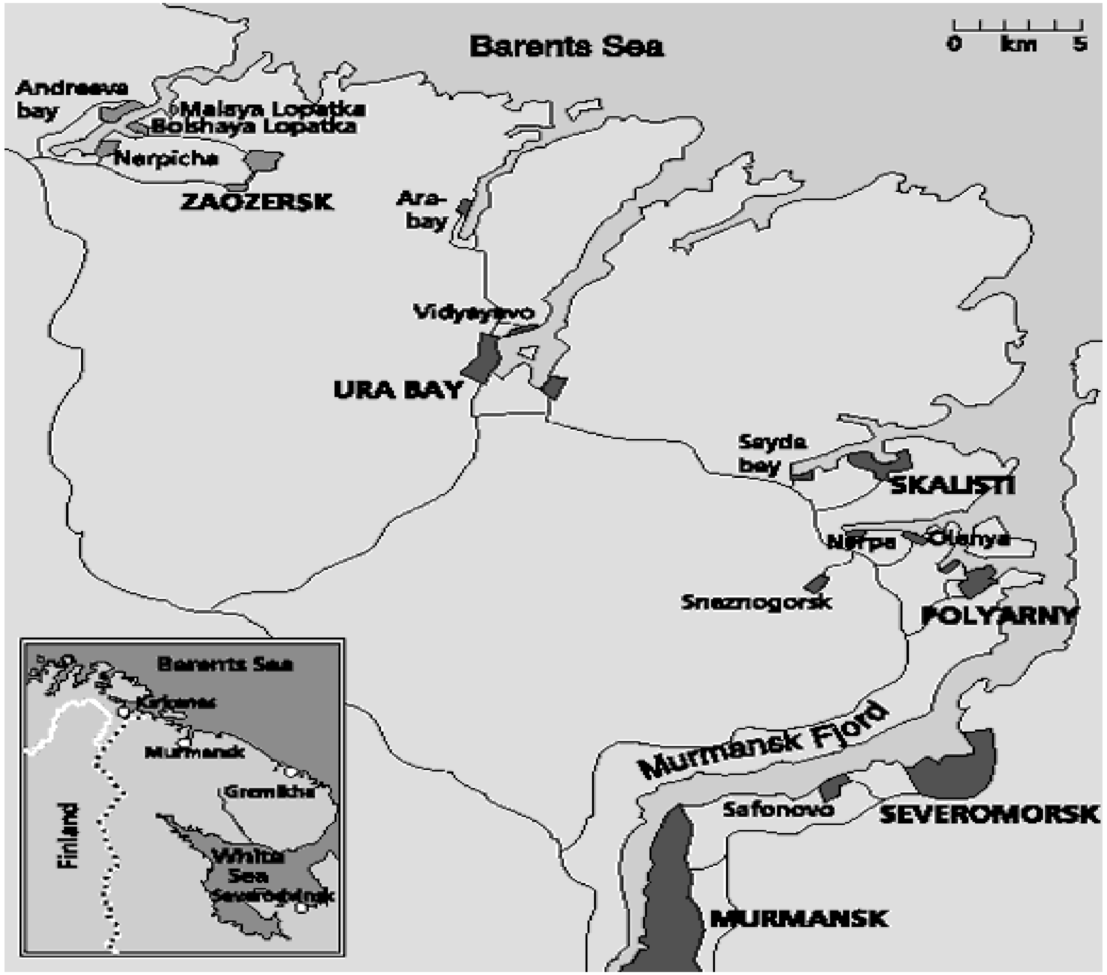
History & the problem

Andreeva Bay



History of the site

- Established in the early 1960s
- Supported the refuelling of nuclear powered submarines, and icebreakers
- Used for interim storage of used fuel, and solid and liquid radioactive wastes
- Leakage in the spent fuel pond storage facility resulted in transfer of the fuel to 3 dry storage tanks (early 1980's)
- Operations ceased early 90s
- Poor infrastructure
- Transferred to civilian ownership (SevRAO, RosATOM)~2000

