Remediation of Sites with constrained and unconstrained Decision Making – A Comparison in Practice

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Overview of Presentation

- Remediation of the British Nuclear Weapons Site at Maralinga
- History of the Site
- The Decision-making Process leading to Rehabilitation
- Derivation of Risk Reduction (Clean-up) Criteria
- The Potential Management Options
- The Selected Option
- Implementation of the Rehabilitation Works
- Conclusions

- Remediation of the Southern Storage Area at UKAEA
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Extra Ordinary Minds At Work

Remediation of the Southern Storage Area at UKAEA Harwell

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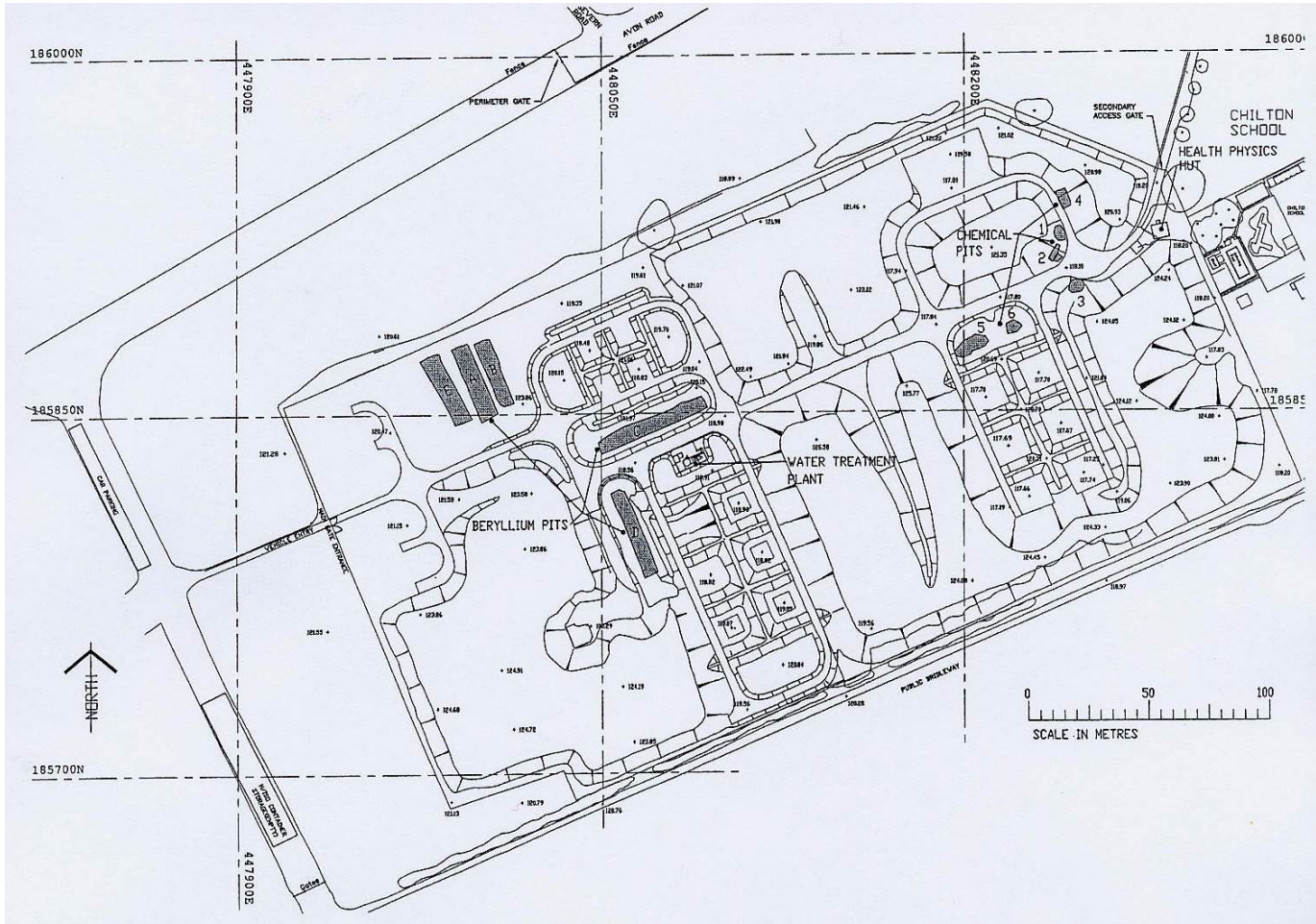
The Southern Storage Area at Harwell

