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Scientific Notebook #048

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This notebook documents the ongoing research into systems engineering (WSE#I) in parts of the NRC high level waste program by Aaron DeWispelare of the Center For Nuclear Waste Regulatory Analyses (CNWRA) in San Antonio, TX

Aaron DeWispelare 6/16/92

This work was in support of tasking associated with sub-task 20-5702-251 Special Projects and 20-5702-252 Program Architecture Support to examine integration issues for insite into technical and progammatic aspects of preparation for license application review.

ARD 10/3/92 ARD

ARD

My first thoughts on this subject, are to try a modified traditional state space approach to the System (Part Assessment) and sub-systems (GS, EDS, ADCO, etc.). The next six pages define the "model".

[signature] 8/12/92

AMD

AMD 8/12/92

SYSTEM MODEL

$$F(\underline{X}) = [A]\,\underline{X} + [B]\,\underline{U} + [E]\,\underline{V}$$

$$\underline{Z} = [C]\,\underline{X} + [D]\,\underline{U} + [H]\,\underline{W}$$

$$LB\,\underline{X} < \underline{X} < UB\,\underline{X}$$

$$LB\,\underline{U} < \underline{U} < UB\,\underline{U}$$

$$G(\underline{X}, \underline{U}) \leq \underline{K}$$

$F(\underline{X}) = [A]\ \underline{X} + [B]\ \underline{U} + [E]\ \underline{V}$
$\underline{Z} = [C]\ \underline{X} + [D]\ \underline{U} + [H]\ \underline{W}$
$LB\ \underline{X} < \underline{X} < UB\ \underline{X}$
$LB\ \underline{U} < \underline{U} < UB\ \underline{U}$
$G(\underline{X}, \underline{U}) \leq \underline{K}$

[A] = SYSTEM MATRIX
[B] = INPUT COUPLING MATRIX
[C] = STATE OUTPUT COUPLING MATRIX
[D] = INPUT/OUTPUT COUPLING MATRIX
[E], [H] = STOCHASTIC EXTERNALITIES COUPLING MATRICIES
$G(\underline{X}, \underline{U})$ = CONSTRAINT MATRIX

AWD 8/12/92

$F(\underline{X}) = [A]\ \underline{X} + [B]\ \underline{U} + [E]\ \underline{V}$
$\underline{Z} = [C]\ \underline{X} + [D]\ \underline{U} + [H]\ \underline{W}$
$LB\ \underline{X} < \underline{X} < UB\ \underline{X}$
$LB\ \underline{U} < \underline{U} < UB\ \underline{U}$
$G(\underline{X}, \underline{U}) \leq \underline{K}$

$\underline{X}$ = STATE VARIABLES
$F(\underline{X})$ = FUNCTION OF STATE VARIABLES
$\underline{U}$ = INPUT VARIABLES
$\underline{V}$, $\underline{W}$ = NOISE, UNCERTAINTY SOURCES
$\underline{Z}$ = OUTPUT/PERFORMANCE MEASURES
$\underline{K}$ = CONSTRAINT FUNCTIONS/PARAMETERS
UB, LB = STATE, INPUT BOUNDS

AWD 8/12/92

Potential entries of the state space model for the HLW repository:

$\underline{X}$ = [temperature, % corrosion, % saturation of medium, radioactive decay level, ,,,,]^T

$\underline{U}$ = [level of climatic change, extent of human intrusion from drilling, level of magmatism affecting the site, seismicity affecting the site, ,,,,]^T

$\underline{Z}$ = [Individual radiation dose, radiation release rate, groundwater travel time, retrievability of waste, ,,,,]^T

$\underline{V}$ = [uncertainty reduction technique success, lack of data due to intervention, ,,,,]^T

$\underline{W}$ = [various distributions associated with natural phenomena]^T

A = [[GS Subsystem] [EBS Subsystem] [GROA Subsystem]]

SUBSYSTEMS

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The GS subsystem = the geologic, hydrologic, and geochemical processes and conditions of the region in which the repository is located.

The EBS subsystem = the constructed waste packages and underground facility involved in permanent storage of the waste.

The GROA subsystem = part of the repository, including both surface and subsurface areas, focusing on waste handling activities prior to closing.

