

Hydropower and dam safety





Teton Dam, ID, 1976

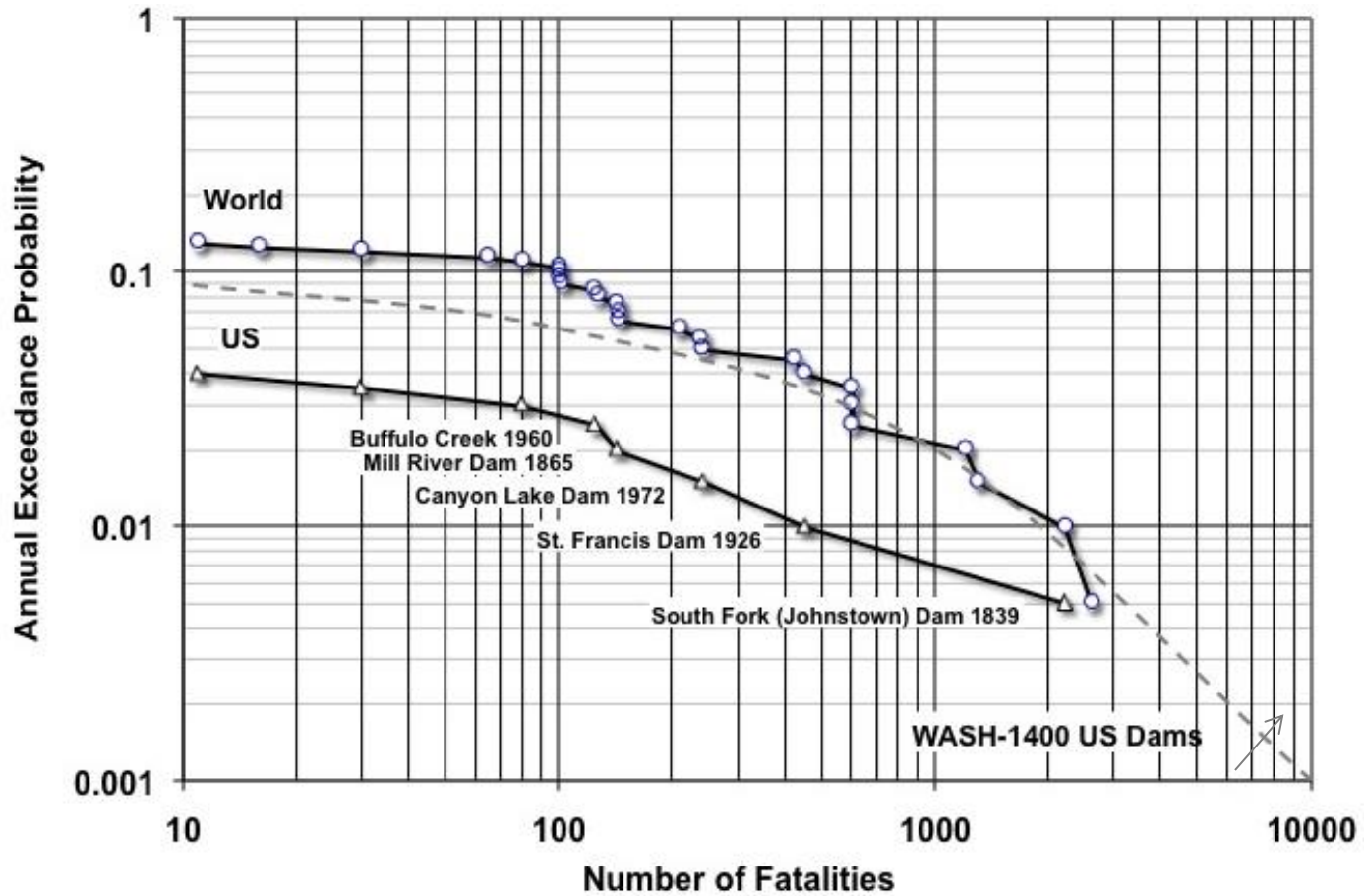


Shih-Kang Dam, Taiwan, 1999

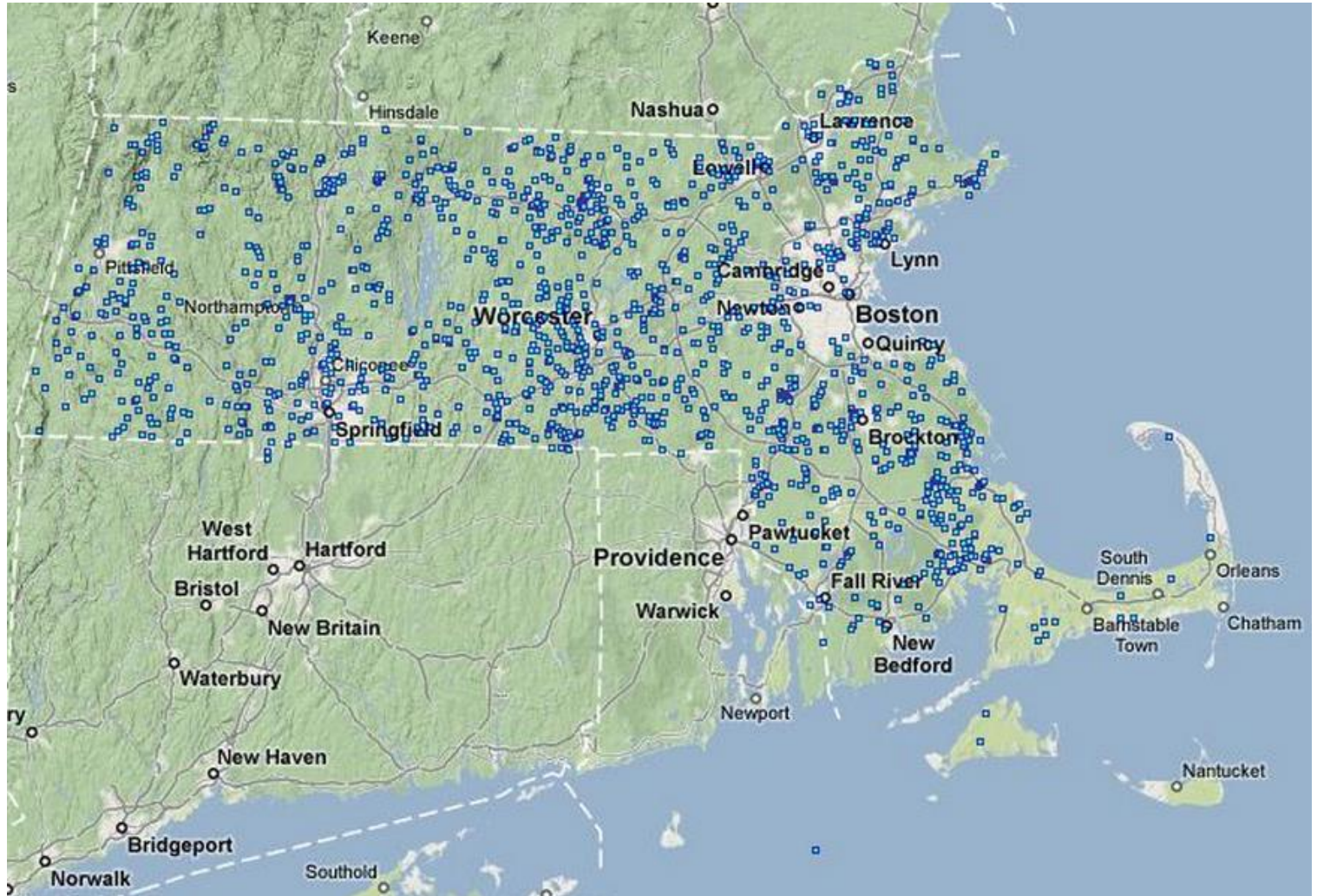


Lake Delhi Dam, IA, 2010

Statistics of dam failures



85,000+ Dams in the US





Fort Calhoun NPP, NE, 2011



New Orleans 2005

Statistics of dam failures (%)

FAILURE	GRUNER 1967	MIDDLE- BROOKS 1953	TAKASE 1967	USCOLD 1975	BABB AND MERMEL 1968
Spillway capacity	23	30	28	38	36
Piping or seepage	40	38	44	44	30
Slides	2	15	10	9	15
Misc	35	17	18	9	19

Baecher, Paté, and de Neufville (1980). "Risk of dam failure in benefit-cost analysis," *Water Resources Research*, 16(3): 449-456