- Location and size: 7.27 ha (375m x 200m) site located 1 km to south of the main Harwell International Business Centre site
- Rutherford Appleton Laboratory (1200 staff) 380 m to north west. Chilton County Primary School (130 pupils and staff) adjacent to eastern boundary. Chilton village (900 residents) 580 m to south east
- 1936-1945 - Munitions Storage Compound for World War II Bomber and Training Base
- 1946-1962 - Waste storage, treatment and disposal area for AERE Harwell. Wastes prepared for sea disposal
- 1962-1990 - Waste storage/disposal area for RRD and Industrial Chemistry Groups

Southern Storage Area from West

Plan of the Southern Storage Area pre-Remediation



Stages in the Remediation Process

- Site characterisation for chemical and radiological contaminants
- Risk assessment and preliminary review of potential management strategies
- Assessments/feasibility studies/trials of remediation options
- Selection of BPEO for Beryllium Pits, Chemical Pits and Common Land areas
- Stakeholder agreement, financial sanction, preliminary safety case and regulatory approvals, etc.
- Process design with safety studies
- Implementation
- Completion and Third Party Validation

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Environmental Liabilities remaining on the SSA in 1999

- Chemical Pits - 6 known pits with potentially others with extensive chemical and radiological contamination. Total volume initially estimated at ~250 m^3.
- Beryllium Pits - 5 pits: A-E, containing ~5000 m^3 beryllium-contaminated equipment and wastes from past decommissioning operations in B220, B47, etc, at Harwell. Included large steel gloveboxes, trunking, drums, etc, and deposits of BeO powder. Some radioactive and chemical contamination, including PCBs, Hg, organic solvents
- Common Land with generally lower levels but a few hotspots of chemical and radiological contamination. Some hazardous materials deposits, e.g. asbestos, unsuitable material and widely distributed munitions

The BPEO Option actual and applied

- **Beryllium and Chemical Pits**
- Actual BPEO – Retain Pit Wastes on-site in engineered containments
- Applied BPEO - Excavation of pit contents with surrounding contaminated material
- Implemented with clearance to Remediation Targets and clay capping of bases and backfilling with clean fill.
- **Common Land**
- Grading of banks and crushing of all concrete bases, roadways, etc.
- Implemented with monitoring and clearance of all areas in 300 mm layers down to 600 mm below RAF levels. Clearance of chemical, radiological and hazardous contaminants to below remediation target levels and removal of any unsuitable material. Grading of site to agreed contours. Reseeding and maintenance of site to public play area standard.

Risk-based Clean-up Levels and Risk Targets

- Two fundamental requirements for the remediation of the SSA were:

- Upon completion a defined human health risk target was to be met for its identified potential uses. It was that the risk of serious harm or death to the most exposed individual should be $\leq 10^{-6}$/a.
- The identified potential use was unrestricted public access for recreational purposes.
- Certain defined categories of waste were to be removed from the site. This included all of the wastes in the Beryllium Pits. It applied irrespective of the levels of risk that the wastes posed. (Section 106 Planning Obligation)
- Risk-based Clean-up Levels (RBCL) were used as conservative, practical expressions of residual concentrations of individual contaminants. The RBCLs for chemical contaminants were applied individually. Those for radionuclides representing carcinogenic risks were applied additively. For chemicals, most values were determined by groundwater protection considerations. Refinement using site-specific data demonstrated later that significantly higher residual levels would still comply with the risk criteria.
- Other factors than the RBCLs alone influenced the desired levels for residual contamination. The concept of "remediation targets" was also introduced. These took account of background levels at the site, the limits of detection for the species of concern, best practice values, waste limits, regulatory constraints, etc, as well as the RBCLs.

Radionuclide RBCL and Remediation Targets

	Remediation Target	RBCL		Remediation Target	RBCL
^{60}Co	0.05 Bq/g	0.05	^{226}Ra	0.09 Bq/g	0.085
^{90}Sr	0.4	6.41	^{210}Pb	0.7	0.69
^{137}Cs	0.12	0.117	^{210}Po	0.42	
^{232}Th	0.27	0.273	^{238}Pu	0.25	0.252
^{228}Ra	0.11	0.11	$^{239/240}Pu$	0.4	0.443
^{228}Th	0.06	0.062	^{236}U		2.9
^{235}U	0.59	0.59	^{241}Pu	0.4	13.04
^{231}Pa	0.18		^{241}Am	0.35	0.345
^{227}Ac	0.03		^{237}Np		0.23
^{238}U	1.4	1.416	^{233}U		2.5
^{234}U	2.5	2.518	^{229}Th		0.08
^{230}Th	0.65	0.654			

