



National Experience. Local Focus.

Progressive Development of Decision Support Tools and Groundwater Models for GSPs

May 3, 2017

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SGMA Timeline is Prescriptive

GSP deadlines:

January 31, 2020 for medium and high priority basins in critical overdraft

January 31, 2022 for other medium and high priority basins



Basins must achieve groundwater sustainability within 20 years of GSP implementation

There's Time to Develop and Improve Our Planning and Implementation Tools

3 years
for planning



Multiple steps to GSP development and implementation

- Data collection and analysis
- Water budget
- Alternatives development for programs and management actions
- Decision-making: What's the plan?
- Implementation
- Monitoring

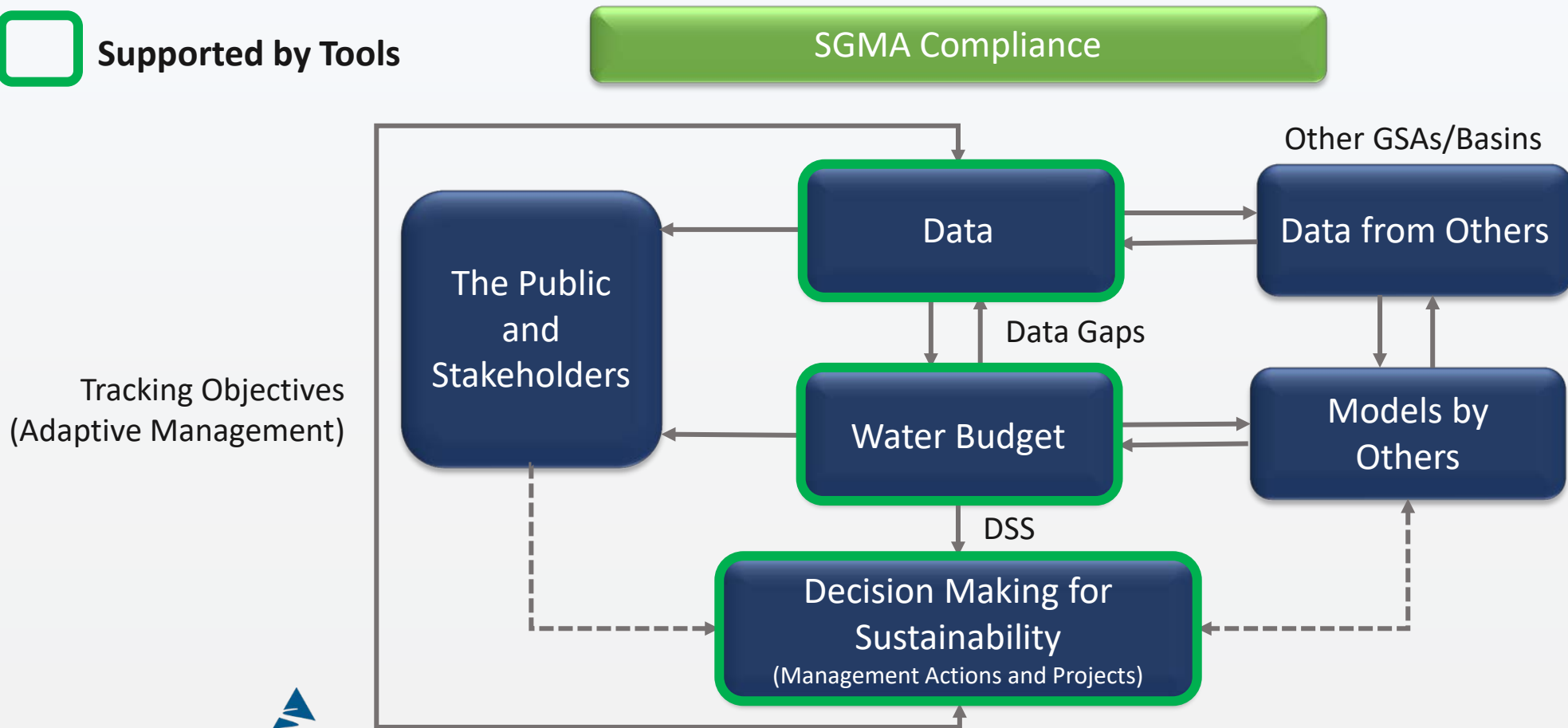


**Plan Updates
Possible and
Expected**

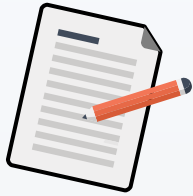
SGMA Compliance Framework



Supported by Tools



A Diverse Toolbox Will Be Required

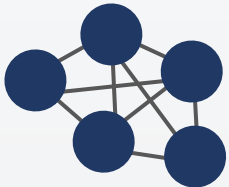


Data Collection and Management



Data Analysis

Water Budget Analysis



Evaluating Alternatives Actions Before Implementation (Forecasting Performance)

Decision-Making



Communication with Stakeholders



Administration

Measuring and Tracking Objectives (Measuring Effectiveness of Actions)