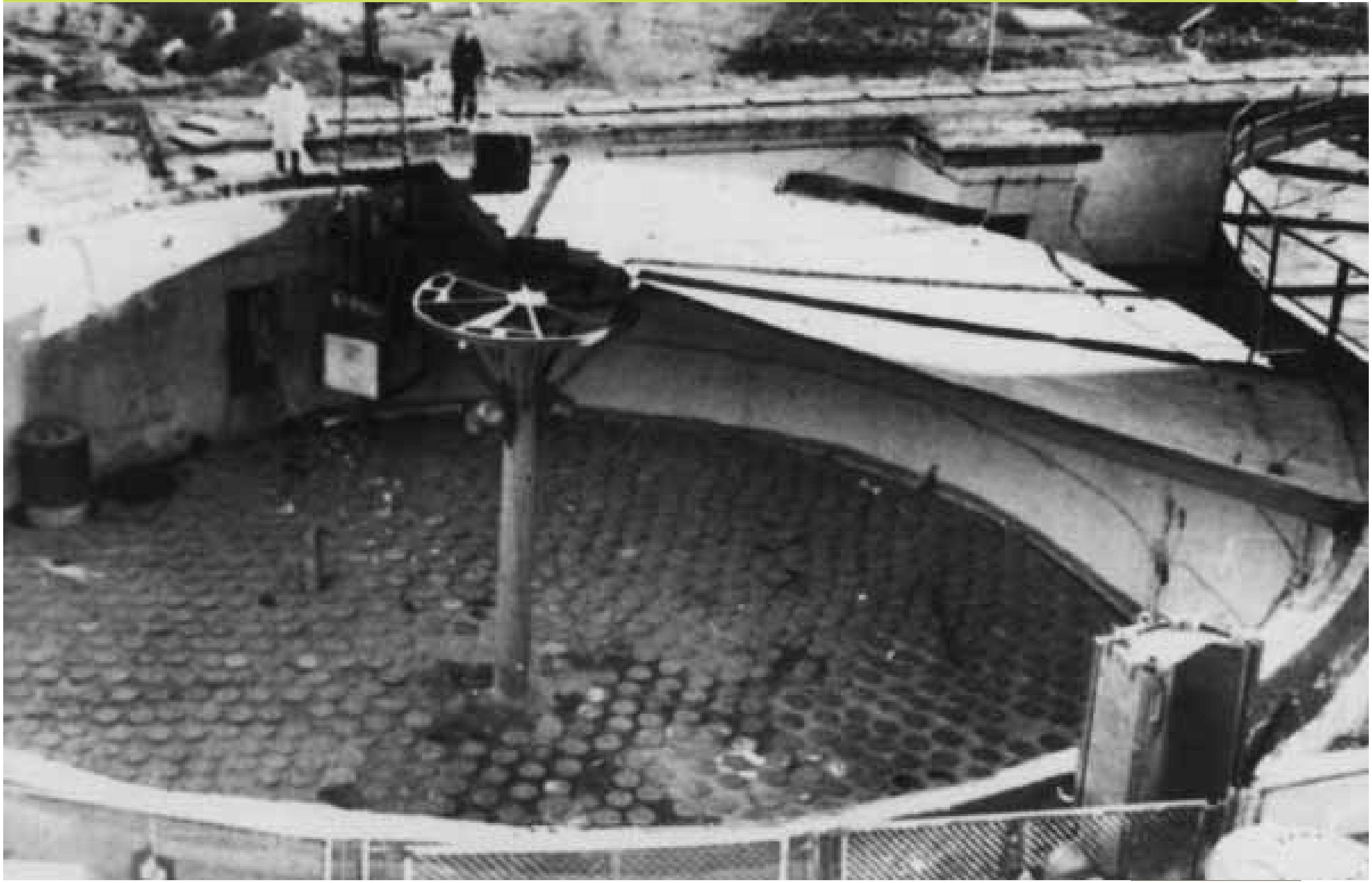
SNF/Radwaste Legacies

- **Very large inventories of radioactive waste present (17,000m^3 SRW)**
- **22,000 SFA's, 90-100 reactor cores, ~50 submarines' worth of SNF,**
- **radionuclide inventory of some 4x10^{18}Bq (about the same as is in the remains of Unit 4 Chernobyl in the sarcophagus)**
- **6 tonnes of fissile uranium 235 (more than in the remains of Unit 4 Chernobyl in the sarcophagus by a factor of about 2)**
- **dry storage systems not weather proof nor proof against infiltrating surface water**
    - leading to corrosion of the canisters and the SFA's and leaching out the radionuclides into the water
    - high specific activities of radionuclides in water, 10^{8}Bq/l
    - surface shielding inadequate, dose rates vary from 100's μSv /hr to 10's mSv/hr (most nuclear facilities have limiting dose rates of 2.5 μSv /hr for workers)
- **Highly contaminated pond storage facility, Building 5**