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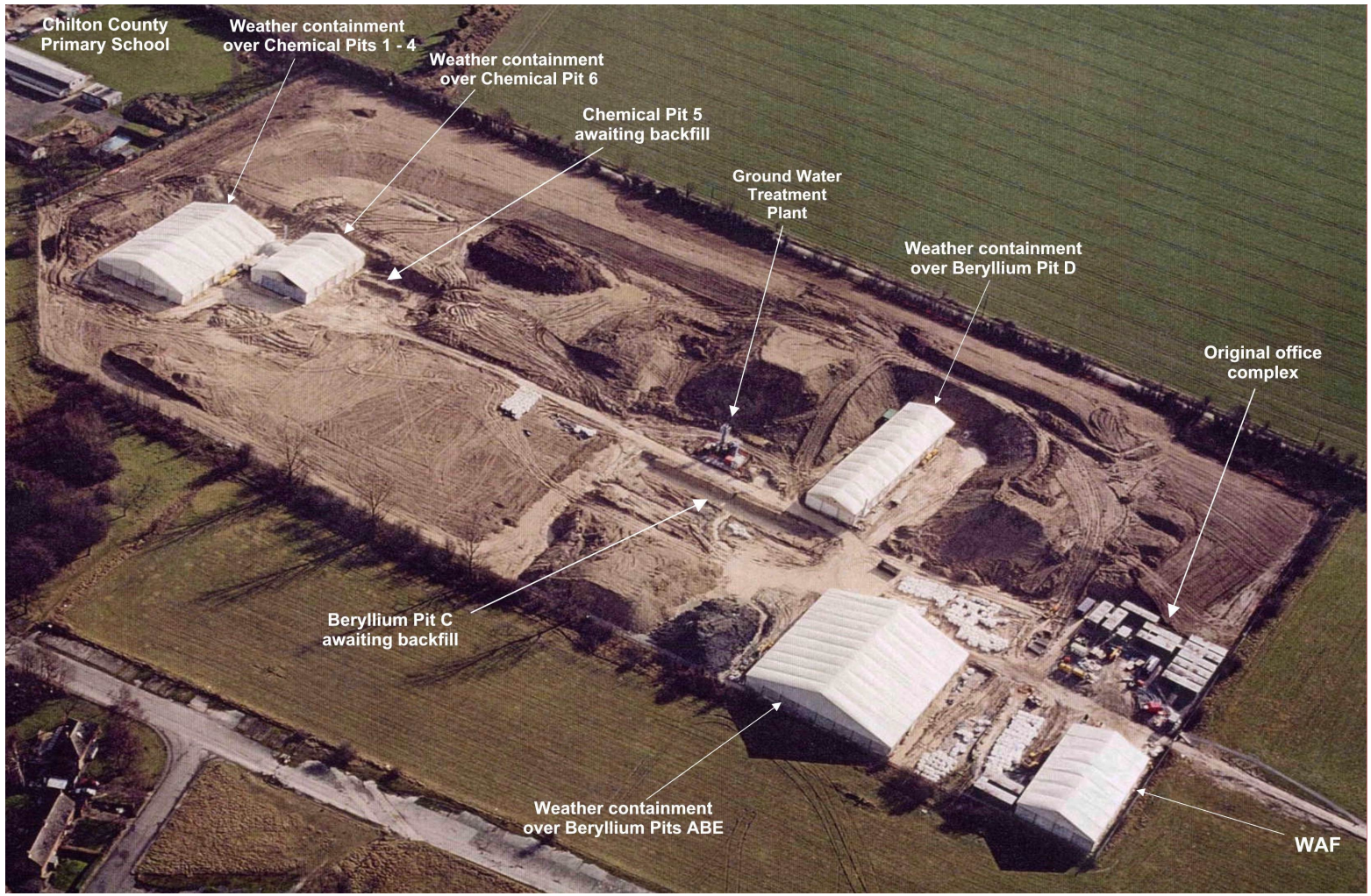
RBCL and Remediation Targets for selected Chemicals

