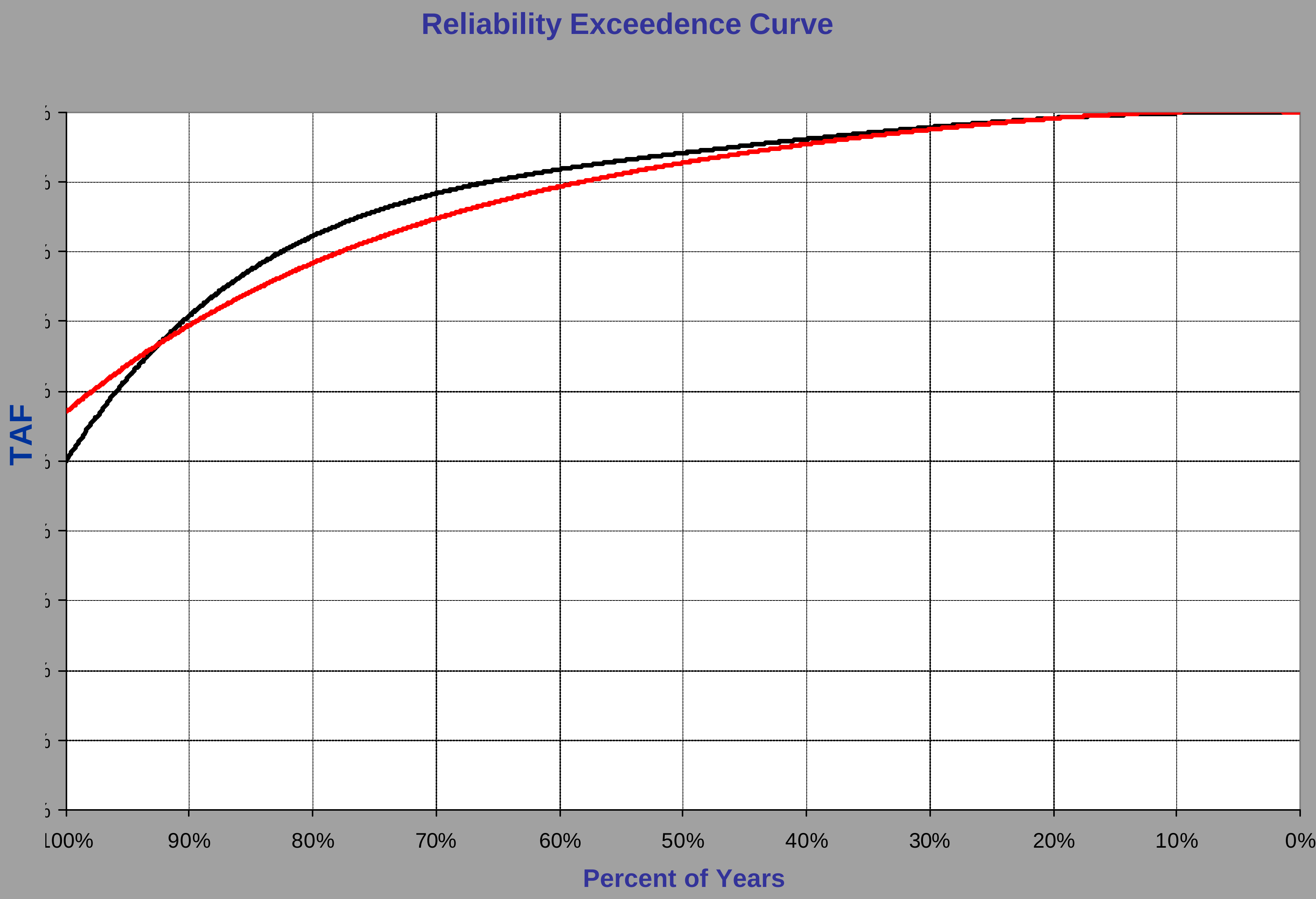
A Tale of Two Models

- Least-Cost Planning Simulation Model
  - Part of the CALFED Surface Storage Common Model Package
  - Underwent lengthy vetting process with participants from DWR, USBR, local water agencies, and CALFED consultants (economists and engineers)
- GBP-NETFLO
  - Proof-of-concept stage

Urban Water Management Planning with LCPSIM

The Analysis Problem



The Issues

- Existing DWR economic analysis methods and tools were inadequate for valuing reliability[1]
- We had DWRSIM to provide yearly delivery information but some type of regional economic systems analysis capability was needed to see how proposed SWP project operations could contribute to regional reliability in the context of existing and forecasted regional operations and available water management options like recycling and conservation
- The approach would have to take into account the ability of regional carryover storage capacity to be used to “firm up” SWP deliveries.