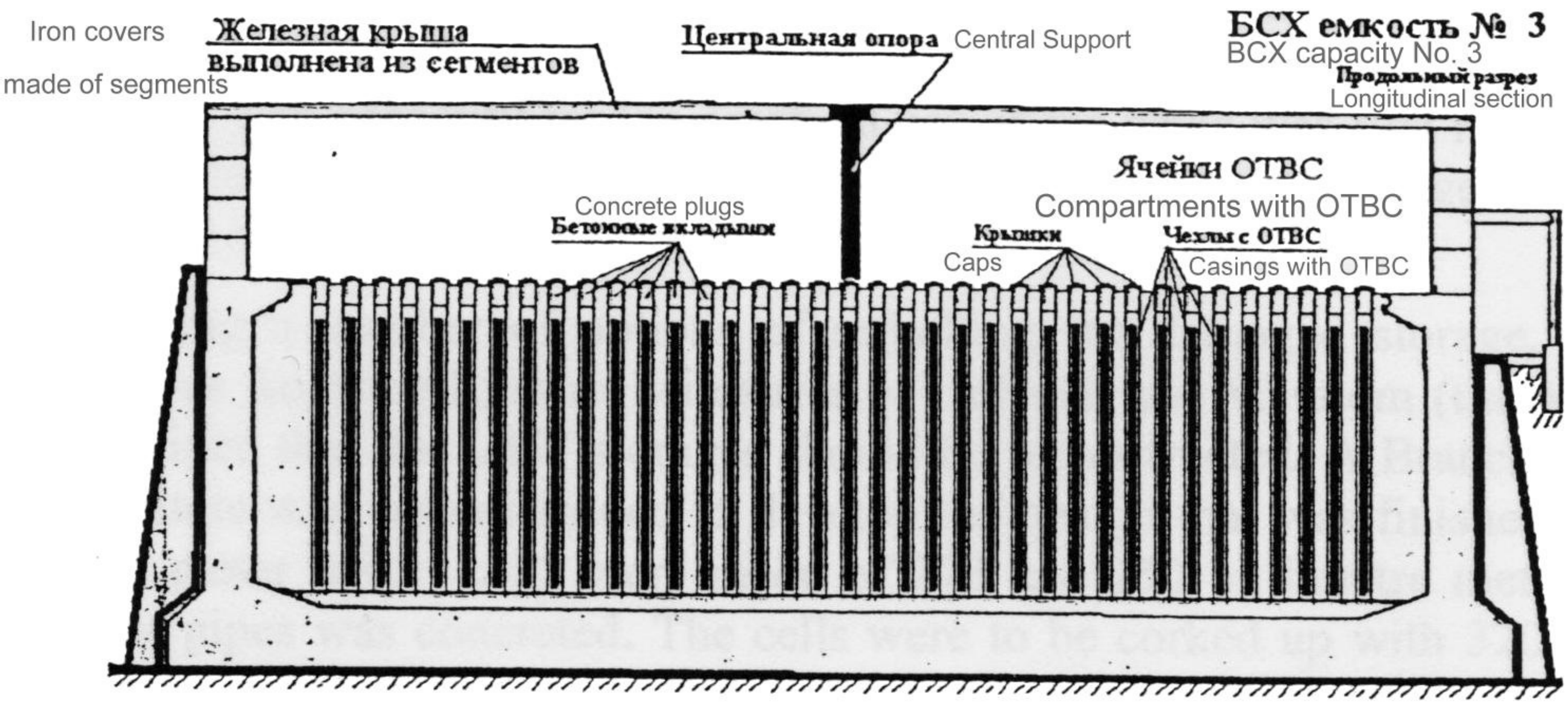
SNF Legacy

Andreeva Bay ~1990

Construction of the DSUs

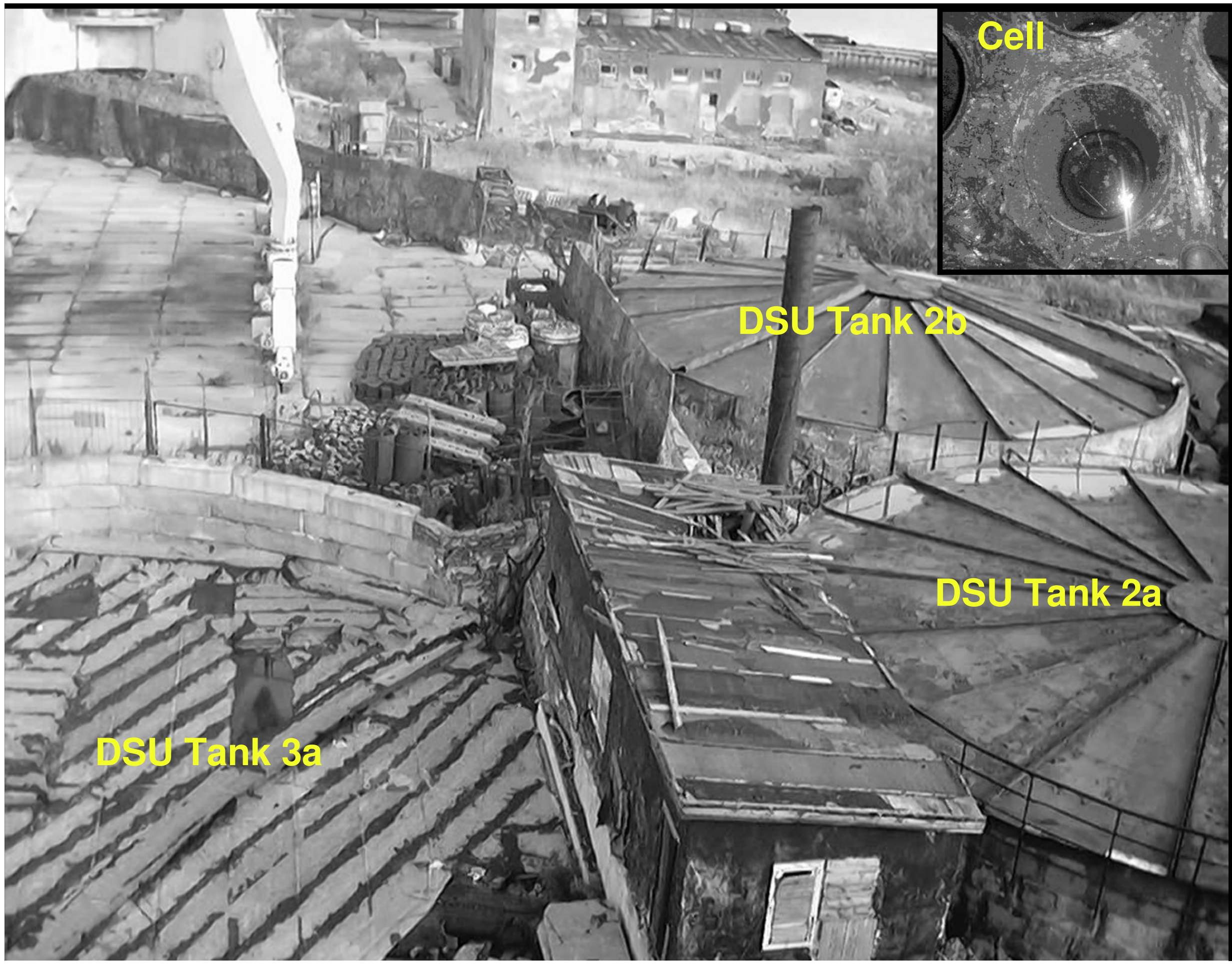


DSU cross-section



Tank 2A

Andreeva Bay – SNF DSUs 2a, 2b and 3a



What have we done?

What have we done?

- Project kick off meeting August, 2002
- Project expenditure to date ~£30M
  - Total predicted UK expenditure ~£90M
  - Total cost for site (SNF plus radwaste plus supporting infrastructure) ~£235M
  - Escalated total costs for the site ~ £366M
- Established ~45 contracts (plus variations) with Russian beneficiaries
  - Information retrieval and surveys to characterise the site and its facilities and to better understand the problems
  - Development of strategy for SNF management
  - Improvement of the site conditions to make it fit for its current purpose and for the proposed new infrastructure
  - Design and construction of new infrastructure to implement the SNF management strategy

Criticality: in-situ

- On-going research since 2003
- Russian and UK studies have shown that a criticality event of any type, including one resulting in the release of all of the radioactive material within the storage units and its dispersion over a wide area, cannot occur.
- Whilst there is a very large amount of fissile material with water present in some cells and corrosion of some of the SNF has occurred, the distribution of the SNF within the storage units precludes a criticality event.
- Even if the entire SNF inventory was to degrade to fuel particulates and deposit on the bottom on the storage units a criticality event could not occur.