**Activities &
Functions =
Different Tools**

A Knowledge Management Hierarchy

Acquisition

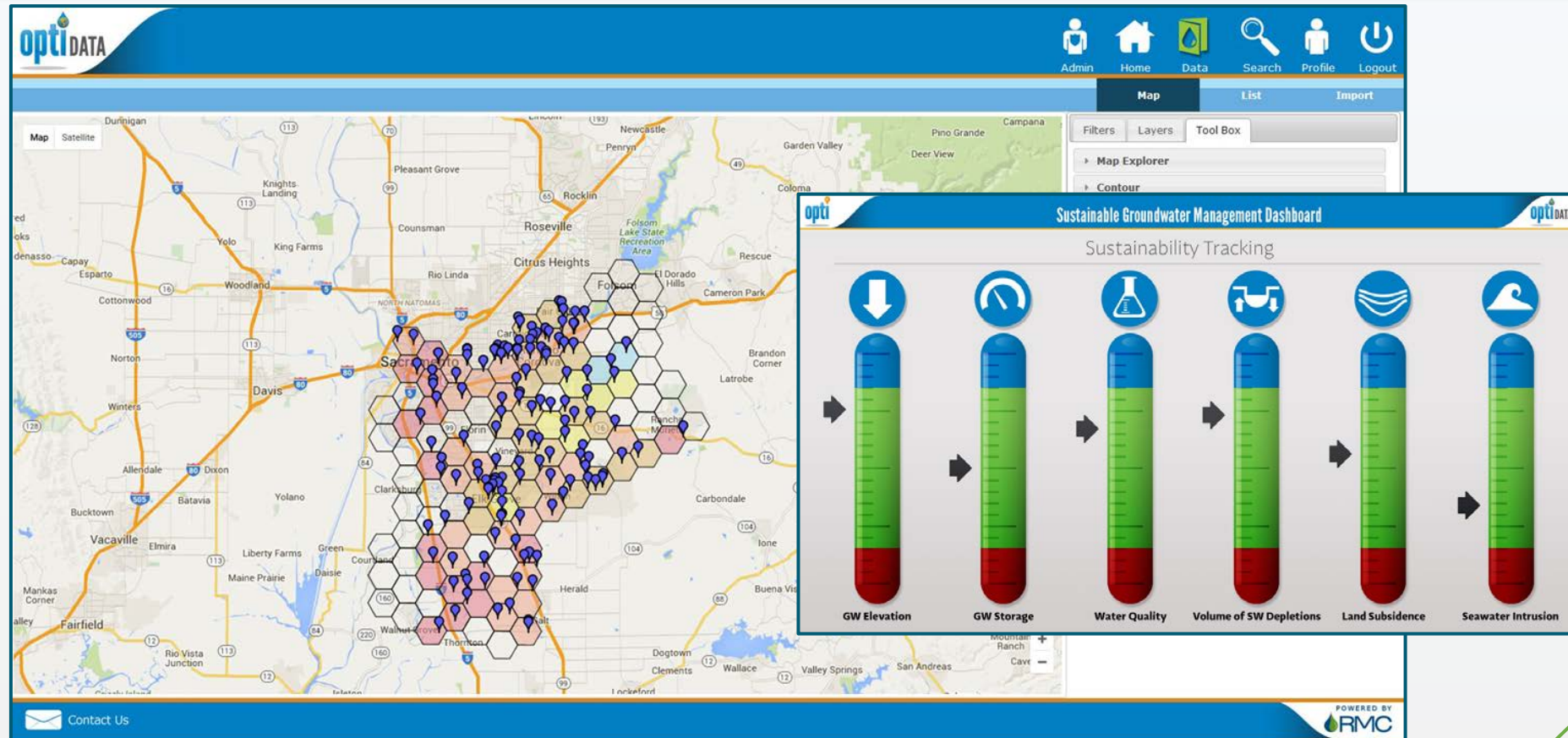


Decision-Making



Data is Fundamental for SGMA

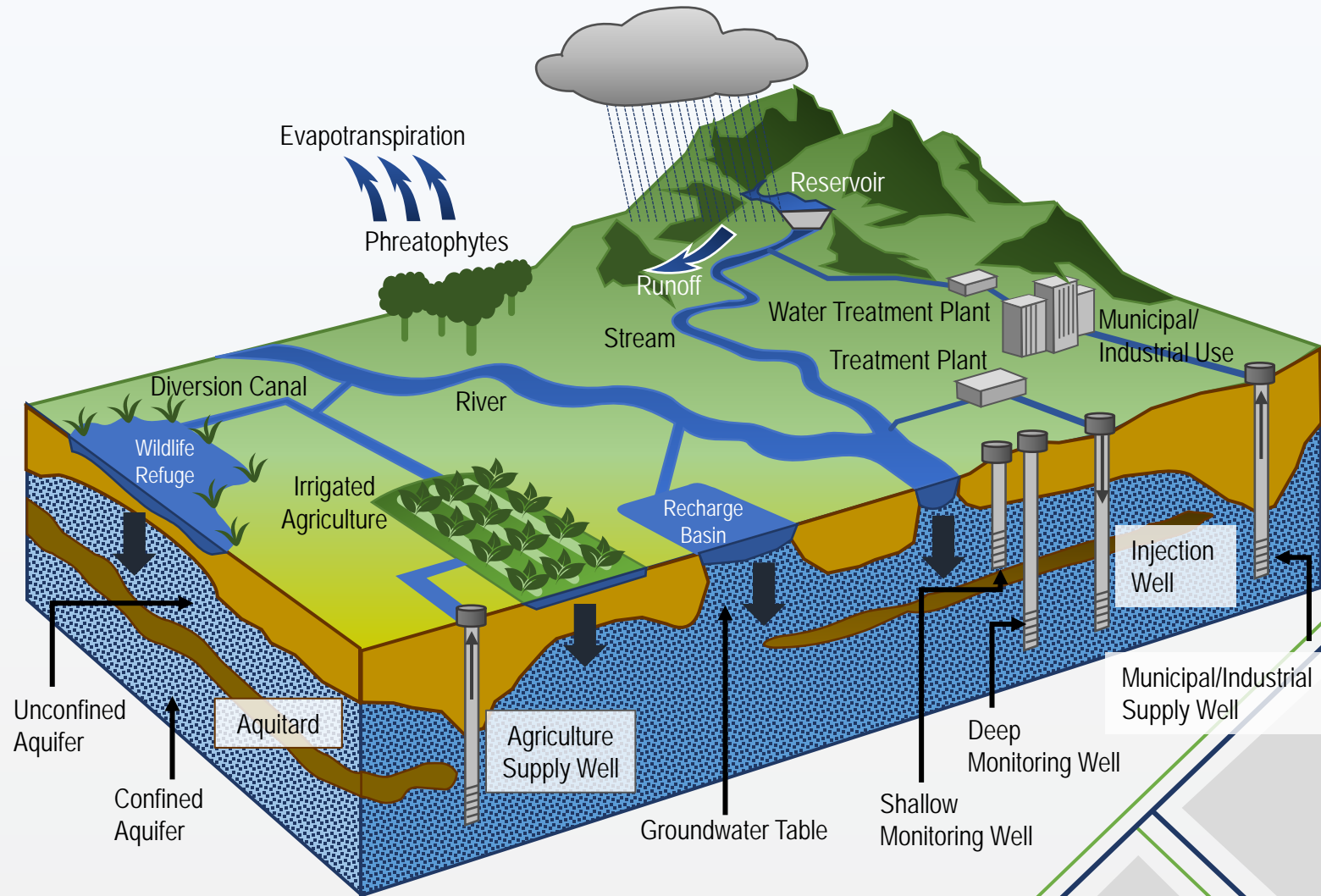
Data Management and Visualization Tools will be Critical



Water Budget is Fundamental

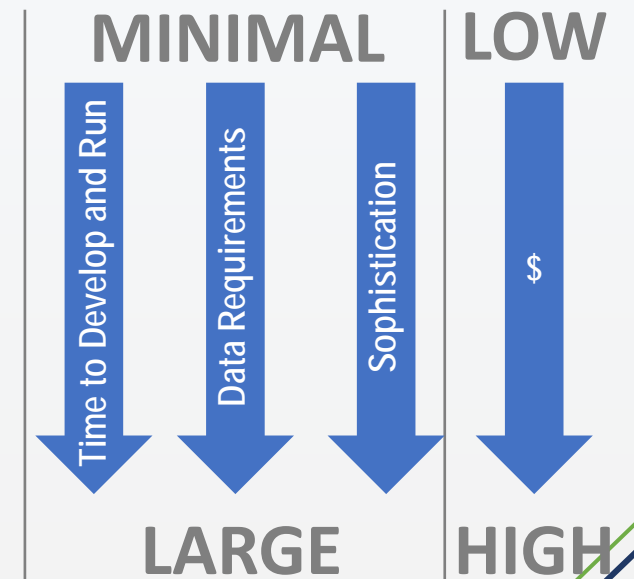
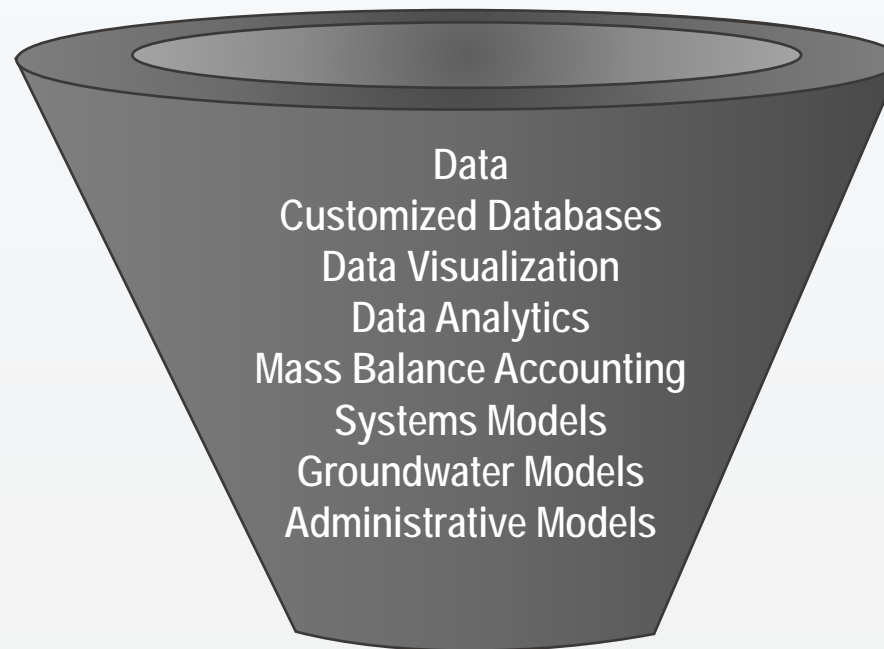
“ **Water budget** means an accounting of the total groundwater and surface water entering and leaving a basin including the changes in the amount of water stored.”