[1]Reliability, defined in economic terms, is the ability of a water service system to avoid adverse economic impacts that result from variable water supply and demand conditions

LCPSIM Description

- Finds the management strategy for which the total of all costs, including operations costs, the costs and losses from shortages, and the costs of long-term and contingency measures to manage shortage is minimized
- Solution found by incrementally adding regional water management options based on their relative cost and running the historical hydrology (currently 1922-2003) for each new level of option use
- Priority-based (where should the water go?), mass balance-constrained (water in equals water out) linear programming used to simulate regional water management operations on a yearly time step, including using dynamically calculated priorities for the operation of surface and groundwater carryover storage capacity

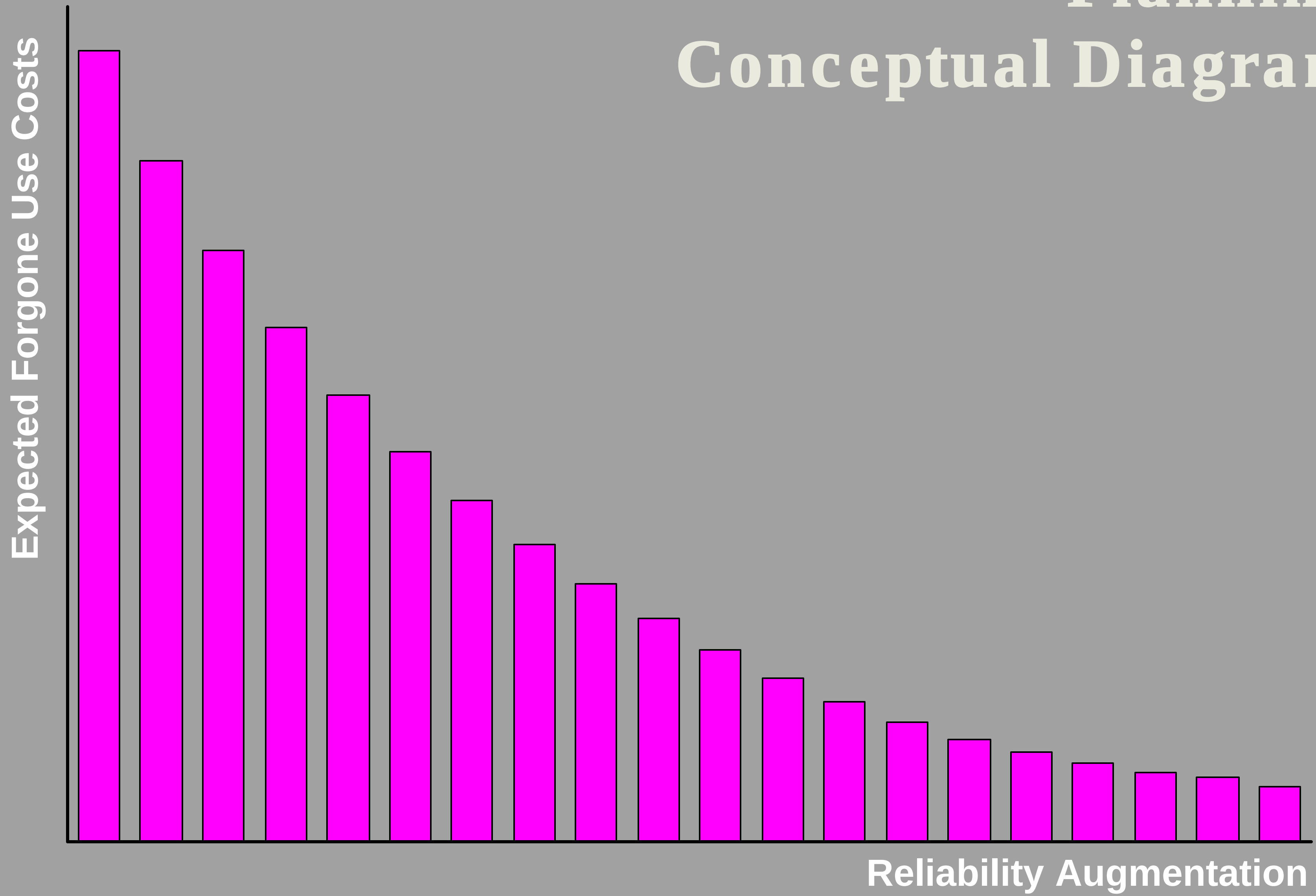
LCPSIM Description (cont.)

- LP constraints used to model carryover put, take, and conveyance capacities; available storage capacities; and SJV Valley banking operation rules; etc.
- Economic losses related to foregone use through a loss function based on residential water user demand and by shortage allocation logic for other water user types
- Delta-to-tap simulation (iterated with CALSIM II)
- Simulation is for a fixed level of development (e.g., 2030)
- Quadratic programming used to minimize the incremental cost of adding to reliability (e.g., conservation, recycling, ocean water desalting)