Based on previous program architecture work, and the transition to Systematic Regulatory Analysis (SRA), the decision by the NRC to decouple System & Sub-systems 112/122 rule making, turns the "Systems" research toward a coupling with performance assessments (PA) for a "System Model".

ARD 6/17/93

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For this approach, a variation of the Leontief Input/Output Large Scale System Model, a coupling between the regulation (citations) must be mathematically coupled to the sub-system models and then through contrived or actual linkages, to the PA "System" model. State vectors of functions (difference, differential, or matrix) would seem to be the natural vehicle for the I/O model structure.

ARD 6/18/93

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Possible Integration model SRA & Perf Assessment (state space approach)

x or $\dot{x} = Ax + Bu$

$Z = Cx + Du$

$\dot{x}[f(x)] = $ [EBS] [EBS] [GRDA] [UNCERT Reg & Inst] $[f(x)]$ + Externalities + Noise

x or $\dot{x}$ or $f(x)$ ≡ state vector, each can be a set of scalars or functions, equations or model(s)

PERF Indicies → $Z = [C][f(x)] + [D][u]$

[D] – coupling matrix from inputs to state matrix; [u] – inputs

eg 1. Ground Water Travel Time

2. Geo Setting 1000 yrs

6/19/93
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Perf Assessment continued: Perf Assessment involved in Hydrologic Transport ← ground water travel

SYSTEM PERF MEASURES

1. INDIV (individual dose radiation) 60.113(a)(1)(B)(ii) A – EBS
2. GW (ground water travel) ~~containment~~ ARD 7/8/94 60.113(a)(2) – Geologic setting
3. REL (release rate) 60.113(a)(1)(B)(ii)(B) – EBS

& EPA standards for all 3

Subsystem PERF MEASURES

– Natural systems (NS) – GWT (ground water travel time)

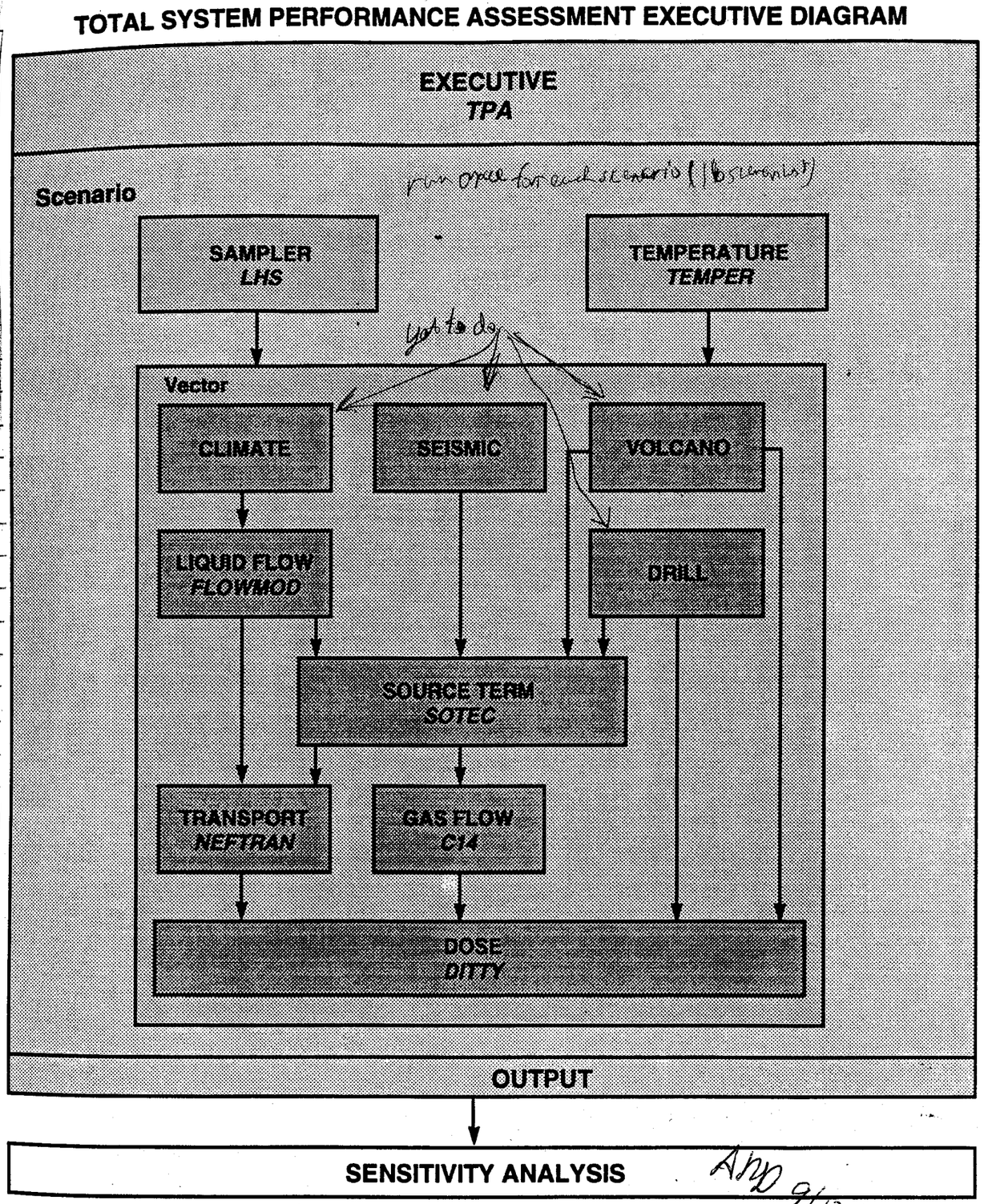
– Engineered Barrier System (EBS)
  – SCC (substantially complete containment)
  – REL (release rate)