Criticality: Extraction of canisters

- Theoretical possibility
  - very low probability
- Mitigation difficult to substantiate
  - Absence of water
  - Integrity of SNF
  - Integrity of canister
- Prevention difficult to substantiate
  - Addition of neutron poisons
- Solution: SFA *not* canister removal
  - Need to open canisters in-situ

Empty SFA canisters at Andreeva Bay

Current concept

- Open canisters in-situ by remote cutting technology
- Remove individual SFAs via retrieval machine
  - *Or if SFAs cannot be removed from canister, remove canister (having drained water from this)*
- Transfer SFAs to new canisters using shielded equipment
- Transfer new canister to TUK-108
  - *Or overpack old canister and transfer to TUK-108*
- Transfer TUK-108 to storage pad near pier
- Ship to Murmansk
- Train to Mayak

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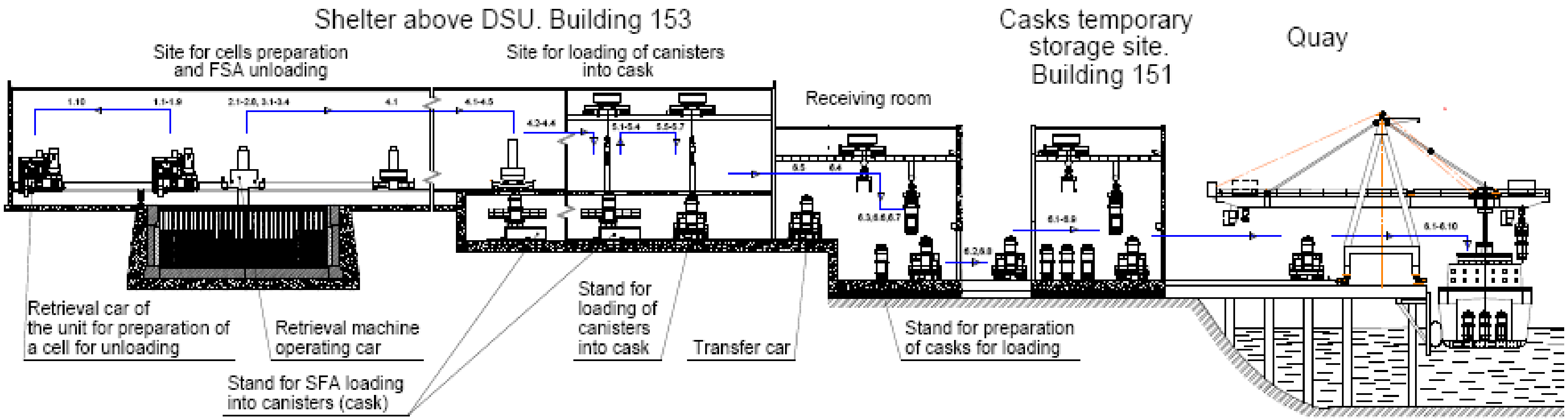
SNF removal process