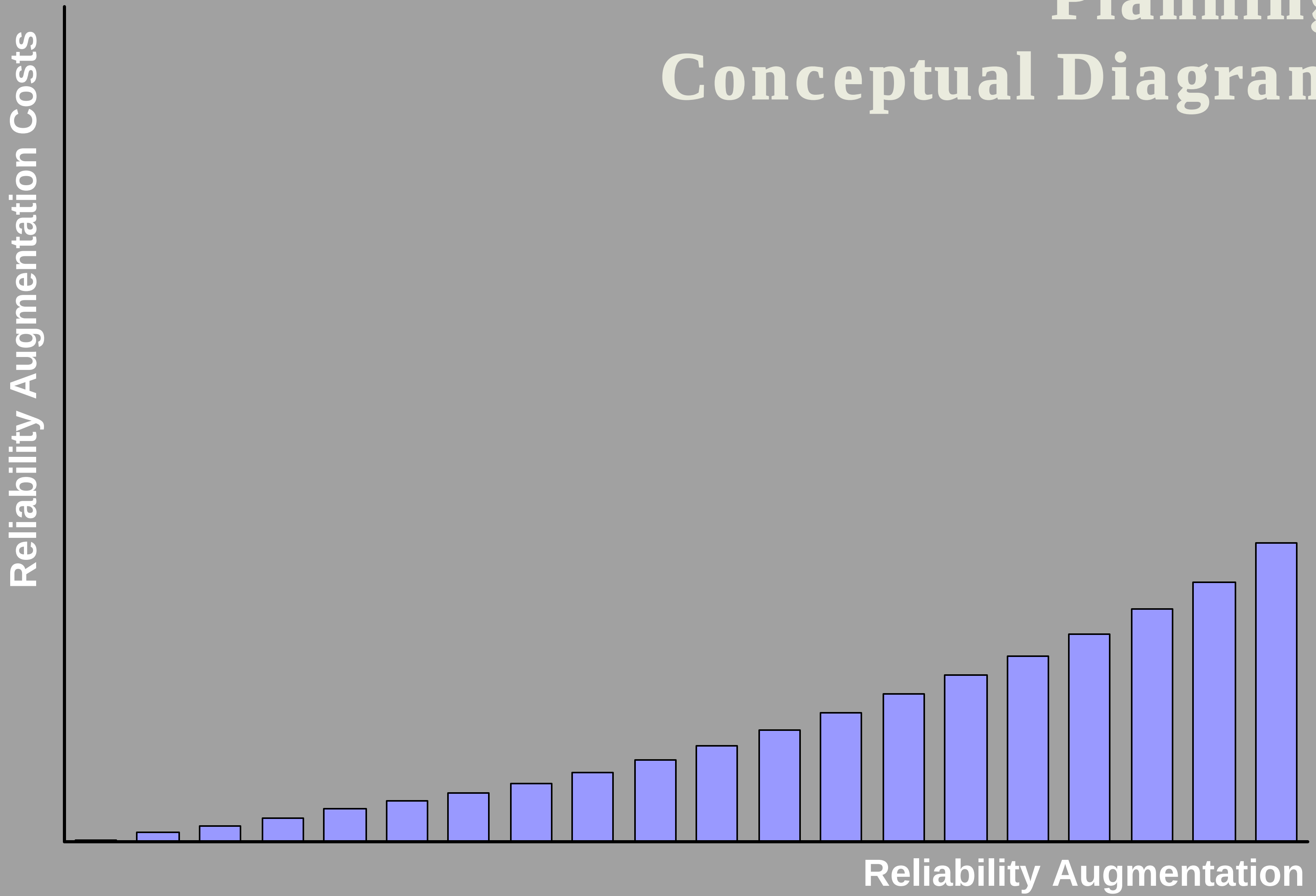
LCPSIM Description (cont.)

- Losses affected by the level of use of long-term conservation measures (demand hardening)
- Accounts for the effect of conservation on reuse
- Water market purchases simulated by quadratic programming, generating the least-cost combination of regional economic losses and transferred water cost (cost of water market purchases vary by year type)
- Model can be used either for optimization or for evaluating a fixed level of adoption of long-term regional water management measures
- Data-driven for flexibility (e.g., carryover storage facilities added by adding a line of parameters to a text file)