– Geologic Repository Operations Area (GROA)
  – RET (retrievability of waste) 60.111(b)
  – REL (radioactive release) 60.111(a)

ARD 6/21/93

PA data flow parallels the "physical" flow which may be fruitful for a large scale systems model certainly supporting the Leontief Input/Output model - see attached → code Module flow as a conceptual vehicle

ARD 9/12/93



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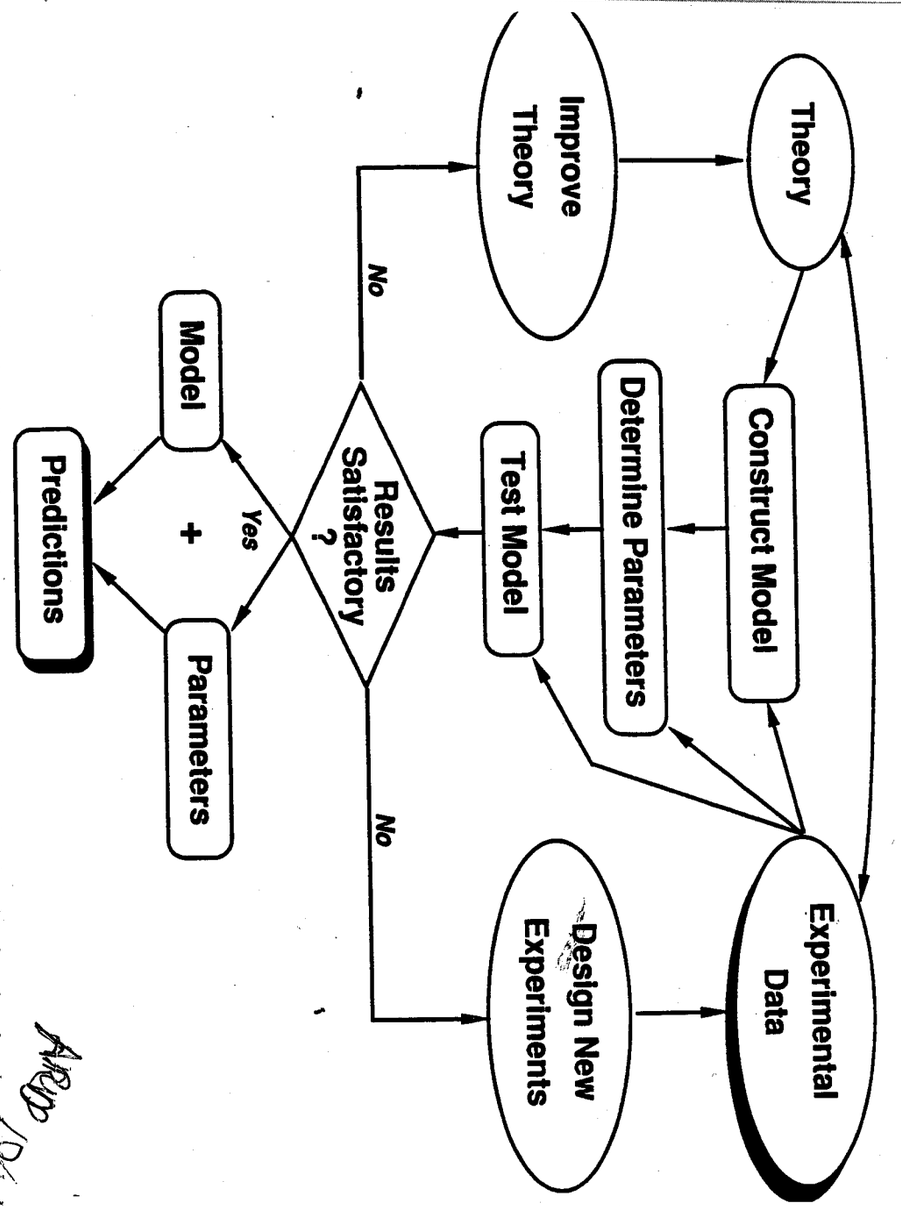