Water Resources System

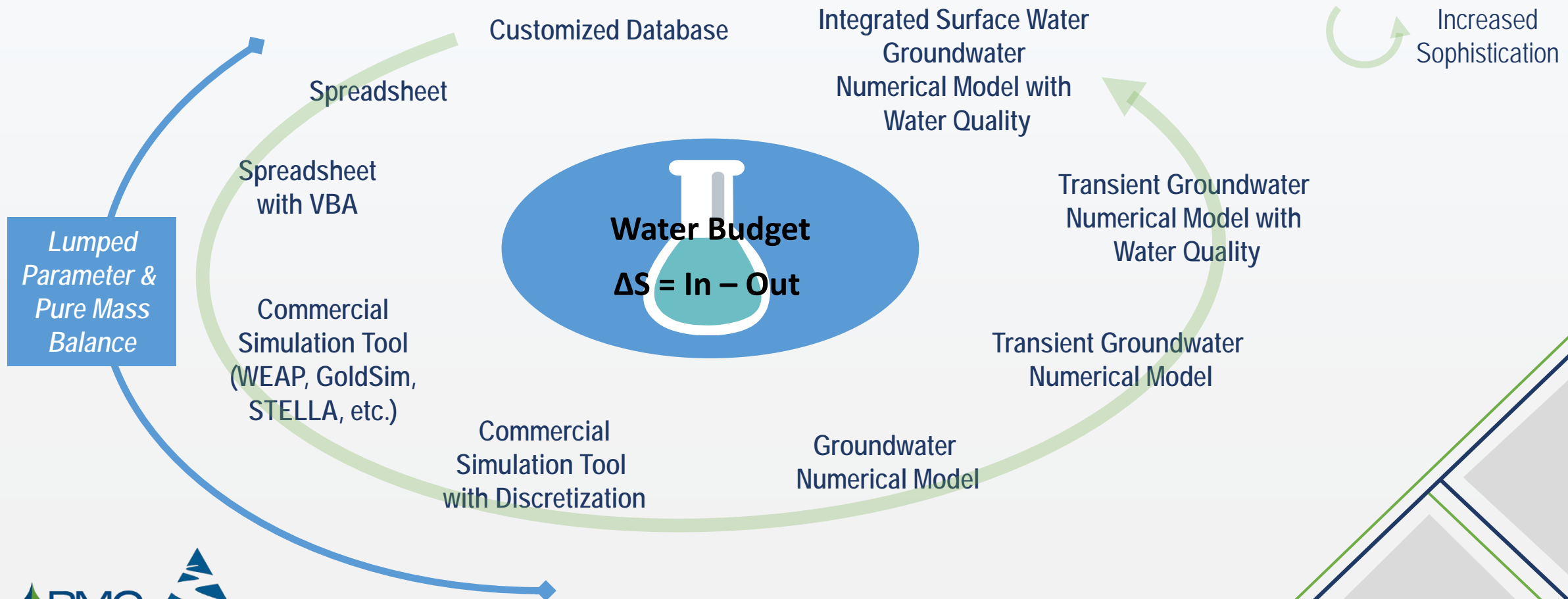


Water Budget Development and Analysis— Groundwater Models are Not the Only Tool

- Groundwater models are powerful tools
- Assessment of available resources and data is critical
- Do not have to start with a model