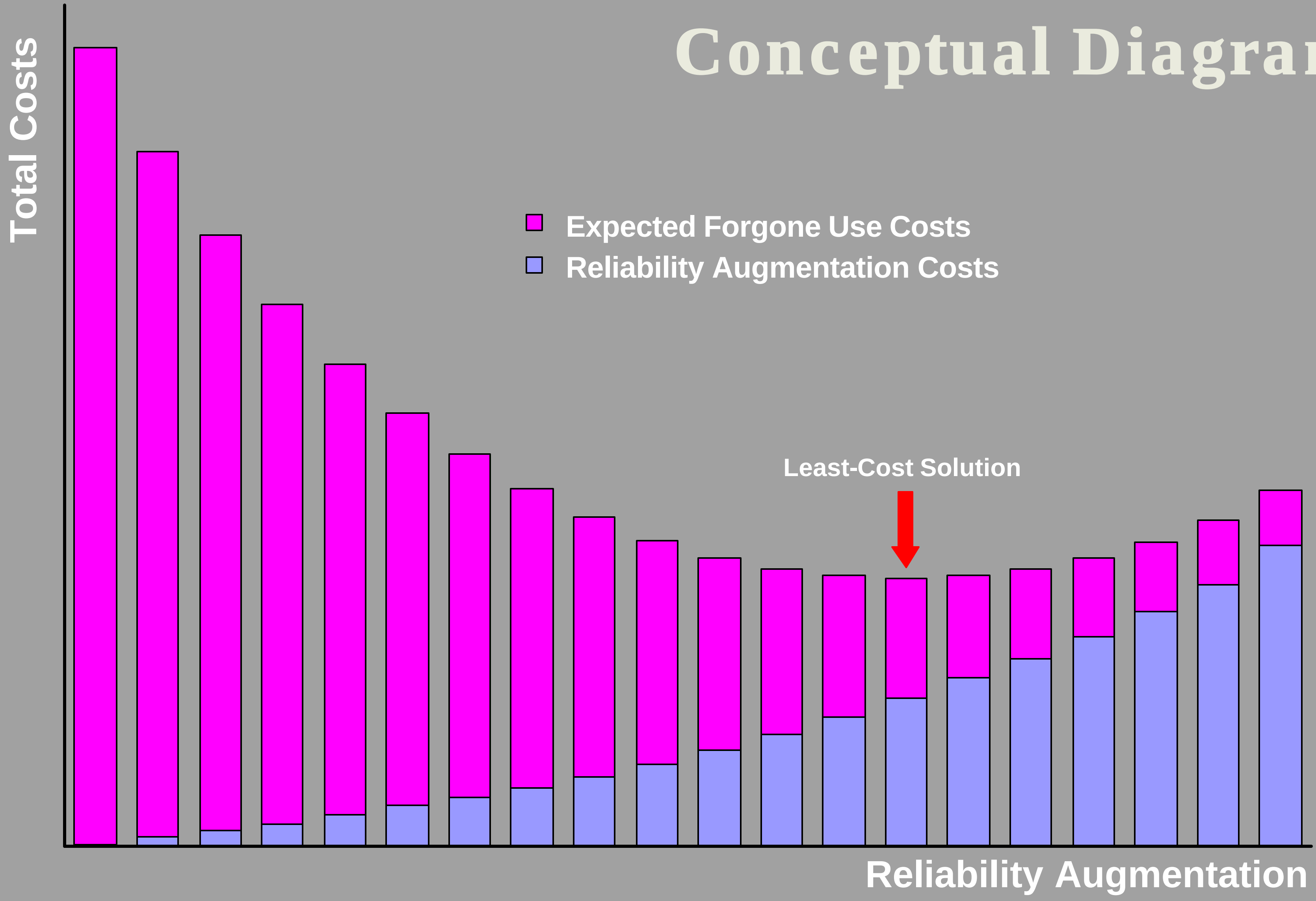
Least Cost Water Management Planning
Conceptual Diagram