	Remediation Target	RBCL		Remediation Target	RBCL
	ppm	ppm		ppm	ppm
Sb	30	133	Benzo(a)pyrene	0.67	0.014
As	11	10.9	Benzo(k)fluoranthene	0.33	0.008
Ba	200	11.6	Carbon tetrachloride	0.003	0.003
B	14	9680	Chlorobenzene	0.43	0.43
Be	5	585	Chloroform	0.24	0.24
Cd	4.5	4.5	Dichloromethane	0.023	0.023
Cr	380	678	PCB 138	0.02	
Cu	130	66600	Pentachlorobiphenyl	0.06	0.056
Pb	150	150	Pentachlorophenol	0.1	0.022
Hg	2	1.1	Phenols	68	0.00057
Mn	820	0.55	Pyrene	11	10.8
O	2	0.65	Tetrachloroethane	0.0024	0.0024
Ni	33	7.9	Tetrachloroethene	0.016	0.016
V	100	183	Toluene	0.92	0.92
Zn	250	15700	Trichlorobenzene	0.1	0.068
111-Trichloroethane	2.6	2.6	Trichloroethene	0.038	0.038
11-Dichloroethene	0.041	0.041	Trichlorophenol	0.41	0.41
Benzene	0.1	0.012	Trimethyl Benzene	0.62	0.62

The Site during Remediation



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Remediation of the Common Land Areas

Waste Retrieval and Remediation in Beryllium Pits

The restored Site

Conclusions

- 11 Landfill pits removed and all contents disposed off site
- 7.3 ha of land completely remediated to base geology and below worked levels. This involved the monitoring and cycling of ~250,000 m^3 of soil
- Land suitable for unrestricted public access and profiled for public sports use
- ~230 m^3 of LLW disposed of in HHISO to LLW repository at Drigg
- ~14000 m^3 of material, including pit contents, which exceeded remediation targets, was sent for disposal to licensed landfill. A very small proportion, ~100 m^3, was sent for off-site thermal treatment or incineration.
- ~4500 m^3 of unsuitable material, including metal scrap, removed from site for disposal at a licensed landfill or recycling.
- 1200 live practice bombs, 13000 rounds of small arms munitions and 30 land mines were retrieved and disposed of by Army and Royal Air Force bomb disposal teams
- No significant radiation exposures were received by any workers.
- There were no off-site releases above background levels
- The site was finally graded and reseeded for public use

Remediation of the Nuclear Weapons Test Site at Maralinga

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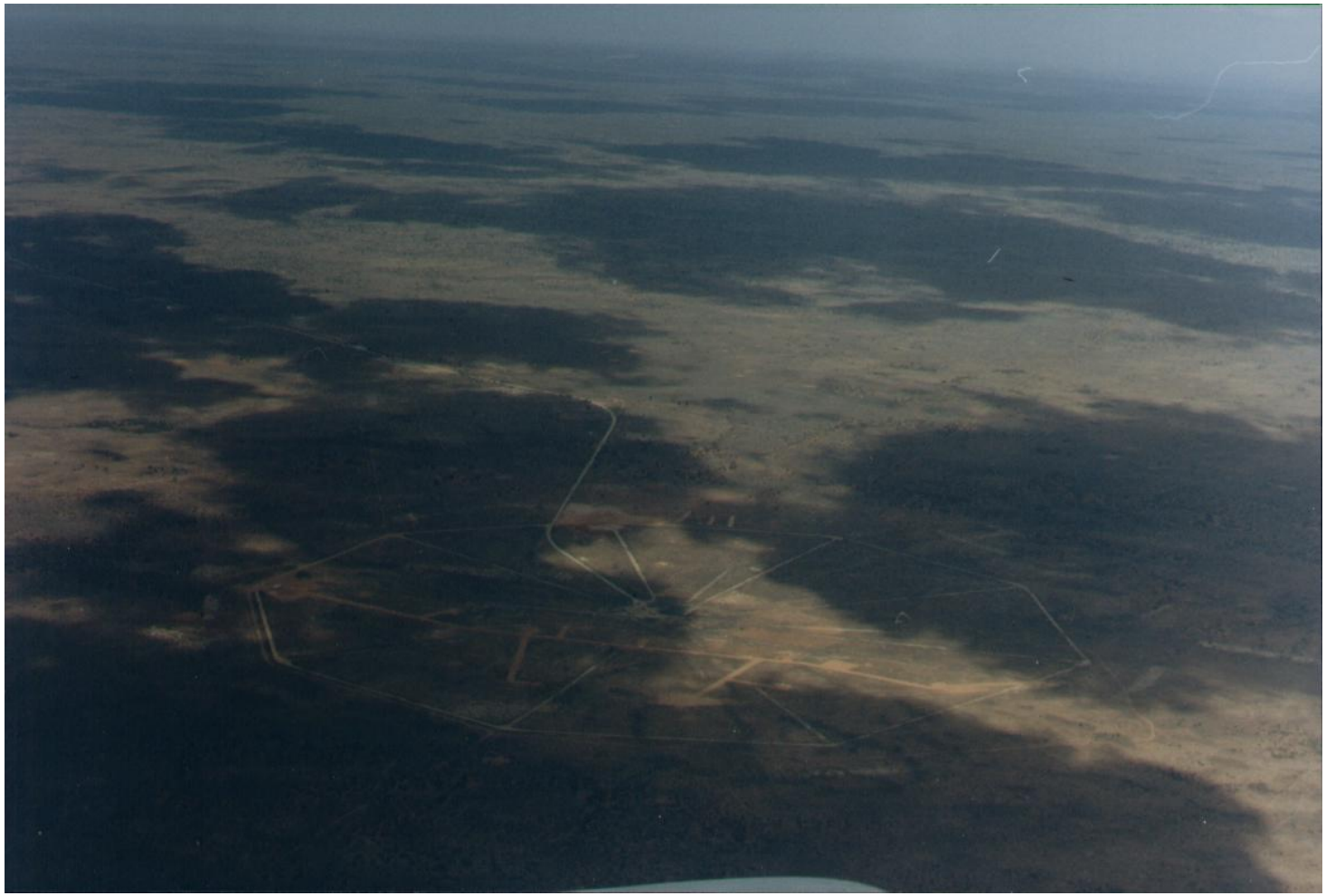
Maralinga Nuclear Test Site in South Australia