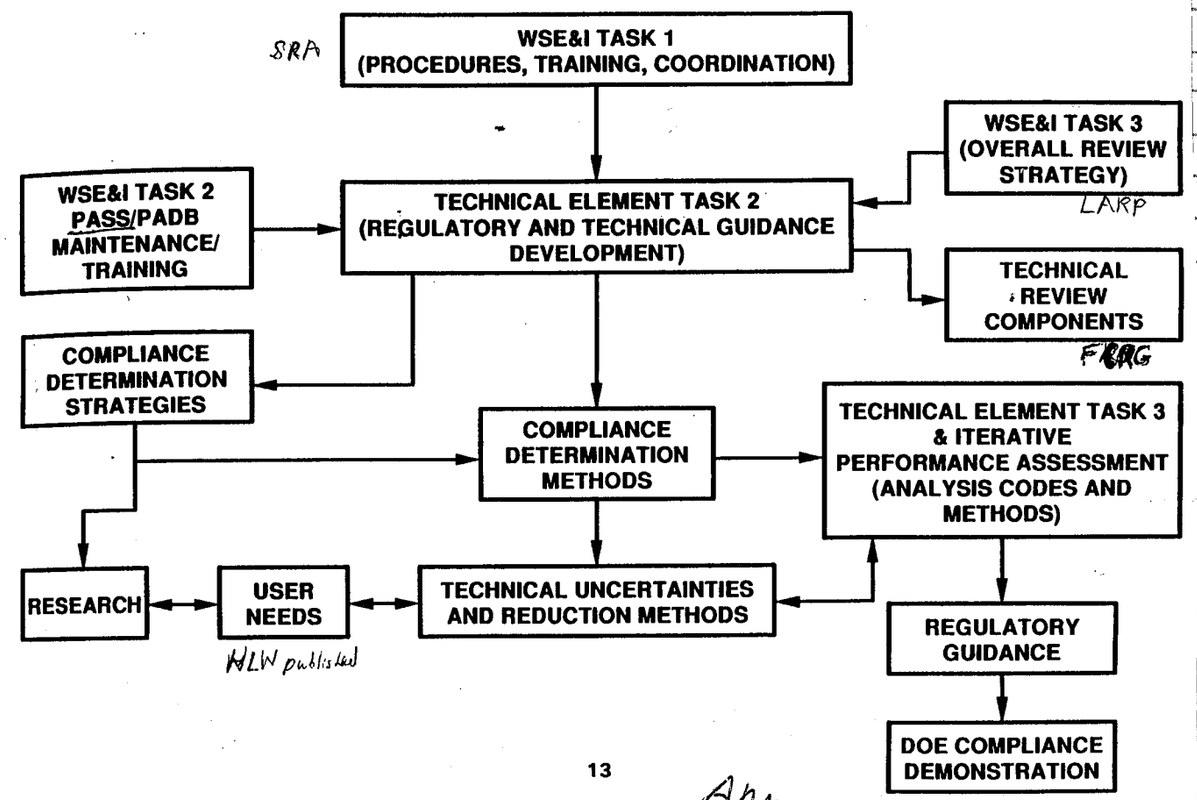
PA Model Flow

Bartlett diagram

Arlup 10/1/93

THE ROLE OF WSE&I IN INTEGRATION:

SCHEMATIC OF RELATIONSHIPS AMONG PROGRAM ELEMENTS



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SRA

LARP

FRAG

HLW published