Least Cost Water Management Planning
Conceptual Diagram



Least Cost Water Management Planning
Conceptual Diagram



LCPSIM Polynomial Loss Function

Willingness-to-pay (WTP) values

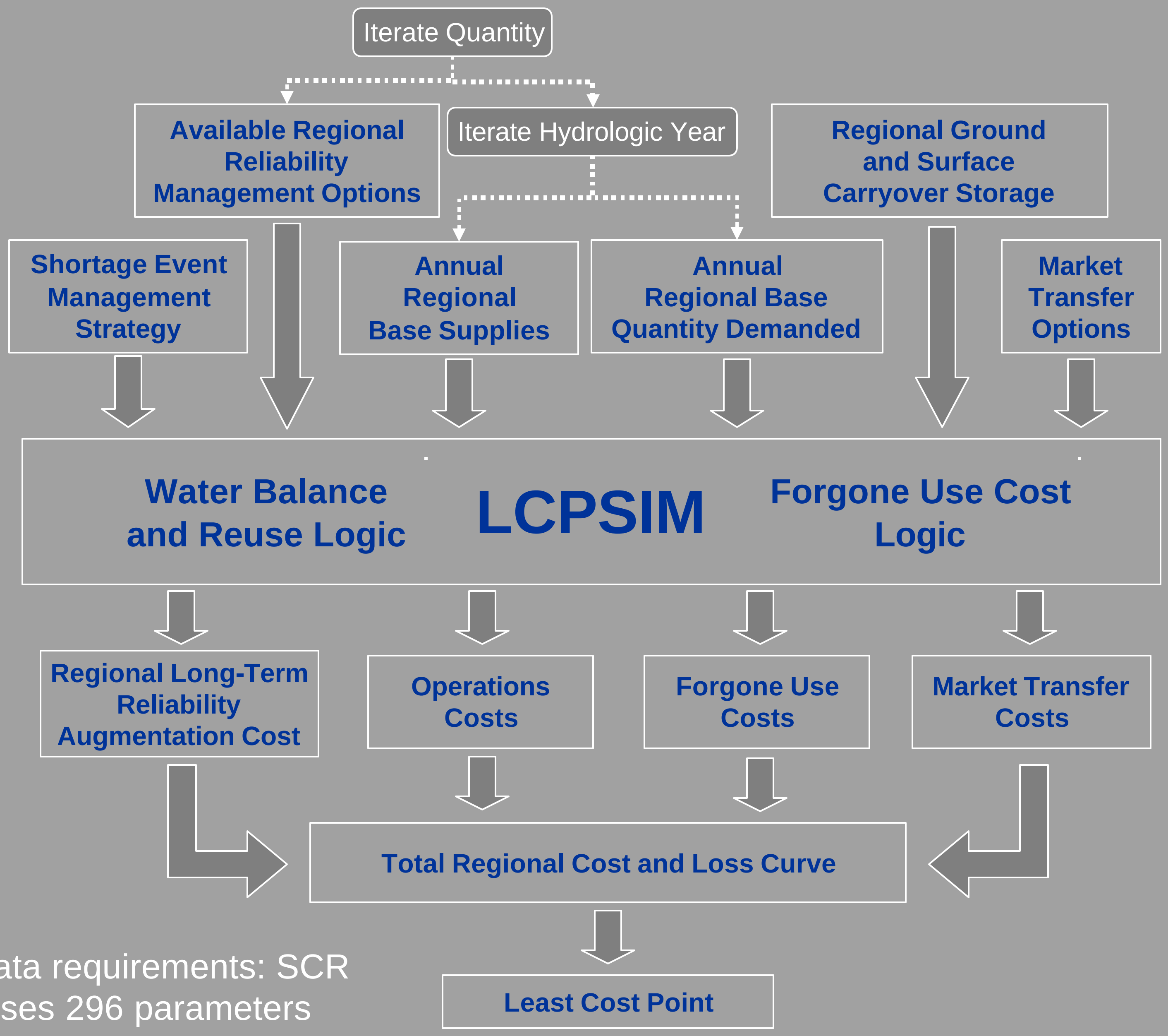
Forgone Use (% of use)	Value Forgone[1] ($)	Average Value[2] ($/AF)	Marginal Value[3] ($/AF)
0.0%	$0	$1,074	$1,074
5.0%	$84	$1,679	$2,270
10.0%	$226	$2,256	$3,381
15.0%	$421	$2,804	$4,404
20.0%	$665	$3,323	$5,337
25.0%	$953	$3,811	$6,176
30.0%	$1,281	$4,269	$6,920
35.0%	$1,643	$4,695	$7,565

[1]Value of forgone use based on one acre-foot of use (e.g., area under the curve between 0% and 5%). If annual use for a residence is 0.5 AF, then WTP is $42 to avoid forgoing 5% of use for one-year (0.5 AF * 5% = 0.025 AF of forgone use), for example.

[2]Value forgone divided by acre-feet forgone (e.g., $84 / 0.05 acre-feet = $1, 680 per acre-foot).

[3]Value per acre-foot of last increment (e.g., last mL) of use foregone.