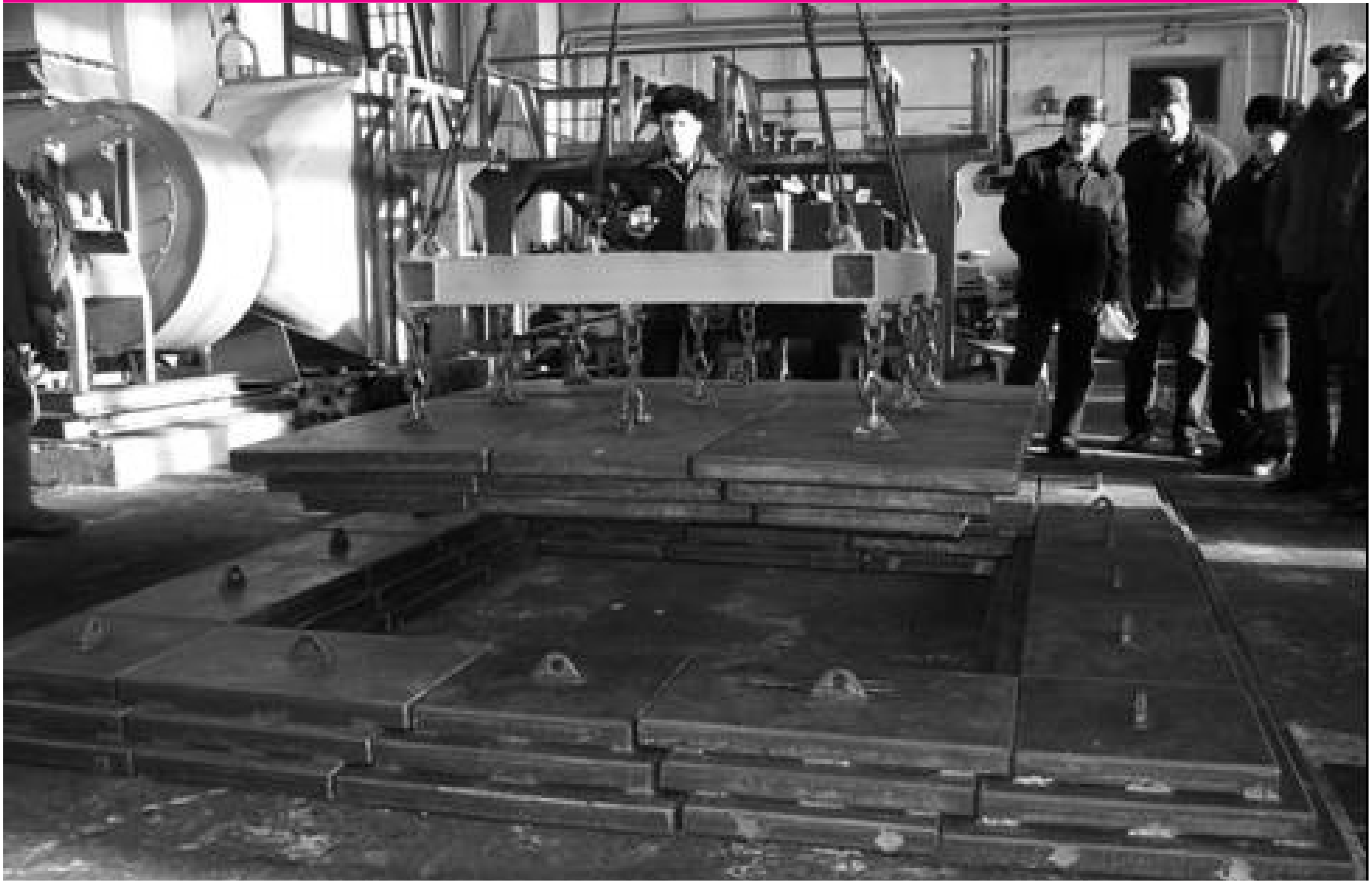
List of main transportation and technological operations
Flow Diagram based on the Spent Nuclear Fuel Facilities

Where do we go from here?

Implementation of the Strategy

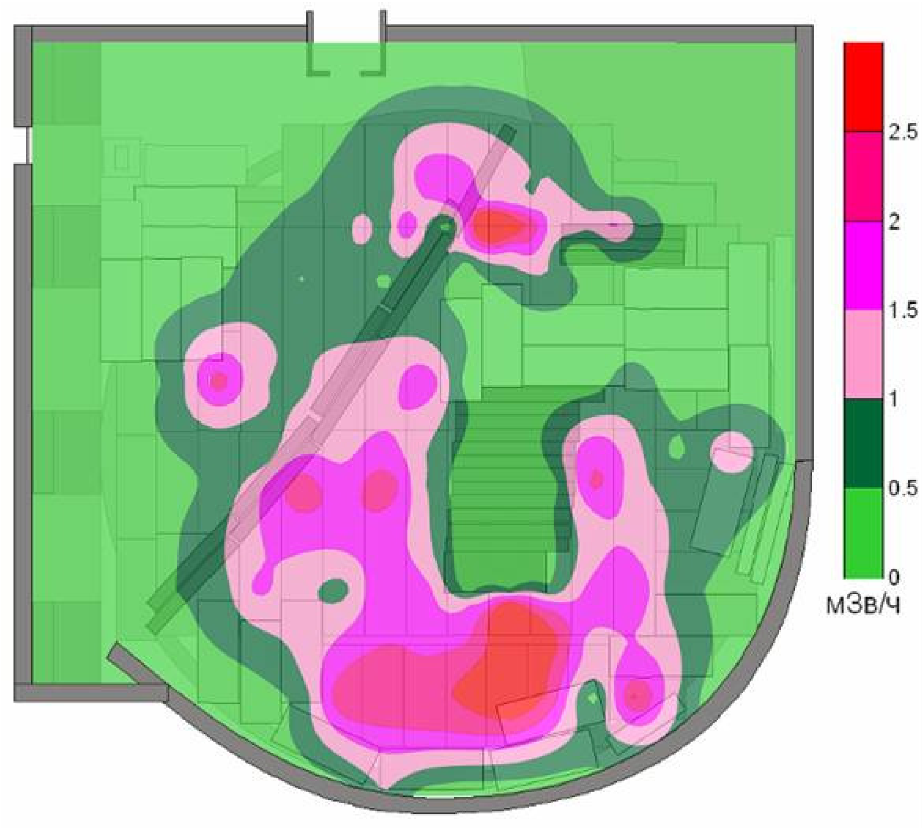
- Prior to the construction of Building 153 horizontal shielding needs to be installed over the DSUs to:
  - create a safe construction environment
  - allow an appropriate interface with the spent fuel assembly (SFA) retrieval equipment
  - allow a safe operating environment within the building
- Horizontal Shielding Implementation
  - Tank 3a: removal of slabs and installation of horizontal shielding
  - Tank 2a and 2b: replacement of cell caps and installation of horizontal shielding
- Detailed design of B153 (containment over the DSU's, SNF recovery and transfer), B151 (cask accumulation area, SNF on-site transport systems) 'special' equipment (retrieval machine, fuel transfer equipment, cask loading equipment, cranes)
- B154 construction (maintenance workshops, store, decontamination facilities)