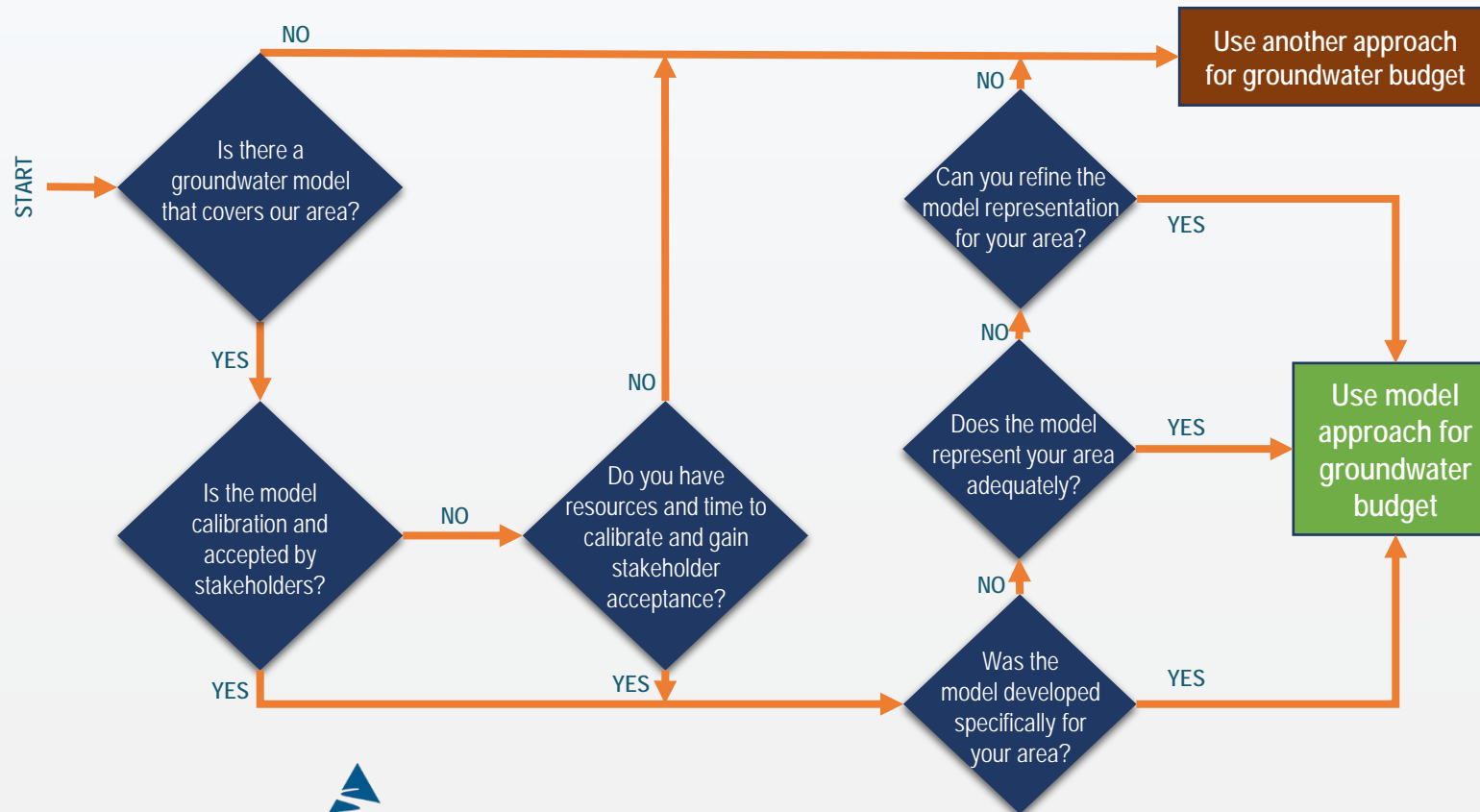


Water Budget Analysis



Water Budget Development – Should I Use a Groundwater Model

Decision Pathway: Groundwater Budget Development



**Develop an accepted
water budget**

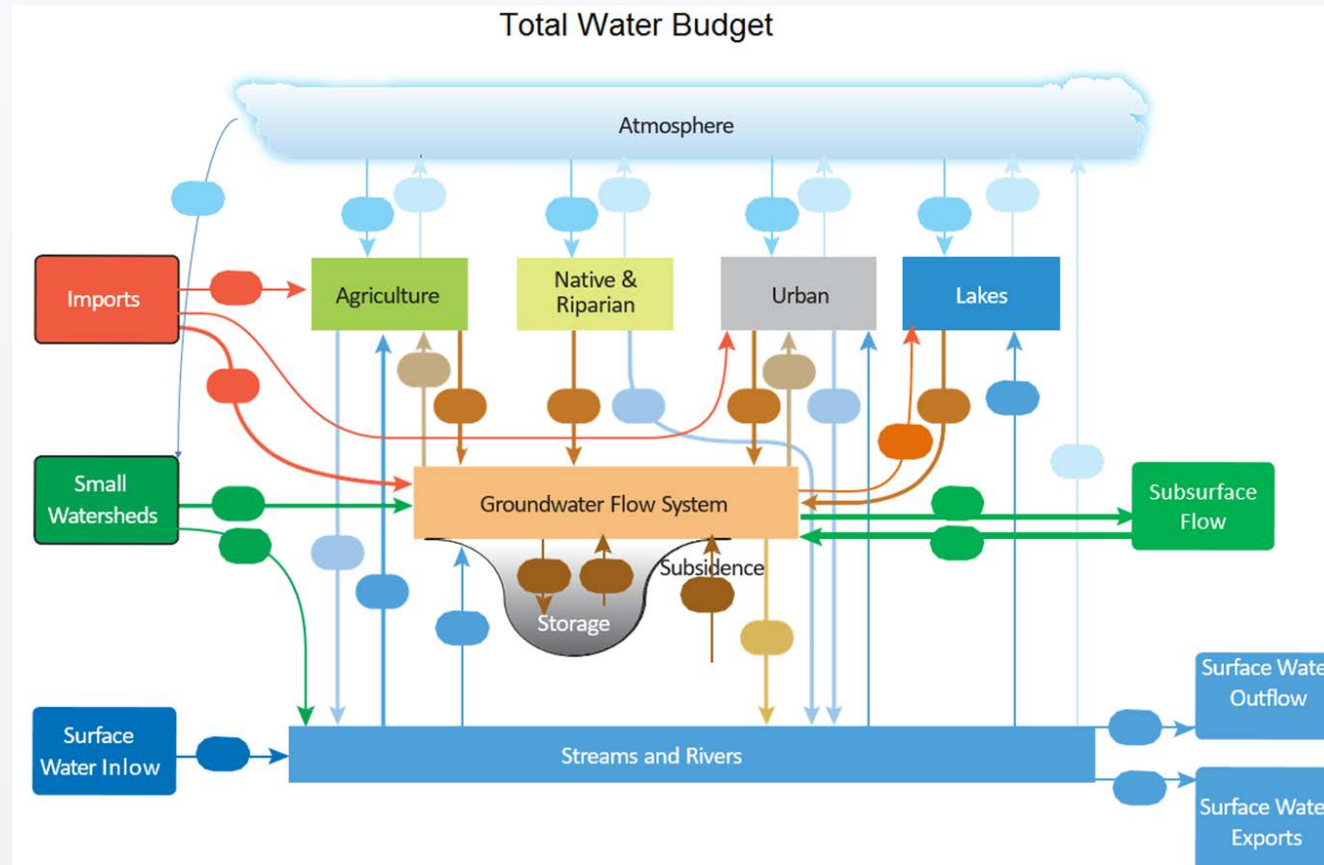
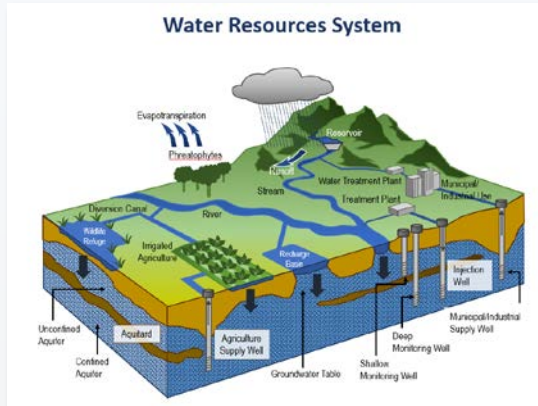
On Decisions about Tools: Consider that GSPs Will Ultimately Have Components of Integrated Planning

	"Traditional" Groundwater Planning	Integrated Resource Planning
Domain	Groundwater	Water resources system
Objectives	Single objective	Multiple objectives
Alternatives	Least cost usually preferred	Multiple benefits preferred
Stakeholder Involvement	Ad hoc or no clear mechanism to accommodate stakeholders	Establishes a process for early and continued stakeholder involvement
Uncertainty	Not formally evaluated or added as sensitivity	Direct evaluation in the analysis

Integrated Planning is More Complex than Traditional Planning – Use Tools & Processes for Decision-Making



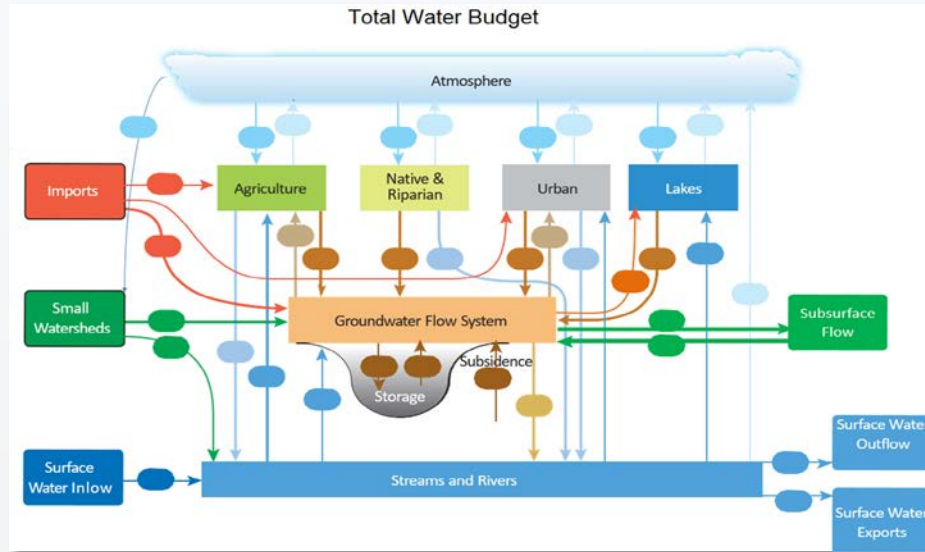
DSS – Systems Models Can Prove Very Valuable



*We may be
modeling the
entire system!*

DSS – Systems Models Can Prove Very Valuable – Reduced Simulation Time & Non-Hydrogeologic Variables

Management
Actions



System Simulation

Compare Performance to Objectives

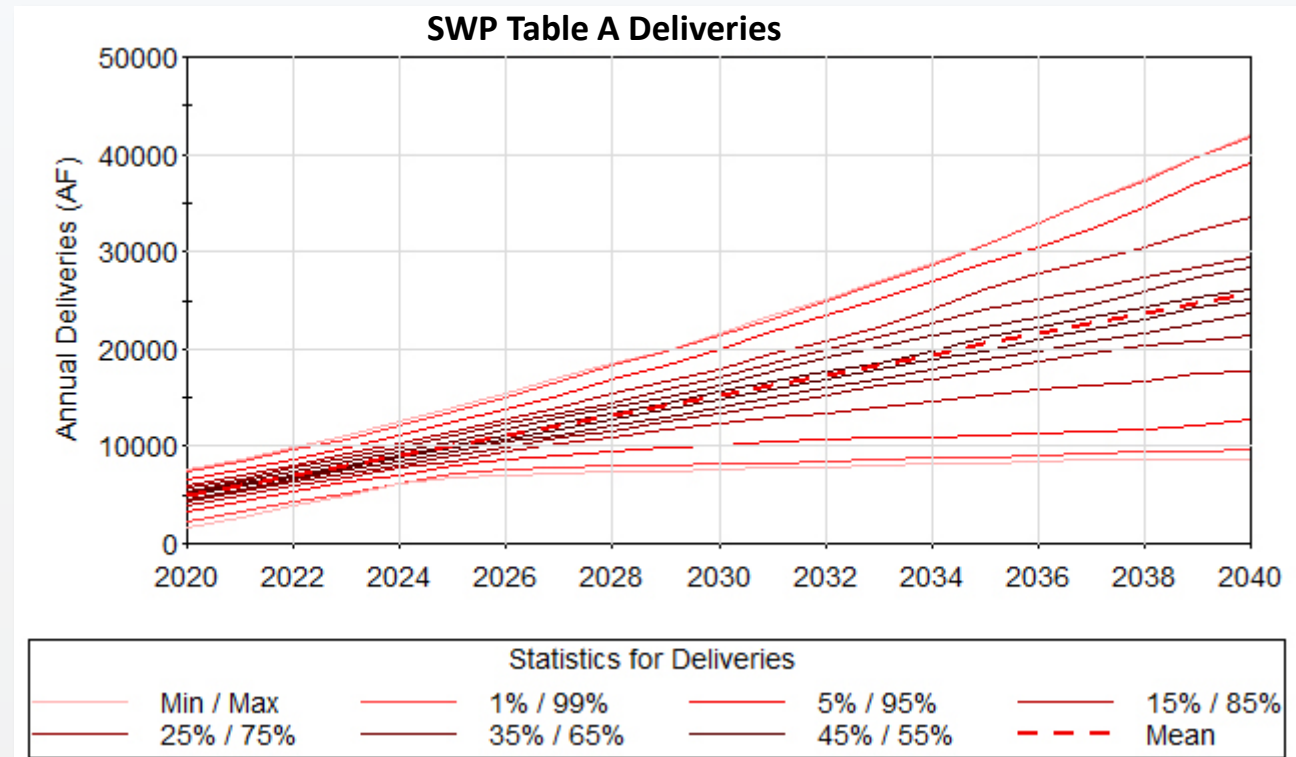
System
Performance

Reduced Run Times
10x – 100x

80% Information
in
20% Effort

Systems Models Can Better Deal with Uncertainty

- Climate change
- Legislative
- Regulatory
- Other basins' actions
- California Water Fix
- Water markets
- Costs of water