Overview of LCPSIM Inputs and Outputs

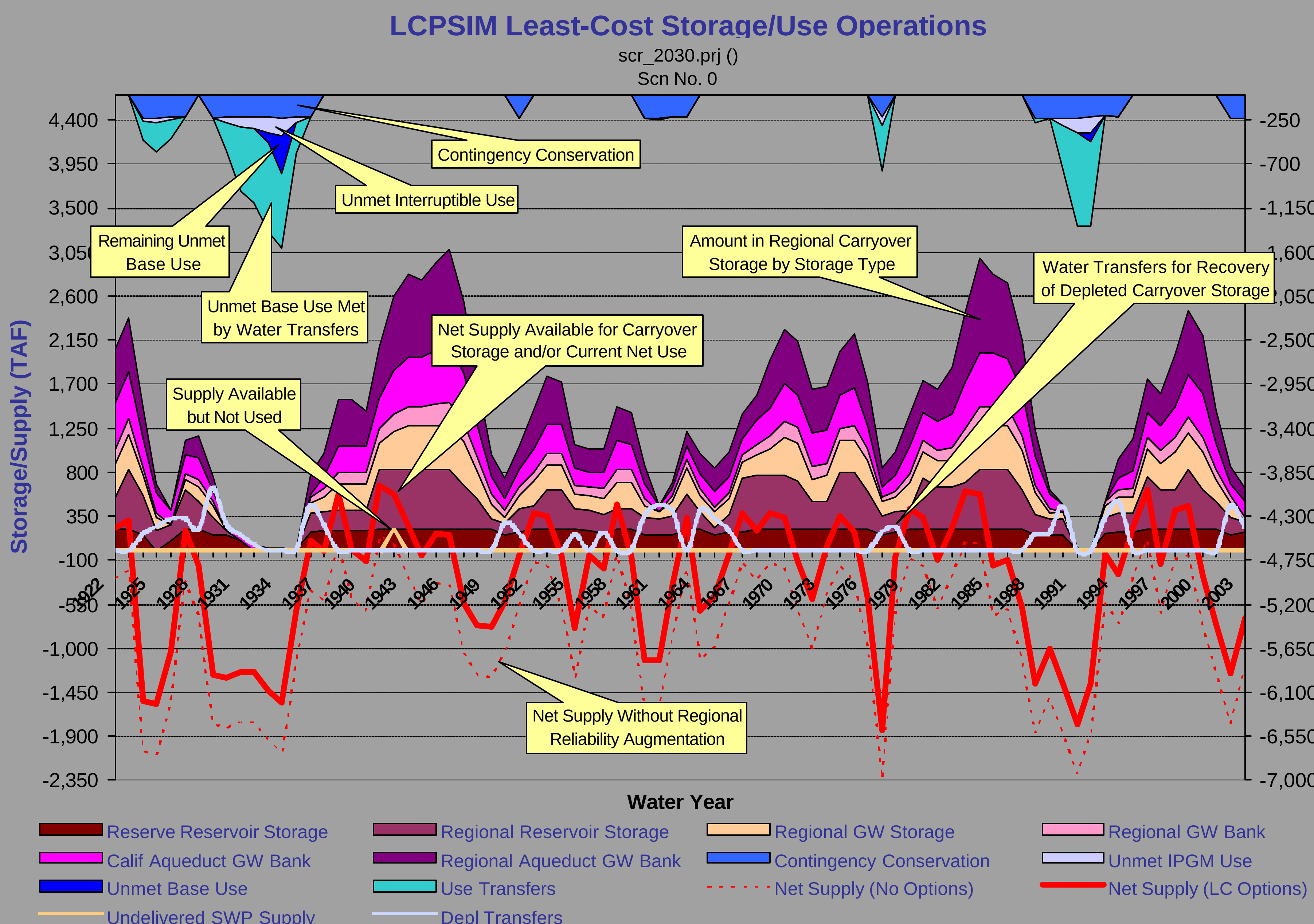


Note on data requirements: SCR LCPSIM uses 296 parameters

LCPSIM Summary Results

- Total annual costs and losses
- Annual shortage-related costs and losses
- Quantity and costs of regional option use by option
- Cost of aqueduct conveyance, including wheeling of transfers and carryover storage, and other regional operations
- Quantity transferred and cost of water market transfers (shortage mitigation & depleted storage replenishment)

Operations Trace Example



Tech Specs

- Written in (in historical sequence)
  - Commodore 64 BASIC
  - PROMAL, a C-like compiler for the C64
  - Turbo Pascal 3.0
  - Turbo Pascal for Windows and Visual Basic
  - Delphi 7.0
- Uses GLPK, a publicly-licensed mixed-integer LP solver, and BPMPD, a freeware quadratic solver

Analysis of Agricultural Drainage Management Options

GBP-NETFLO

Options for Drainage Management

- Drainage water reuse
  - Source blending
  - Sequential application to salt-tolerant crops and halophytes
- Drainage water treatment
  - Reverse osmosis (w/option to market displaced prime supply)
  - Biological system
- Disposal of target constituent(s)
  - Solar evaporator
  - Evaporative tower
- Discharge without treatment

The Issues

Devote resources to evaluate which management options?

- Many options and combinations of options with different feasible configurations
- Which methods should be used for evaluations?

The Proposed Course of Action

Evaluate all options in all feasible combinations and configurations at the same time

- Use two-stage LP analysis
- Use mixed-integer LP programming to exclude infeasible/incompatible option combinations