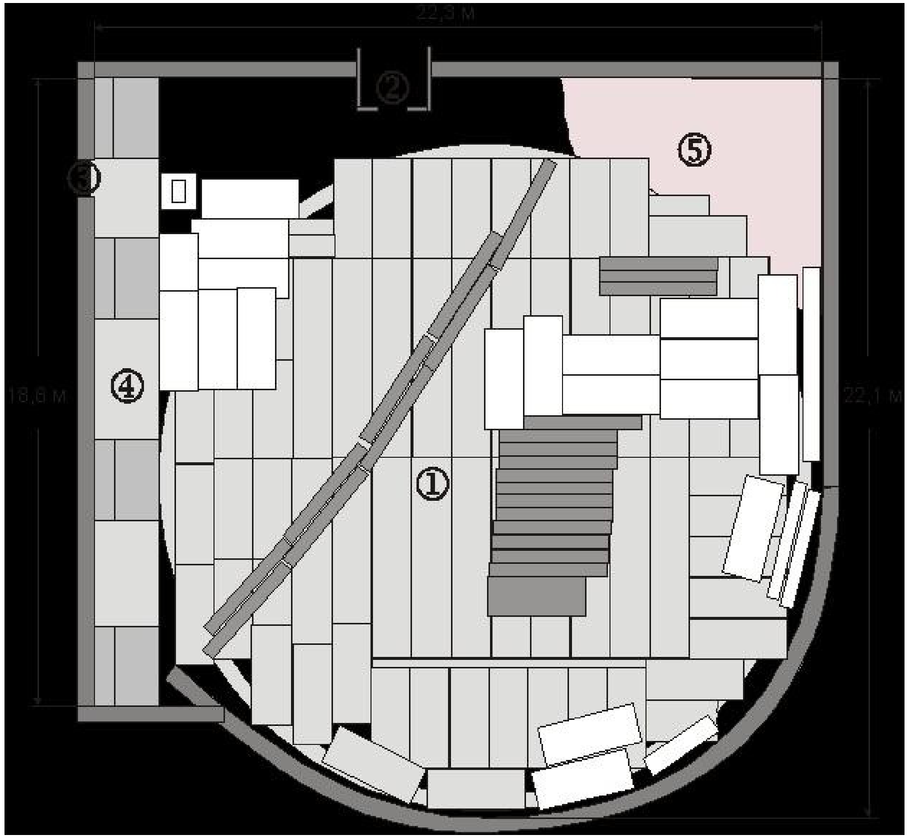
Horizontal Shielding



Isolation of Tank 3a: previous and current state of the Tank

Isolation of Tank 3a: dose distribution





Risks and Hazards

Safety and Environmental Issues

- **There are substantial health and safety and environmental concerns from the site:**
  - **environmental hazards**
    - workers (attempting to monitor and manage the SNF safely)
    - local communities/environment (if no action is taken, a plume of contaminated groundwater will eventually reach the sea and large areas of contaminated ground will be formed with the potential for radionuclide uptake to the biosphere)
  - **security and non-proliferation threat**
    - uncontrolled source of highly radioactive and nuclear materials (impossible to determine whether any materials had been lost or misappropriated)
    - security only possible through administrative controls (deployment of portal monitoring systems)
  - **safety concerns**
    - As the canister and SFA conditions continue to deteriorate recovery operations will become more hazardous
      - higher ambient dose rates,
      - higher possibilities of canisters and SFA's failing in-situ or becoming stuck on removal from the cells/canisters requiring more intervention and longer timescales for operations