Some Simulation Tools Allow for Probabilistic Analysis

1

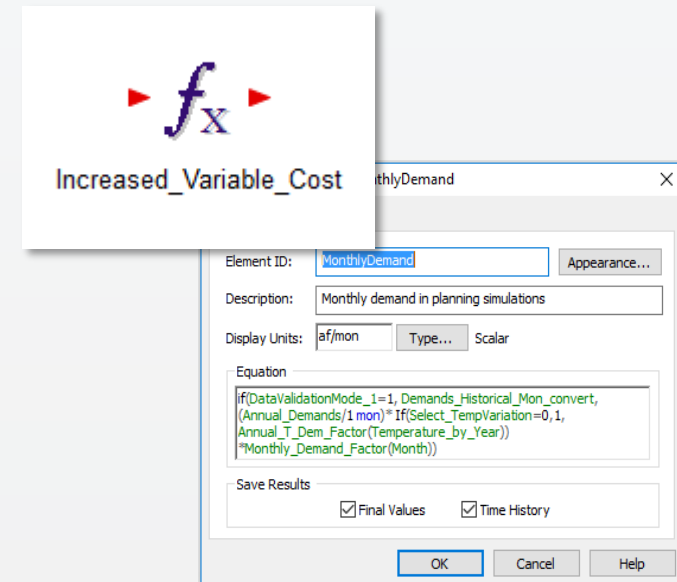
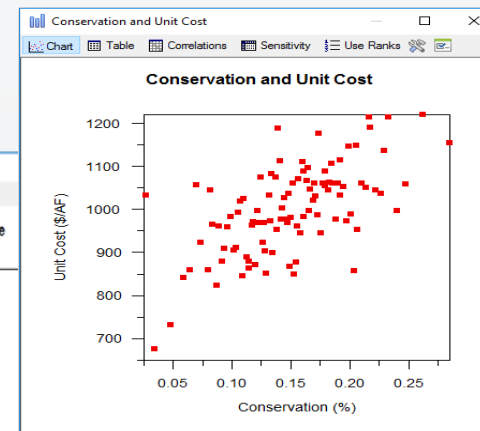
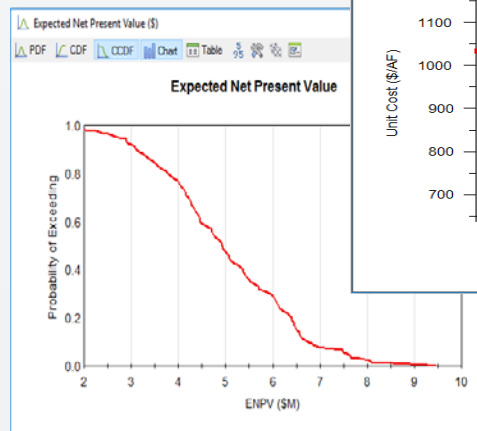
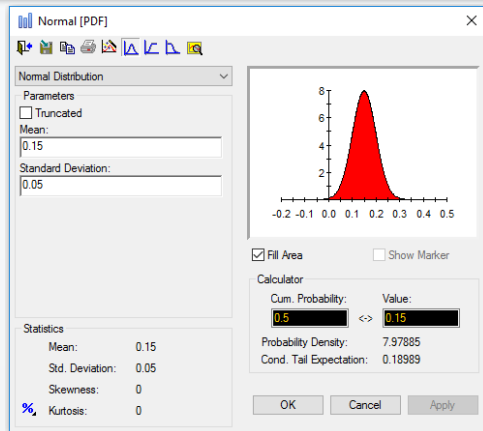
Define Distributions for Uncertainty Drivers

2

Use Cost Functions to Translate Uncertainty into Monetary Risk

3

Obtain Probability of Desired Financial Outcomes



Progressive Development Example – Data to Water Budget

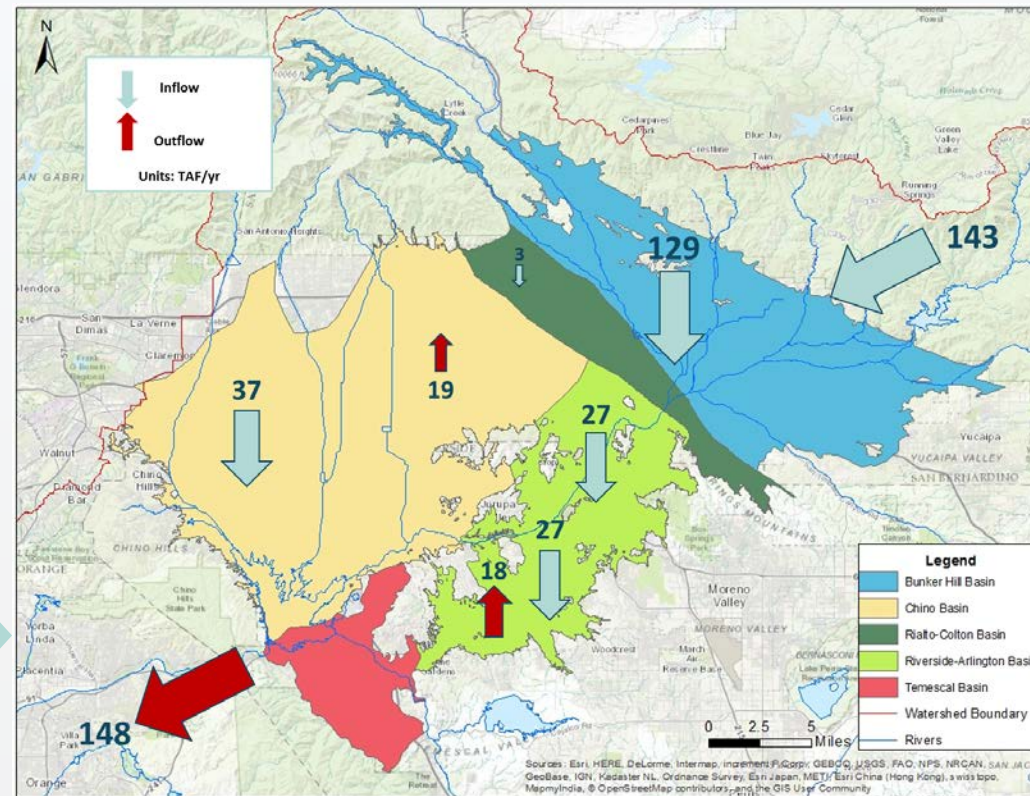
Microsoft Excel - tab_qtr_wb_by_subunit.xls

Quarterly Ground Water Budgets for Palomar Subunit - Scenario 1 (Units in Acre-ft)