Elements of Modeling Approach

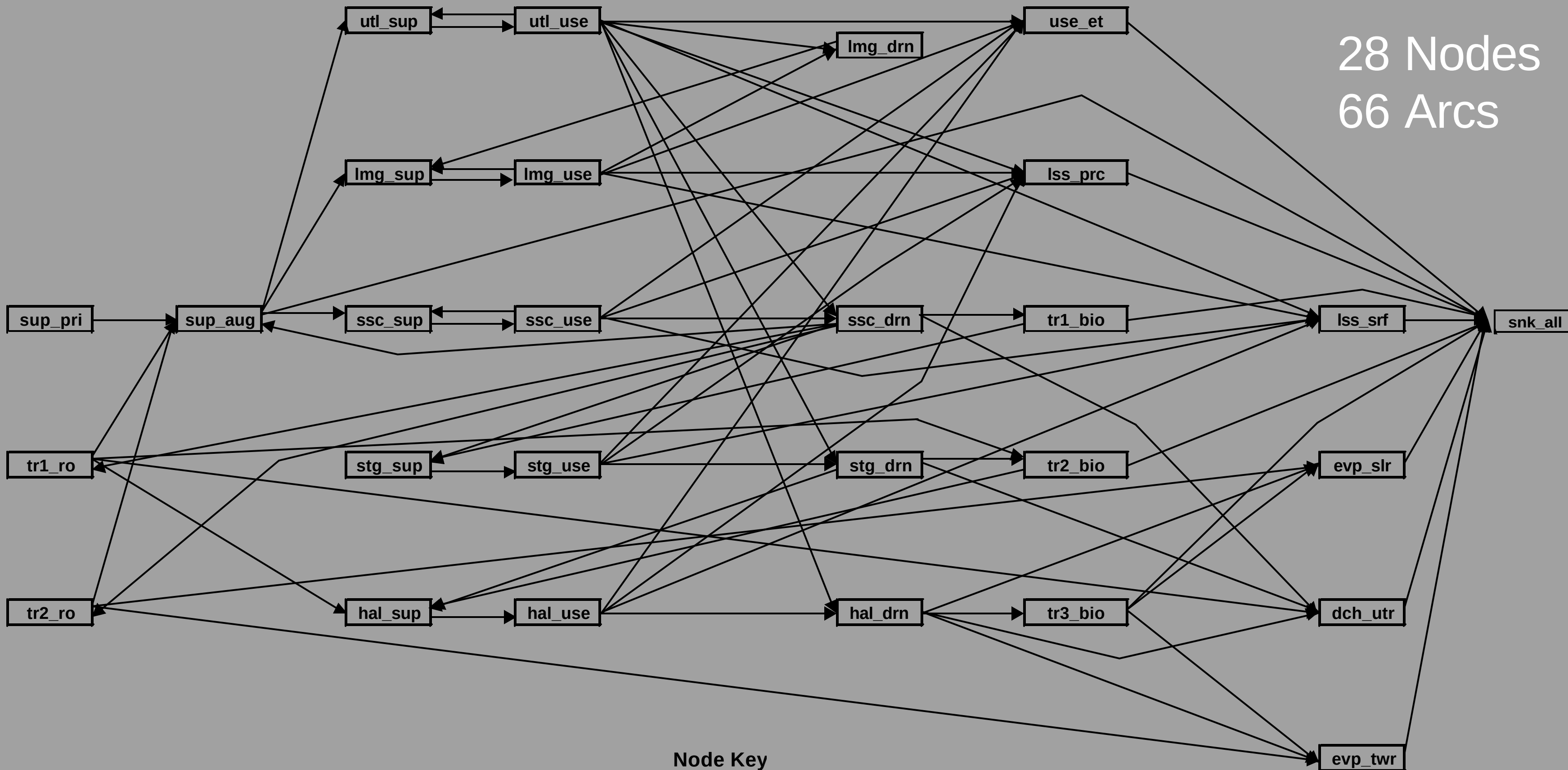
- Maximization of net benefits (i.e., farm income less costs) using two-stage linear programming[1]
- Network flow modeling framework for system water movement mass balance
- Selenium discharge load limits by year type
- Constituent loads and land use tied to water flows by coefficients at points where there are associated costs and constraints
- Economic costs and benefits tied to water flows, constituent loads, and land use by coefficients

[1] Credit: Jay Lund

Two-Stage Linear Programming

- Activities requiring an investment in long-term capacity (e.g., crop production, land set aside for halophytes or evaporation ponds, drainage treatment facilities) can be efficiently sized while allowing for variable use of capacity
- Flow relationships among multiple arcs can be specified and flexibility in the use of constraints to evaluate scenarios is facilitated
- Shadow values can show the marginal costs imposed by constraints, possibly leading to improved management strategies