Aerial View over Taranaki Site



British Nuclear Weapons Tests in Australia

- Buffalo Maralinga 1956
- One Tree (27.9.56) 31 m Al tower 15 kT
- Marcoo (4.10.56) 0 m Ground 1.5 kT
- Kite (11.10.56) 150 m Air burst 3 kT
- Breakaway (21.10.56) 31 m Al tower 10 kT

- Antler Maralinga 1957
- Tadje (14.9.56) 31 m Al tower 1 kT
- Biak (25.9.57) 31 m Al tower 6 kT
- Taranaki (9.10.57) 300 m balloon 25 kT

- Kittens - Neutron initiator development
- Emu - 1953
- Kittens Lanes at Naya - 1955-57 and 1959-61
- Tims and Rats - Fissile material compression tests
- Kuli, TM2 at Naya, TM50, TM100 and TM101 - 1955, 1956-61 and 1963
- Rats Lanes at Naya - 1956-60
- Vixen A - Safety tests concerned with consequences of accidents, especially fires, involving nuclear weapons and radioactive materials. Study of dispersion of Pu, U and Be in particulate form.
- Wewak - 1959-61
- Vixen B - Study of safety characteristics of nuclear warheads.
- Taranaki - 1960, 1961 and 1963

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The Maralinga Landscape

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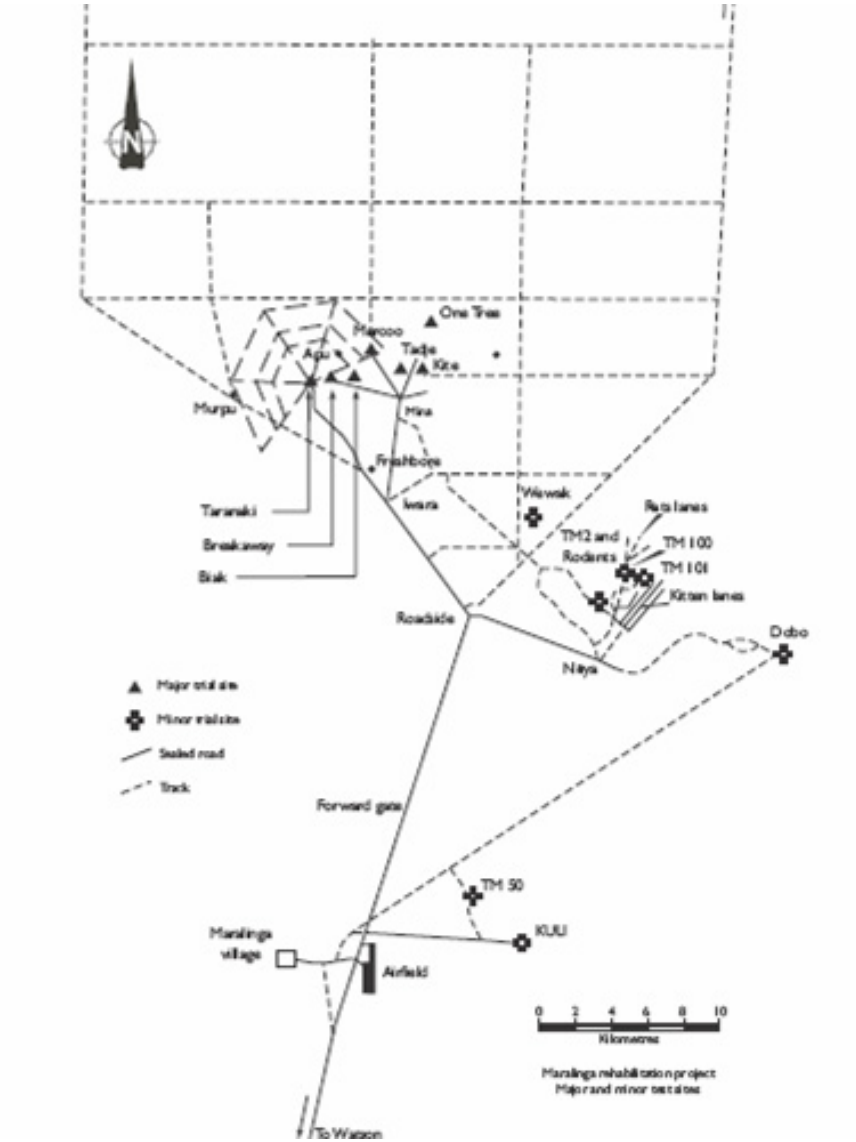
The Test Sites at Maralinga



Radiological Risk Assessment - Purpose

- Determine the current level of risk posed by the site in areas and as a whole, now and with time without remedial action, to native occupants, visitors, etc.
- Determine the corresponding levels of risk posed after application of different remedial strategies
- Determine level of risk posed to operators, etc, during remedial action programme with application of different remediation approaches
- Determine optimum risk management strategy

Assessment and Decision Making

- Technical Assessment Group - Composition and Objectives
- Consultation with Stakeholders to refine Programme Objectives
- Maralinga Commission - Composition and Objectives
- Choice and Evaluation of Clean-up Options
- MARTAC - Maralinga Technical Advisory Committee
- Subsequent Actions and Implementation

Routes to Intake and Factors influencing Risk

- 1. Inhalation of contaminated dust, resuspended from the surface by wind and raised as a result of human activities.
- 2. Ingestion of food which contains radioactive material or has been contaminated by active soil and dust during its preparation.
- 3. Entry into body of radioactive materials through open flesh wounds and abrasions.
- 4. External exposure to ionising radiation emitted by radioactive material or in the ground.

- **Factors influencing Significance of each Pathway for Aborigines**
- Sleeping and eating practices
- Hunting and food gathering
- Food preparation practices
- Sources of food items, including the mixture of local and imported foods and seasons when local foods gathered
- Recreation activities, e.g. children playing in dirt
- Health practices, e.g. rubbing wounds with dirt and leaves
- Cultural practices, e.g. ceremonial wounding

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The Acceptable Level of Risk

- Remediation situation is an intervention not a practice
- Judgement involving social and economic as well as scientific factors
- Annual risk of fatal cancer following inhalation or ingestion of contaminated soil should not exceed 1 in 10^4 by the 50^{th} year
- Contour corresponding to an annual committed dose of 5 mSv defines the boundary between acceptable and unacceptable risk. This was derived from lifetime risk of developing a fatal cancer of 5.0×10^{-2} for a nominal population of equal numbers of males and females of all ages, who are chronically exposed to low doses of ionising radiation. This contour corresponded to 5 kBq(^{241}Am)/m^2.
- Judgements made using Multi-Attribute Decision Analysis.