Year	Qtr	Recharge from Mountain Front Runoff	Areal Recharge	Reven Flow	Stream Percolation	Underflow	Total Inflow	Evapotranspiration	Pumping by Others	RCWD Pumping	Gaining Streams	Underflow	Total Outflow	Change in Ground Water Storage
1935	1st	0	11	251	44	704	1,050	0	69	87	27	679	963	187
1935	2nd	0	0	311	32	667	1,010	0	92	136	29	454	911	99
1935	3rd	0	0	335	32	639	1,006	0	88	153	31	444	922	94
1935	4th	0	0	335	32	639	1,006	0	88	153	31	444	922	94
1936	1st	0	0	335	32	639	1,006	0	88	153	31	444	922	94
1936	2nd	0	0	335	32	639	1,006	0	88	153	31	444	922	94
1936	3rd	0	0	335	32	639	1,006	0	88	153	31	444	922	94
1936	4th	0	0	335	32	639	1,006	0	88	153	31	444	922	94
1937	1st	504	147	251	311	618	1,531	0	69	87	43	569	1,118	1,013
1937	2nd	0	0	311	48	647	997	0	92	136	31	454	911	106
1937	3rd	0	0	335	38	645	1,017	0	86	151	37	453	927	98
1937	4th	0	0	299	40	613	952	0	83	100	39	443	963	94
1938	1st	875	225	251	523	1,544	2,158	0	69	87	64	655	1,755	1,652
1938	2nd	0	0	311	47	754	1,112	0	92	136	42	671	941	170
1938	3rd	0	0	335	45	692	1,072	0	86	151	45	489	963	109
1938	4th	40	12	299	63	655	1,069	0	83	100	47	667	997	171
1939	1st	74	22	251	81	627	1,055	0	69	87	49	651	956	199
1939	2nd	0	0	311	51	699	1,170	0	92	136	51	674	954	217
1939	3rd	0	0	335	59	674	1,067	0	86	151	54	650	950	118
1939	4th	0	0	299	56	613	973	0	83	100	57	639	979	95
1940	1st	160	47	251	126	1,126	1,631	0	69	87	60	626	941	345

Inflows **Outflows**

Simple Database



Scenarios of Static Water Budget

Progressive Development Example – Data to Conceptual Systems Model for GSP Actions Analysis

The spreadsheet displays a detailed water budget over a 25-year period (1975-2000). It includes columns for Inflows, Outflows, and Storage. The 'Inflows' and 'Outflows' sections are highlighted in red. The 'Inflows' section includes columns for Recharge from Mountains, Recharge from Groundwater, and Recharge from Surface Water. The 'Outflows' section includes columns for Evaporation, Pumping by Others, RCWD Pumping, Groundwater Storage, and Total Outflow. The 'Storage' section includes columns for Total Inflow, Evaporation, Pumping by Others, RCWD Pumping, Groundwater Storage, and Total Outflow. The 'Change in Groundwater Storage' column shows the net change in storage for each year.

Year	Recharge from Mountains	Recharge from Groundwater	Recharge from Surface Water	Total Inflow	Evaporation	Pumping by Others	RCWD Pumping	Groundwater Storage	Total Outflow	Change in Groundwater Storage
1975	11	251	46	308	1,050	0	49	87	1,186	-878
1976	0	0	0	0	1,010	0	92	136	1,238	-1,238
1977	0	0	0	0	1,088	0	56	151	1,295	-1,295
1978	0	0	0	0	941	0	0	0	941	0
1979	0	0	0	0	962	0	0	0	962	0
1980	0	0	0	0	911	0	0	0	911	0
1981	0	0	0	0	932	0	0	0	932	0
1982	0	0	0	0	1,058	0	0	0	1,058	0
1983	594	147	251	992	1,331	0	49	87	1,467	-475
1984	0	0	0	0	947	0	92	136	1,175	1,175
1985	0	0	0	0	1,017	0	56	151	1,224	-1,224
1986	0	0	0	0	957	0	53	100	1,110	1,110
1987	0	0	0	0	954	0	69	87	1,110	0
1988	0	0	0	0	1,112	0	92	136	1,340	-1,340
1989	0	0	0	0	1,072	0	56	151	1,279	1,279
1990	0	0	0	0	1,069	0	53	100	1,222	1,222
1991	74	22	251	347	1,055	0	49	87	1,191	1,191
1992	0	0	0	0	1,111	0	92	136	1,339	-1,339
1993	0	0	0	0	1,267	0	56	151	1,474	-1,474
1994	0	0	0	0	973	0	53	100	1,123	1,123
1995	160	47	251	458	1,187	0	69	87	1,333	-875

Simple Database

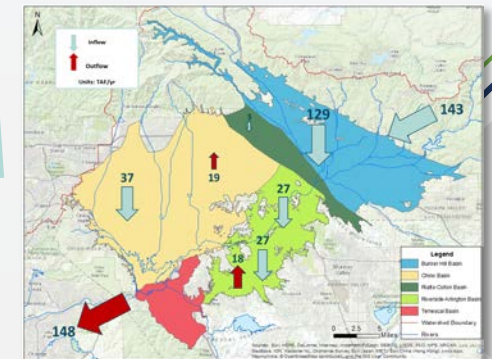
The Marin WaterSim interface displays various system parameters and operational decisions. The 'System Operations' section includes 'Emergency Storage' and 'Imported Supply'. The 'Operational Yield' section shows 'Emergency Storage (%)' and 'Supply Deficit'. The 'Operational Decisions' section includes 'Reservoir Operational Assumptions' and 'Operational Triggers'. The 'Evaluation of GSP Actions' section shows a table of results for different GSP actions.

Row Variable [AF]	Result [Acres]
0	0
110.4800857	2
179.5301392	4
	8
	16
	29
	45
	64
	87
	110
	135
	165

Evaluation of GSP Actions

Dynamic Water Budget

Systems Model (Lumped Parameter)



Progressive Development Example – Data to Advanced Database with Visualization and Analytics

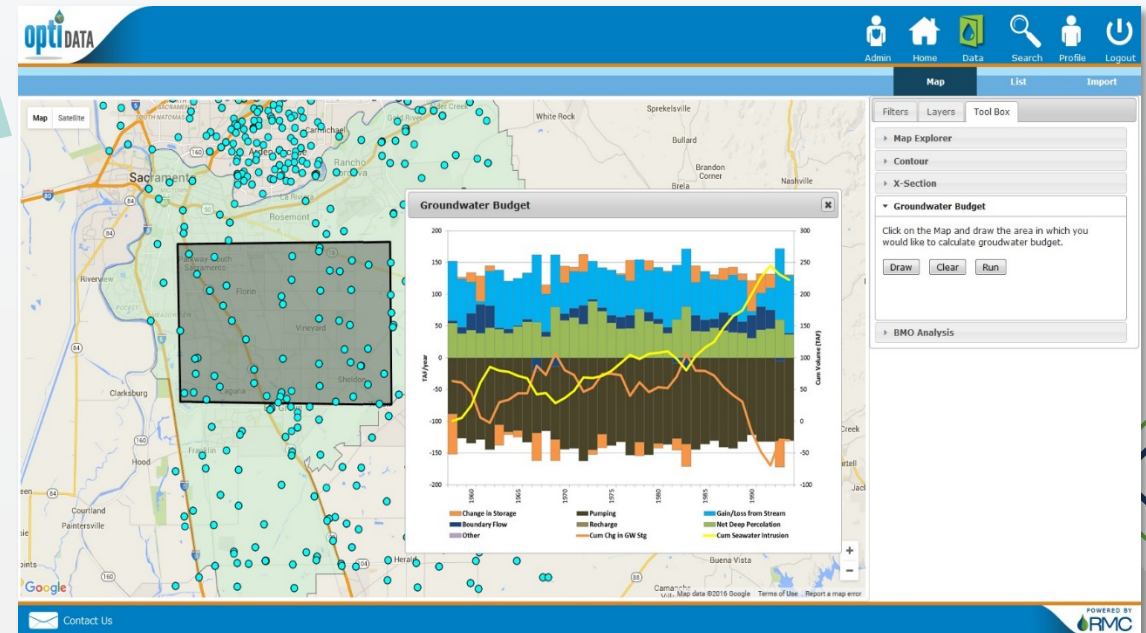
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Quarterly Ground Water Budgets for Palomar Subunit - Scenario 1 (Units in Acre-ft)