GBP-NETFLO Node Flow Diagram

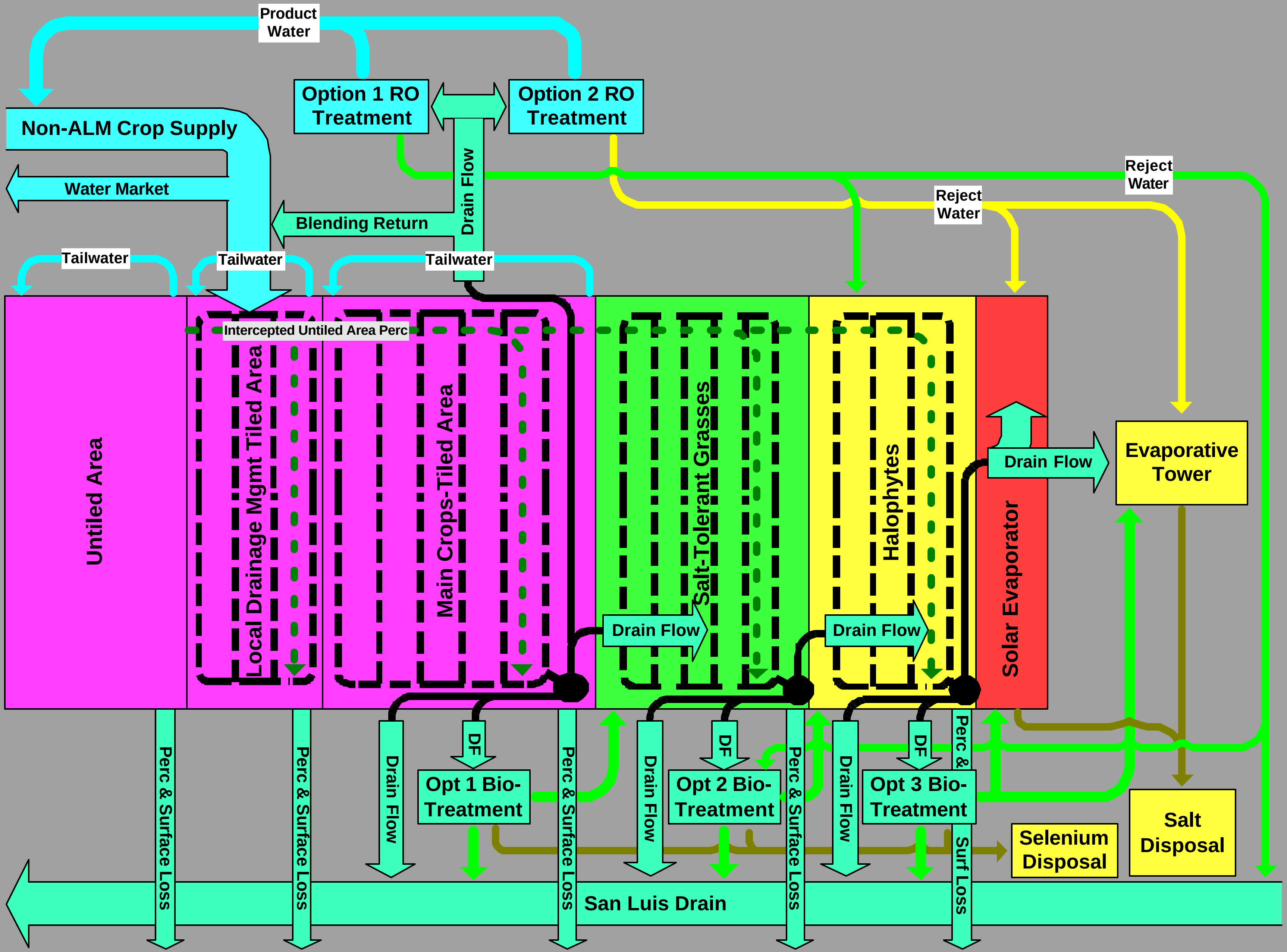


28 Nodes
66 Arcs

Node Key

sup_pri Primary water supply
sup_aug Blended water supply
utl_sup Water supply for untiled area
lmg_sup Water supply for local drainage management tiled area
ssc_sup Water supply for salt-sensitive crops
stg_sup Water supply for salt-tolerant grasses
hal_sup Water supply for halophytes
utl_use Applied water use for untiled area
lmg_use Applied water use for local drainage management tiled area
ssc_use Applied water use for salt-sensitive crops
stg_use Applied water use for salt-tolerant grasses
hal_use Applied water use for halophytes
drn_lmg Locally-managed drainage return system (100% return of captured drainage water)
ssc_drn Percolation captured by the drainage system for salt-sensitive crops
stg_drn Percolation captured by the drainage system for salt-tolerant grasses
hal_drn Percolation captured by the drainage system for halophytes
tr1_ro Low product RO treatment of salt-sensitive crop drain water
tr2_ro High product RO treatment of salt-sensitive crop drain water
use_et Crop ET
lss_prc Percolation losses
tr1_bio Biological treatment of salt-sensitive crop drain flows
tr2_bio Biological treatment of salt-tolerant grasses drain and low product RO reject
tr3_bio Biological treatment of halophytes drain flows
lss_srf Surface losses (uncaptured runoff, evaporation, etc.)
evp_slr Solar evaporator evaporation
dch_utr Discharge of untreated drain flows
evp_twr Evaporative tower evaporation
snk_all Total system water losses

GBP-NETFLO Conceptual Diagram



Example Results

Effect of User-Paid Salt Hauling/Disposal Cost

	With $42/Ton Salt Hauling/Disposal Cost	With No Salt Hauling/Disposal Cost	Effect of No Hauling/Disposal Cost on Optimal Solution
	Primal Value	Primal Value	Primal Value
Overall solution			
Fixed crop prod costs (dollars)	$15,254,547	$15,165,415	-$89,132
Drain mgmt cap costs (dollars)	$161,602	$44,471	-$117,131
Total fixed/cap costs (dollars)	$15,416,149	$15,209,886	-$206,263
Expected net benefits (dollars)	$27,587,016	$28,119,408	$532,392
Bio treat salt-sens capacity (af)			
Bio treat salt-tol capacity (af)			
Bio treat halophytes cap (af)	2,118		-2,118
Biological treatment area (ac)	29		-29
Low product RO capacity (af)			
High product RO capacity (af)			
Solar evaporator capacity (af)		1,756	1,756
Solar evaporator area (ac)		425	425
Evaporative tower capacity (af)			
Untiled area (ac)	33,000	33,000	
Local management tiled area (ac)	10,000	10,000	
Salt-sensitive area (ac)	50,603	50,852	249
Salt-tolerant area (ac)	3,110	2,577	-533
Halophyte area (ac)	659	546	-113
Total area (ac)	97,400	97,400	

Tech Specs

- Written in LPL, a GAMS-like LP Matrix Generator (was freeware)
- Uses GLPK, a publicly-licensed mixed-integer LP solver

Thank You