Remediation Approaches - Treatment Components

- Restrict access by exclusion and/or warning fences
- Collect and bury contaminated soil in specially constructed trenches, possibly decontaminating first to concentrate radioactivity
- Mix lightly contaminated soil in untreated outer plume areas with clean underlying soil to reduce concentration
- Treat burial pits in-situ by pressure grouting or vitrification to immobilise contents and provide better containment
- Exhume and bury pits contents in specially constructed trench or borehole

The Options, Costs and Details

Option	Cost, A$M(1990)	Area released, km^2	Detail
1	13	1560	Construct warning fences around whole area
2(a-d)	13-41	1920	Fence area north of option line with pits at Taranaki, TM101/Tiekins, Airstrip Cemetery and Unnumbered pits, grout other numbered pits
3(a-d)	19-37	2020	Fence area north of option line and all pits bar other numbered and DC/RB pit. These are to be exhumed and reburied
4(a-b)	20-37	2155	Fence area north of option line, Taranaki and unnumbered pits. Exhume and bury all other pits.
5(a-b)	21-66	2820	Fence area north of option line and pits at Taranaki, TM101, Tiekins and unnumbered pits. Exhume and bury all other pits.
6(a-j)	82-653	2820-3120	Fence area north. Previously treated land remove/bury or treat by TRUclean process. Exhume/bury, grout or use ISV to treat all other pits.
7(a-d)	52-82	2430	Fence all contours W of Right Street. Mix soil E of Right Street. No action on Taranaki, DC/RB and unnumbered pits. Exhume/bury or grout or ISV other pits.

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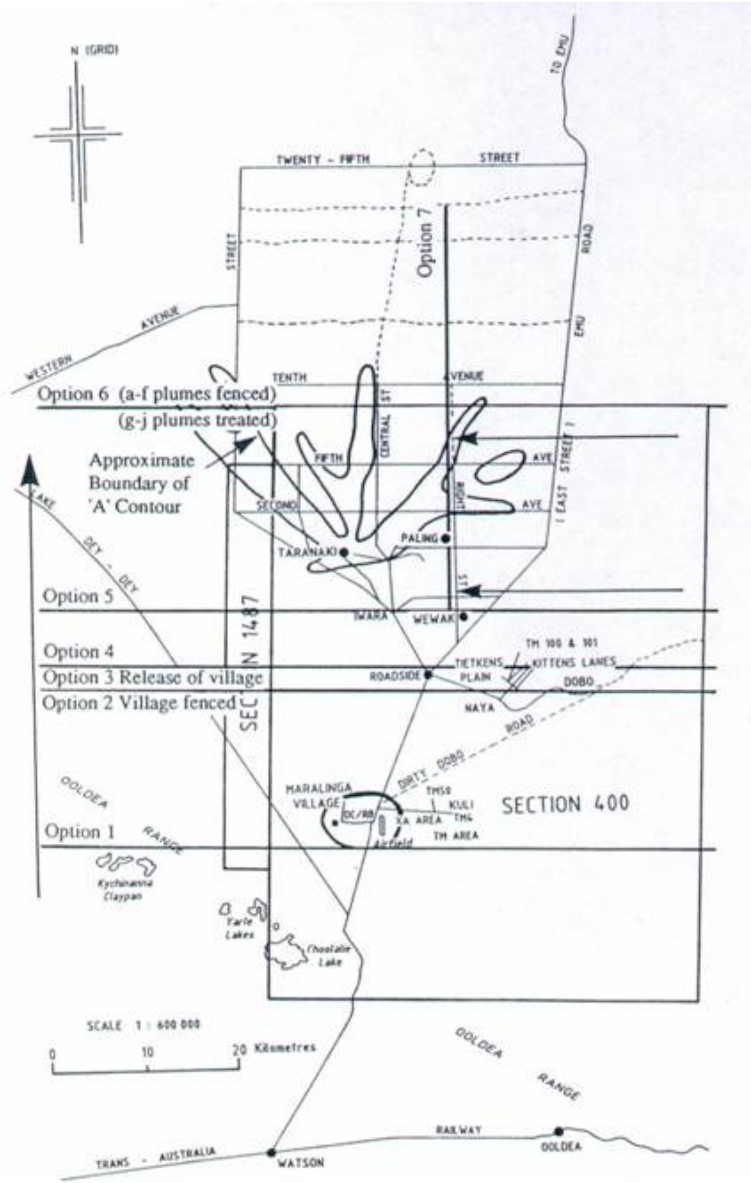
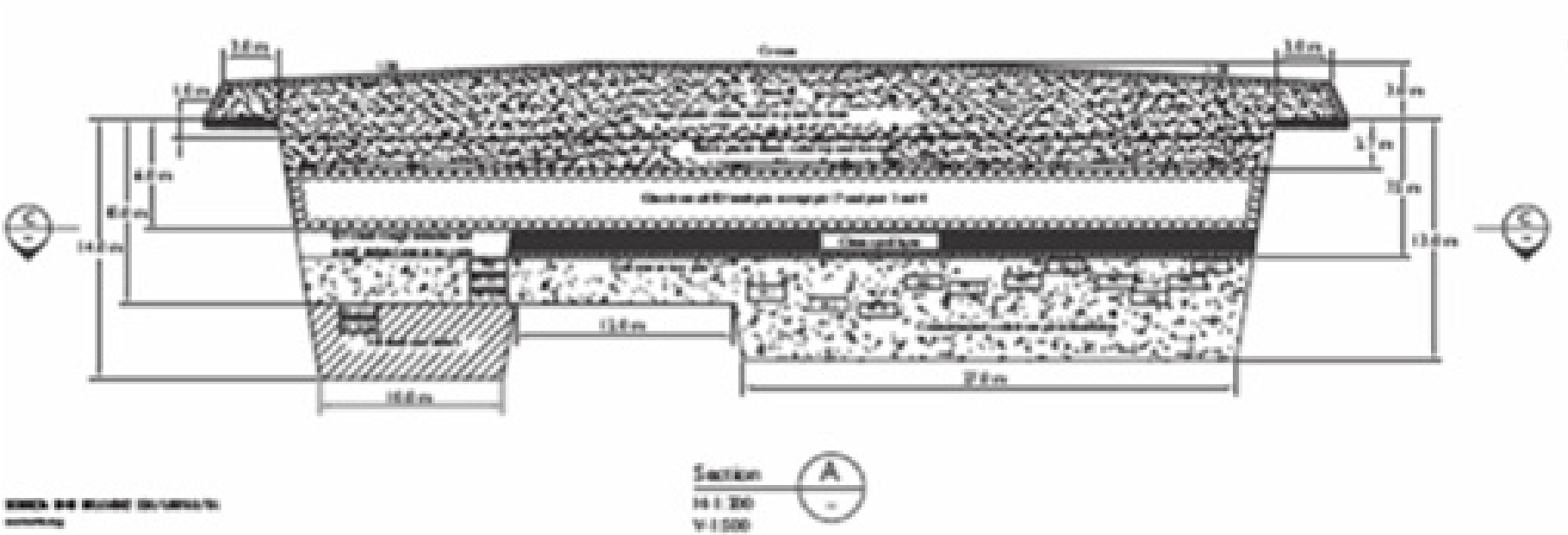
The Options on Site