AMD 10/3/93

The role of integration of WSE&I/PA is "natural" for providing the system flow of INFO to the matrices for connectivity of calculations.

AMD 10/5/93

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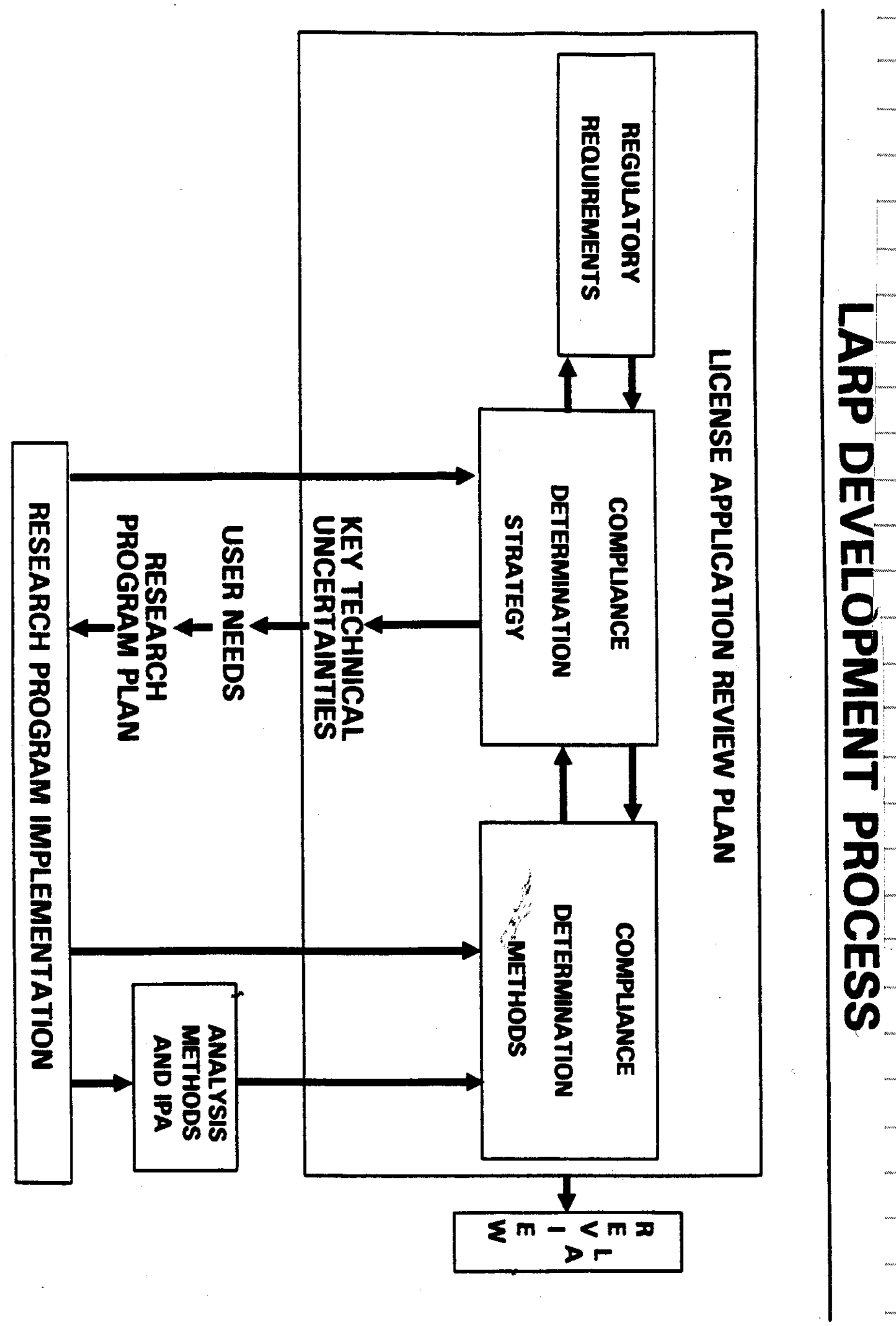