Systems thinking about flow control



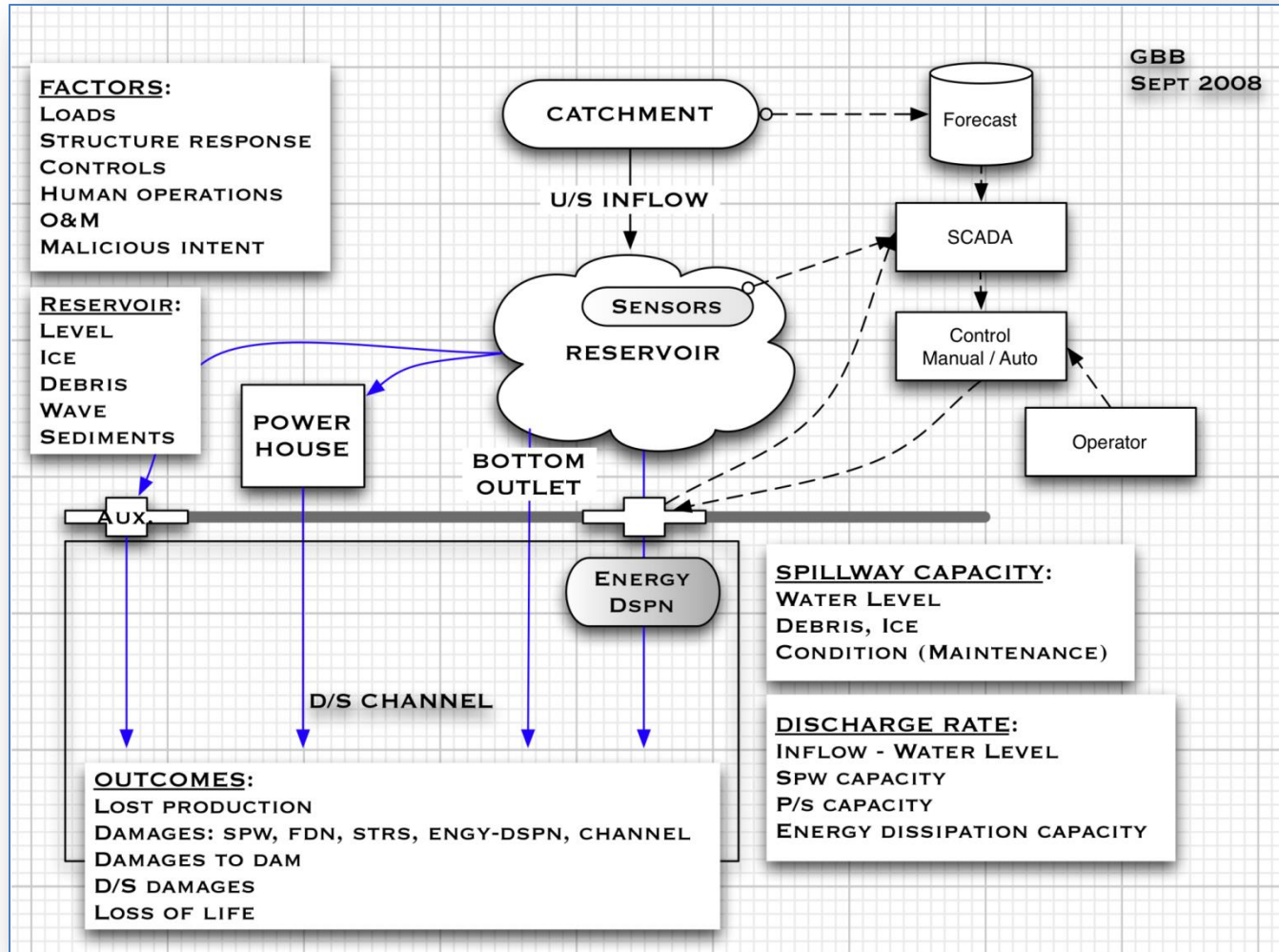


Systems thinking about flow control

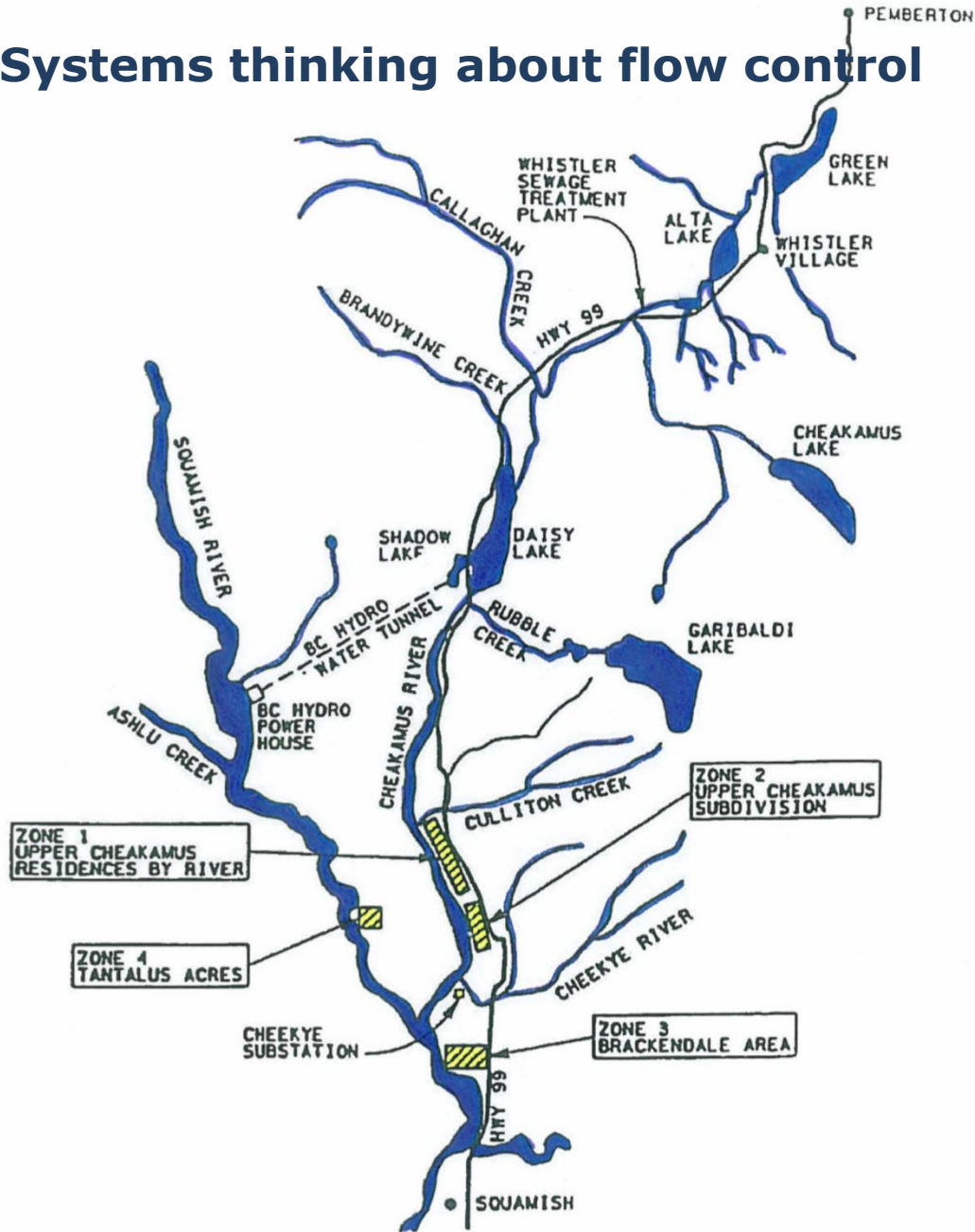
The uncommon combination of common events

1. Occurred on a Saturday night.
 - Extreme precipitation and high ground water level.
 - Mechanical fault in hoisting stop logs.
2. Difficulties using roads.
 - Transmission poles fell, resulting in blackouts.
 - Telephone went dead.
 - Problems getting (sober) crane operators.
 - Helicopters unable to fly.
 - The helicopter radio could only communicate with an airforce base – but not on Saturdays, when it is closed.
3. At Vässinkoski there were difficulties providing large capacity pumps.
 - Unforeseen high downstream water level, preventing normal opening of the gate in the diversion tunnel.
 - Complications when trying to drain the tunnels, since the raised upper water level surpassed the intake gate, filling the tunnels.
4. Staff problems
 - Exhausted personnel.
 - Hard getting hold of qualified extra personnel to work 24-hour shifts during a weekend.