Environmental Threat

- Current
  - It is generally assumed that Andreeva Bay represents a substantial regional environmental threat. Whilst it is certainly an undesirable situation, any threats are to the very local site environment rather than to local or remote communities.
  - The dry storage units (DSU's) appear to be intact and are not leaking radionuclides in to the environment. The water present in the tanks comes from precipitation and from occasional inflow (to the top of the DSUs) from the adjacent perched water table during the spring floods.
  - There is no evidence of atmospheric discharges from the DSU's; the filtered extract from the temporary cover on Tank 3a does not show any contamination. Therefore the environmental impact from the SNF at the site is currently negligible.

- Future
  - Without any intervention the situation would deteriorate, the SNF and cladding, canisters, etc. will eventually completely corrode and the DSU's will discharge radionuclides to the local soil and this would in time migrate through the underlying rocks/soils to be discharged into the sea.

  - However, these radionuclides will be largely adsorbed onto the soils and sediments and dilution and dispersion in the local geology and the sea will greatly reduce any environmental impact to local communities.

Security and non-proliferation threat

- Inventory of radioactive materials is unknown
  - Type
  - Location
  - Activity

- No seals, surveillance

- Physical Protection
  - Inside military exclusion zone
  - Via fences, guards, gates, portal monitors
  - Theft of conventional materials (copper cable) has occurred

- Access to site is rigidly controlled, particularly so for non-Russian citizens

- SNF would be difficult to sneak out (size, mass, dose rate)

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Safety Concerns

- Current SNF storage conditions are very poor
- As the canister and SFA conditions continue to deteriorate recovery operations will become more hazardous
  - SFA’s stuck in canisters
  - Canisters stuck in cells
  - High active LRW management
- Control operational conditions
  - Shielding
  - Remote handling operations
  - Containment
  - Ventilation
  - Decontamination

Potential Risks from removing the SNF

- Accidents during removal
  - Contamination
  - Dose rates
  - Contained within buildings

- New SNF accumulation pad near the pier for TUK-108 casks (weather protected, monitored, accountancy system)

- All SNF leaving B153 will be in TUK-108 casks (certified to international standards storage/transport container)

- All cask movements done by certified nuclear cranes or specialised transport trolleys/vehicles

Consequences should critically occur from moving an un-drained canister

- A criticality event could occur during the removal of a canister of SNF from a cell. For this to happen four fuel assemblies need to have completely degraded to particulate form, water must be present and the base of the canister must fail upon lifting. The consequent mixture of fuel particles, water and the cell geometry could cause a transient criticality event.
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- The most significant consequence of such an event would be a sudden increase in gamma and neutron radiation levels in the immediate vicinity of the storage cell. In a worst case scenario, this could result in potentially fatal doses to personnel working above the affected storage cell. An excursion would also cause heating of the water in the affected storage cell.

- The fuel particles are very dense, so they will settle quickly and the potential for criticality will be over.

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Likelihood of other 'explosive' risks in the storage units

- Corrosion of the metallic components in the cells could produce hydrogen (if corrosion occurs in the absence of oxygen) which in some circumstances (mixed with oxygen and with an ignition source) is explosive.

- However, corrosion will occur very slowly and the quantities of hydrogen generated will easily disperse throughout the cell volume. The storage units are not gas tight. There is no likely ignition source for an explosion.

- The canisters are placed on the floor of the storage units and cannot drop.

Conclusions

- Studies by UK and Russian scientists have shown that a criticality event of any type cannot occur given the current disposition of SNF in the storage tanks
- The removal of the SNF by the selected technical option will ensure a criticality event cannot take place
- While the inventory of radioactive material at the site is substantial there are no mechanisms for distributing this material into the atmosphere and to disperse it over wide areas
- The site is well secured, within a military exclusion zone, with check points on roads and there is a modern security fence around the site including a guard force.
- There are radioactive monitoring systems funded by the UK at the SNF storage tanks and an automated radiation monitoring system will be completed this year

Acknowledgements

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- Their support is gratefully acknowledged

Thank you

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