Integration - Technical & Regulatory; Interface with Key Technical Uncertainties (KTU's)

ARD 10/10/93

State Space Model — more than one possible since they are not generic (i.e. they are site or design specific eg Yucca MTN - Hot repository and Yucca MTN - Cold repository)
— different portions of submodels inside and perhaps different states also

10/17/93

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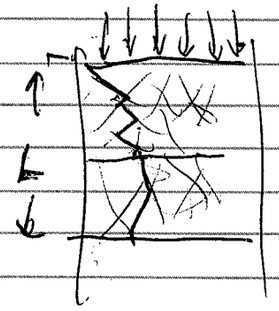
Optimization Notes: Ross Bagtzoglou

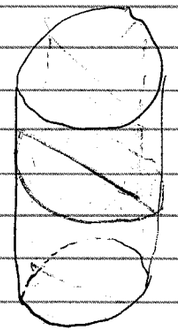
problem: determine shortest path / shortest water travel time.

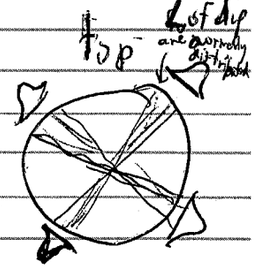
faults in aquifer

least section



side view

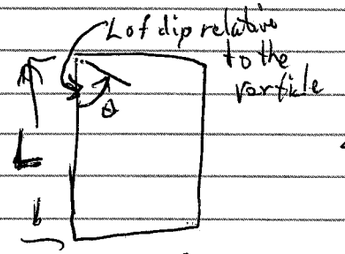


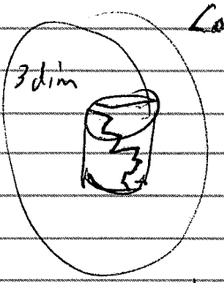


∠ of fault (dip) azimuth

∠ of fault (strike) elevation

2 dimensional first





min dist, $\theta = 0°$, distance = dist = $\cos^{-1}\theta \cdot L$

$= \sec\theta \cdot L$

for 45°, dist = $\frac{1}{\cos\frac{\pi}{4}} \cdot L = 1.414 \cdot L$

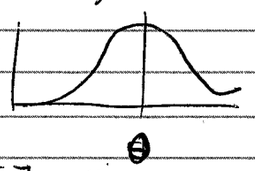
where θ_i is the angle relative to vertical of fault i with ~~angle~~ length to intersection of ~~fault~~

$\sec\theta = \frac{1}{\cos\theta}$

0°	45°	60°	90°
1	$\frac{2}{\sqrt{3}}$ 1.15	1.414	2

vertical length = $\sum_i \sec\theta_i \cdot L_i$

Stochastically:



$E[\theta] = \int f(\theta)\, d\theta$

ave length = $\sec[E[\theta]] \cdot L$

shortest = $\sec[\theta - 3\sigma_{min}] \cdot L$

longest = $\sec[\theta - 3\sigma_{max}] \cdot L$

ARD 10/21/93

Pages 1 through 19 of this Scientific Notebook were reviewed for compliance with QAP-001 in response to Corrective Action Request 94-02. Corrections and clarifications were made as appropriate. In some cases, the date of a change will reflect the date of this review rather than the date of the original Scientific Notebook entry.

[signature] 9/9/94 Randy Folk 9/9/94

I have reviewed this scientific notebook and find it to comply with QAP-001. There is sufficient detail so that another equally qualified technical person to follow and reproduce.

RG Baca 2/15/97