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1935	1st	0	11	251	46	704	1,050	0	49	87	27	679	563	187
1935	2nd	0	0	311	32	667	1,010	0	92	136	29	654	911	99
1935	3rd	0	0	335	32	639	1,006	0	56	151	33	644	912	94
1935	4th	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	1st	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	2nd	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	3rd	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	4th	0	0	0	0	0	0	0	0	0	0	0	0	0
1937	1st	504	147	251	311	618	1,831	0	89	87	43	599	1,118	1,819
1937	2nd	0	0	311	46	647	997	0	92	136	33	631	893	104
1937	3rd	0	0	335	32	645	1,017	0	56	151	37	653	927	90
1937	4th	0	0	299	40	618	957	0	83	100	39	642	863	94
1938	1st	875	255	251	311	654	2,355	0	69	87	64	655	1,755	1,602
1938	2nd	0	0	311	47	754	1,112	0	92	136	42	671	941	170
1938	3rd	0	0	335	45	692	1,072	0	86	151	45	680	963	109
1938	4th	40	12	299	43	655	1,049	0	83	100	47	647	897	171
1939	1st	74	22	251	81	627	1,055	0	89	87	49	651	856	199
1939	2nd	0	0	311	51	809	1,170	0	92	136	51	674	954	217
1939	3rd	0	0	335	59	674	1,067	0	86	151	54	658	950	118
1939	4th	0	0	299	56	618	973	0	83	100	57	639	879	95
1940	1st	160	47	251	128	601	1,187	0	69	87	60	626	941	345

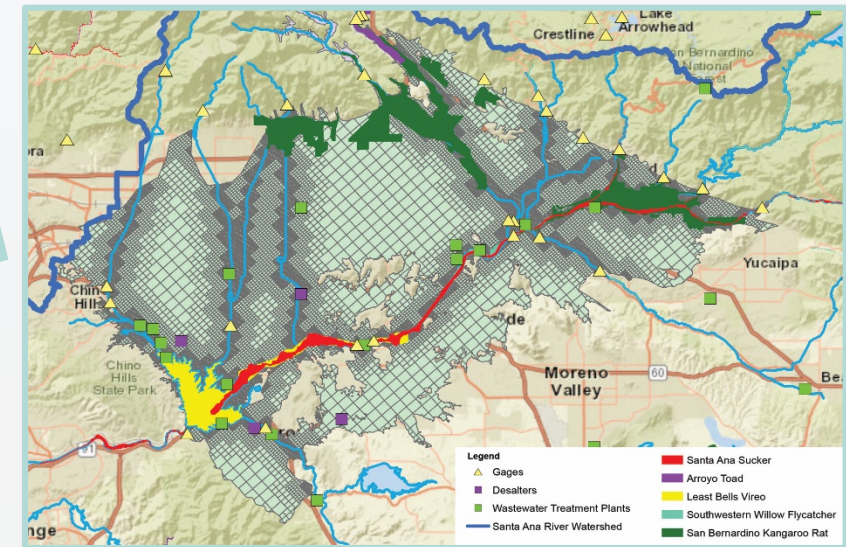
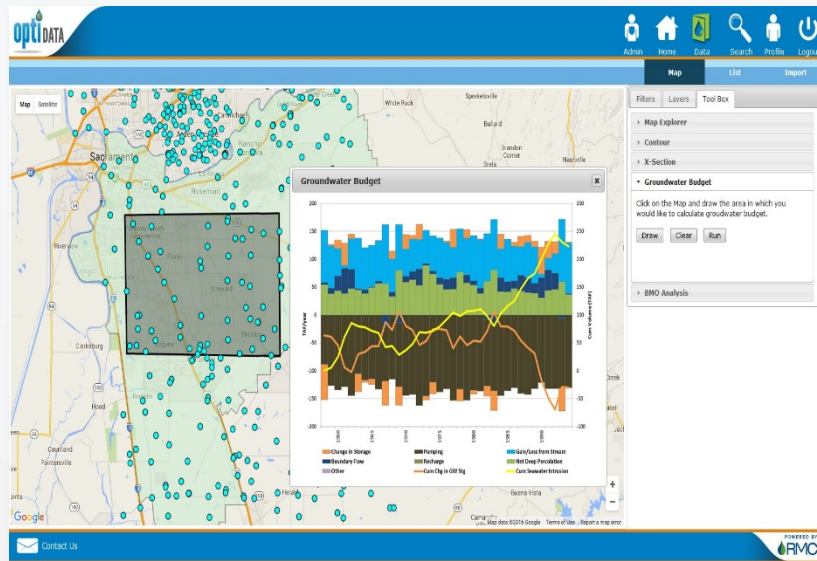
Simple Database