Contaminated Soil Removal in the Field

Scrapped Soil Removal Area at Taranaki

Cross-section through one on-site Waste Disposal Trench at Tarankai



The Geosafe In-situ Vitrification Plant treating a Debris Pit

Occupational Safety Performance

	Comparative element (country and division)						
	Australia (all industry)	**Australia** (construction)	**USA** (all industry)	**USA** (construction)	**Maralinga**	**UMTRA**	**Enewetak**
Comparison year	1994/95	1994/95	1997	1997	1996–1999	1980–1999	1977–1980
No. of workers	6.8 E+6	2.88 E+5	1.31 E+8	7.84 E+6	230 FTE	13 880 FTE	8 033 FTE
No. of inj. & illness	148 563	12 752	3.8 E+6	3.9 E+5	56	378	63
Non-fatal inj. & illness freq. rate	10.9	22.1	14.5	24.8	TRC 23.9 LWC 15.2	TRC 13.6 LWC 5.2	LWC 3.9
Non-fatal inj. & illness incident rate	21.8	44.3	29	49.7	TRC 47.8 LWC 30.4	TRC 27.2 LWC 10.4	LWC 7.8
No of fatalities	408	43	5 100	1 105	0	2	6
Fatal freq. rate	0.03	0.07	0.02	0.07	0	0.07	0.37
Fatal incident rate	0.06	0.15	0.039	0.135	0	0.14	0.75

Conclusions

- "*Blank Paper*" start permitted by Australian Government
- Best international approaches considered in developing rehabilitation plans
- Results of all assessments with supporting data published for public and peer review
- Rehabilitation to be a "risk reduction" not full clean-up
- Selected approach involved removal of all major risks and optimum cost/land area released
- Extensive public and parliamentary consultation on all aspects of the rehabilitation programme
- All stakeholders closely involved at all stages in the decision process
- National political consensus achieved on strategy and approach
- Particular attention paid to concerns and aspirations of the indigenous Aboriginal population
- Agreement reached with UK for additional settlement

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Thank you