Advanced Database with Visualization



Progressive Development Example – Geodatabases to Numerical Groundwater Model

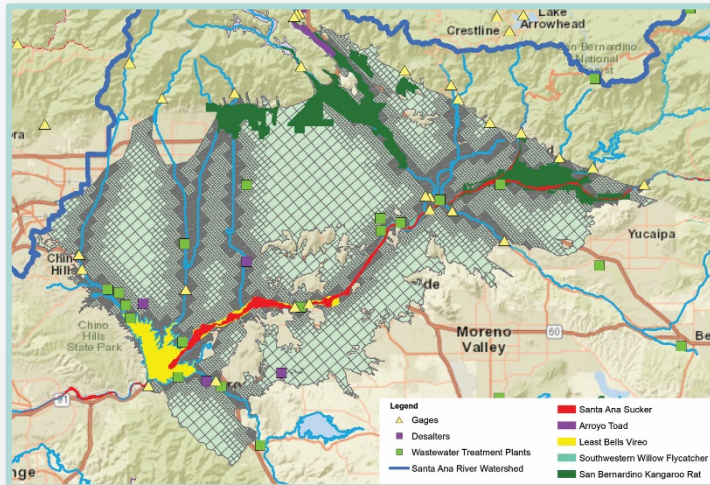
Advanced Database with Visualization



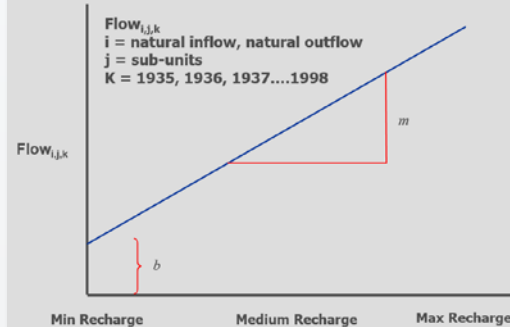
Numerical Groundwater Model

Progressive Development Example – Improve Systems Model with Groundwater Model

Numerical Groundwater Model

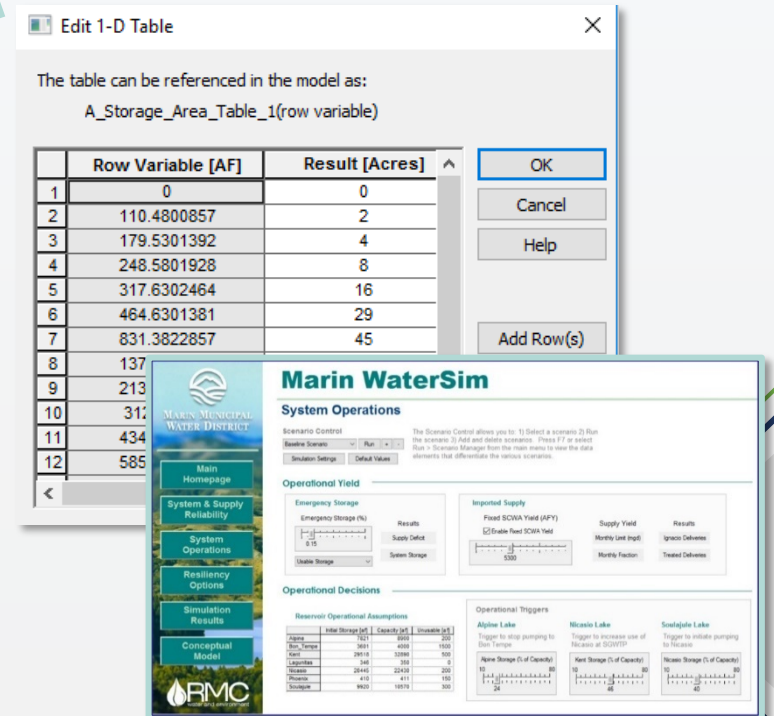


Linear regression

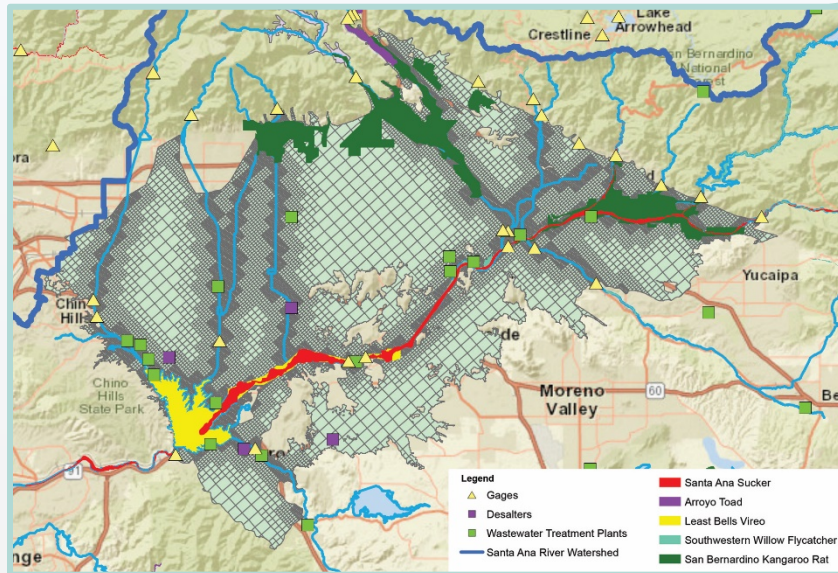


Response Functions

Refined Systems Model

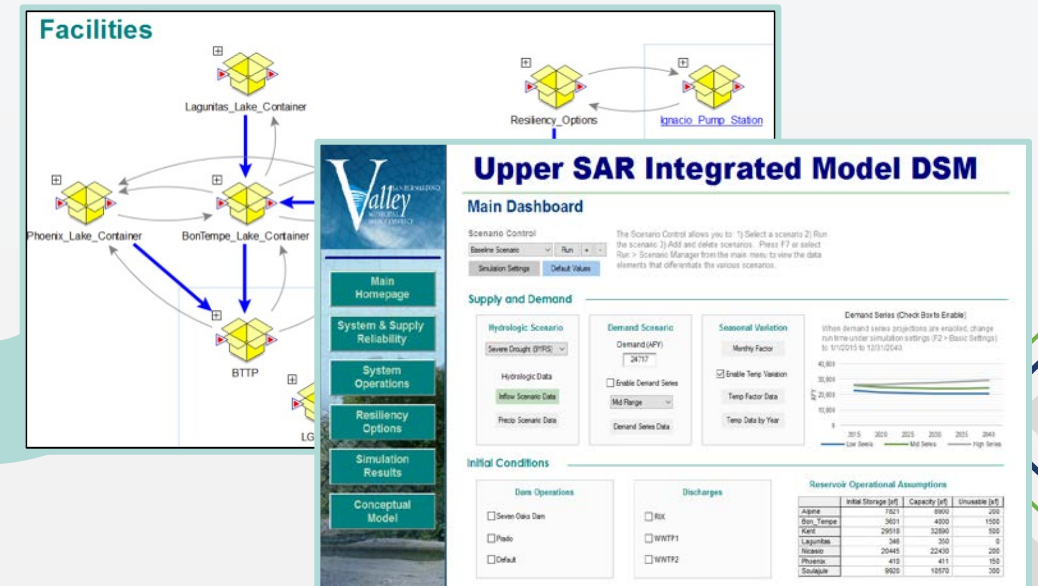


Systems Models Can Work in Tandem with Numerical Groundwater Models



- Critical areas for Groundwater Model
- Critical data gaps
- High-Value options and scenarios

- Response functions for system interrelationships
- Validation of results of high-value options and scenarios

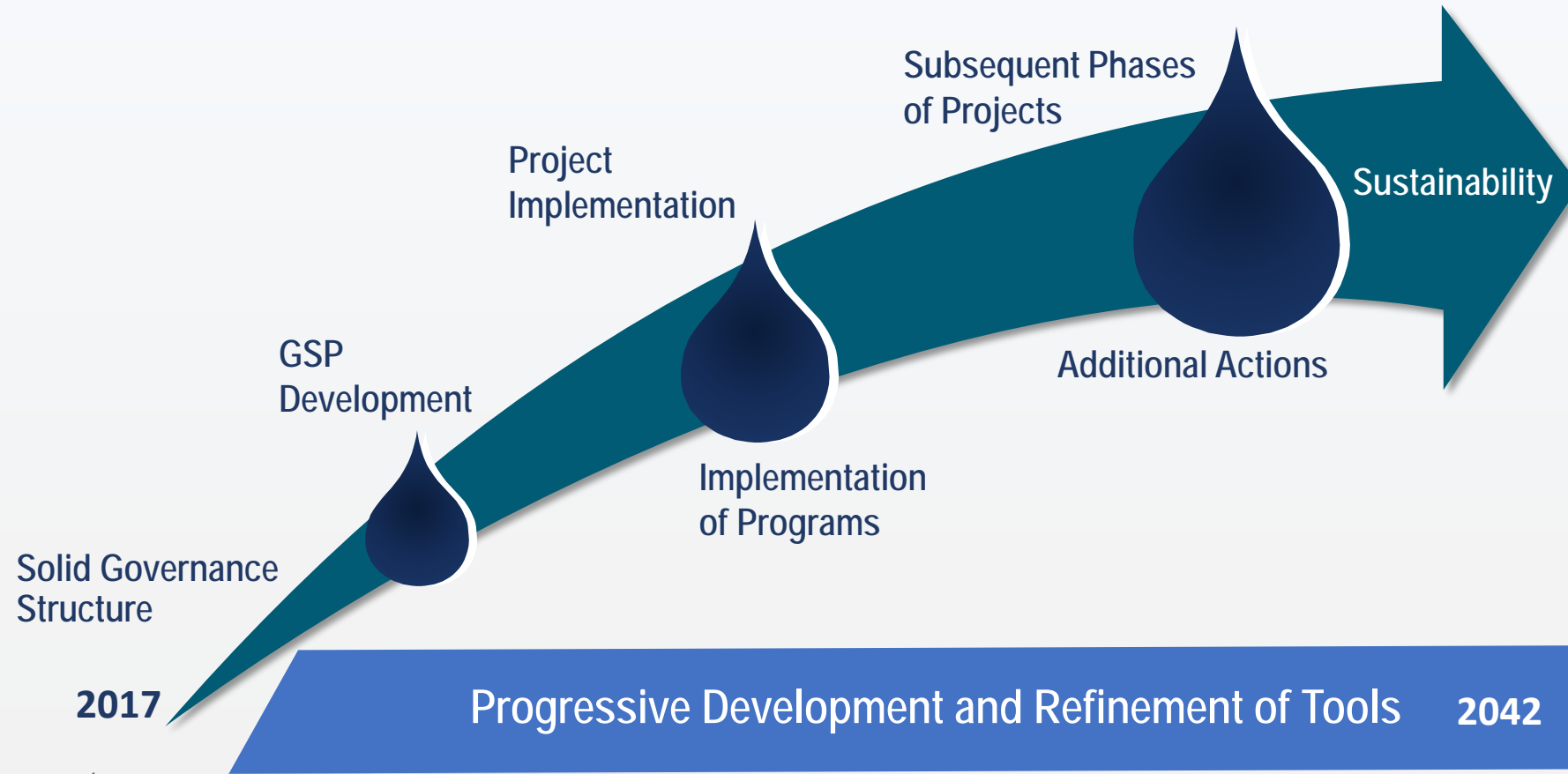


When Defining Modeling and Analysis Needs

- Consider appropriateness for desired outcomes
- Phase of the GSP
- Scalability and expandability



Three Years of Planning - 20 Years of Action





National Experience. Local Focus.

Questions

May 3, 2017

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Leslie Dumas