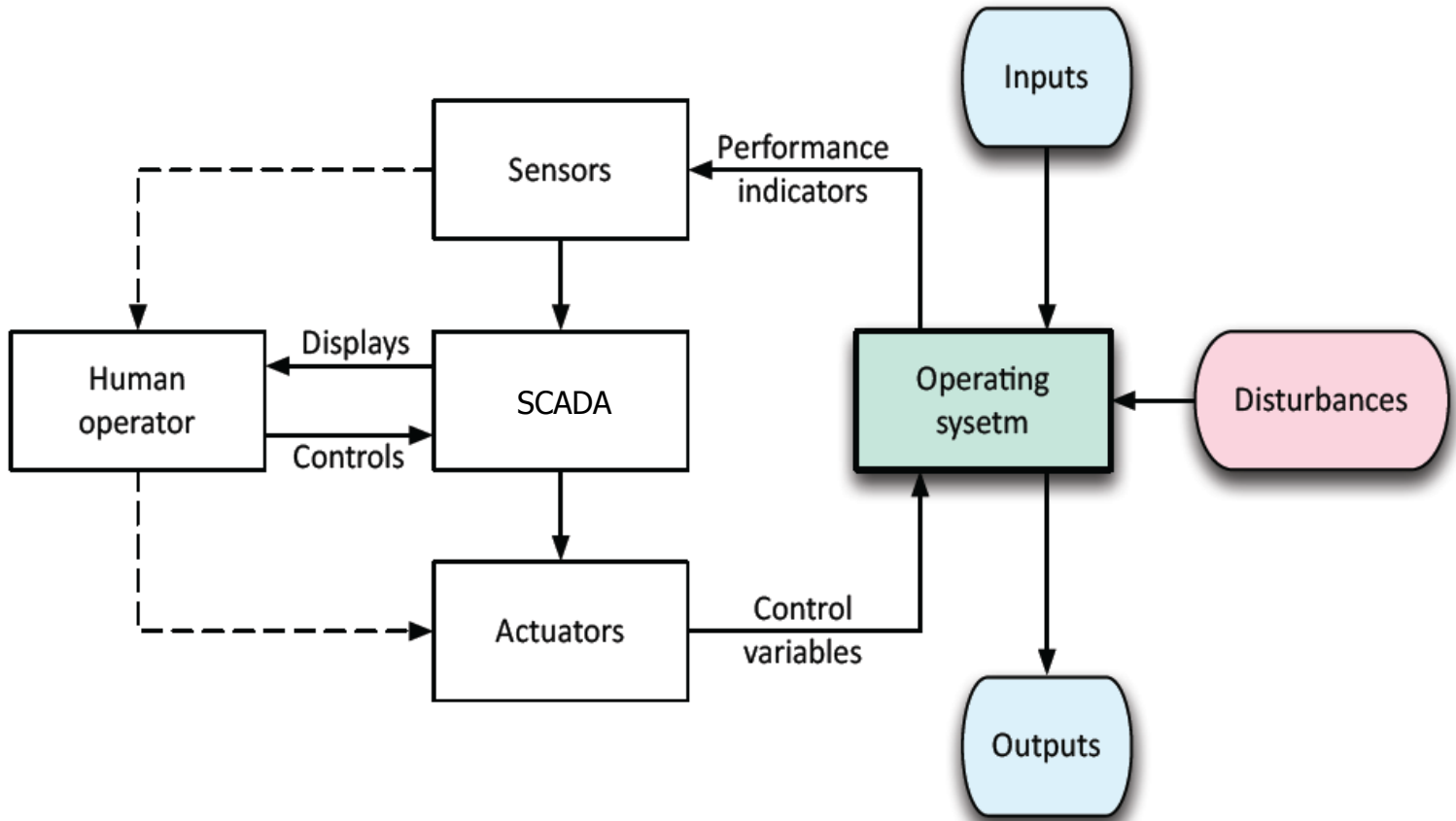
Systems thinking about flow control



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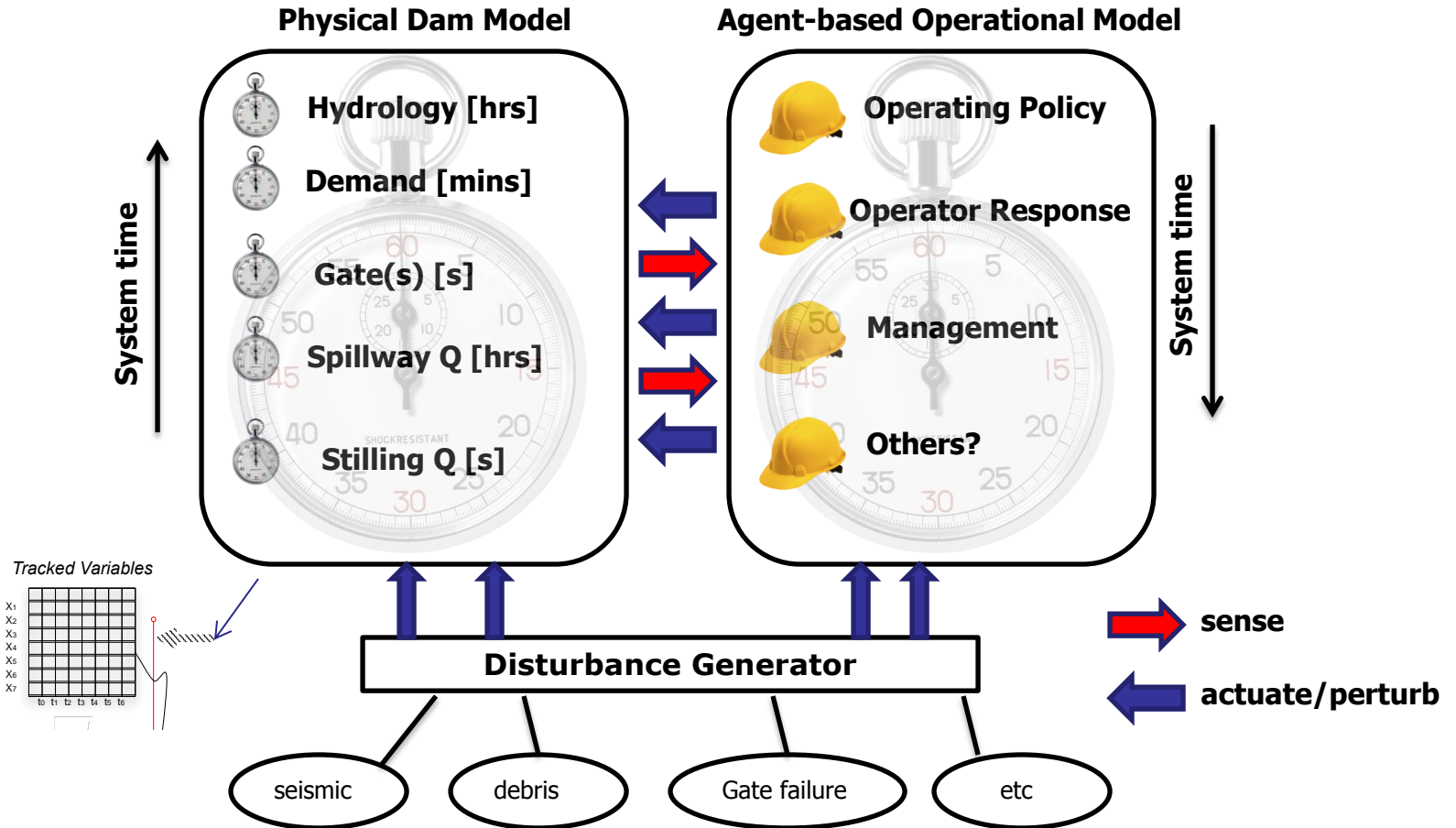


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Adapted from Leveson 2012

Model-Disturbance-Operations Interaction





Göta River

Göta River catchment

~ 1/10 of area of Sweden
~ 51 000 km²

Climate conditions

north – stable winters & spring flood
south – unstable winters

Mean annual runoff

~ 550 m³/s

Power generation

1,6 TWh ~ almost 5 % of Vattenfall's hydro generation

Göta älvs avrinningsområde

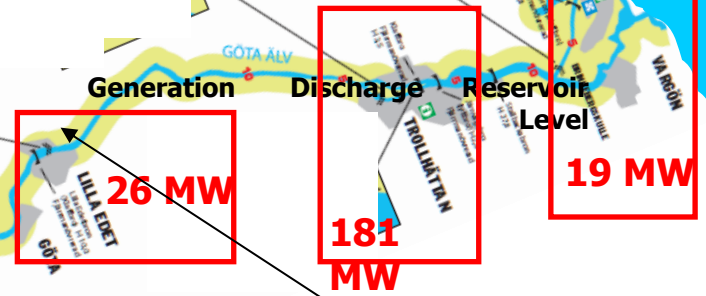
WI Facilities



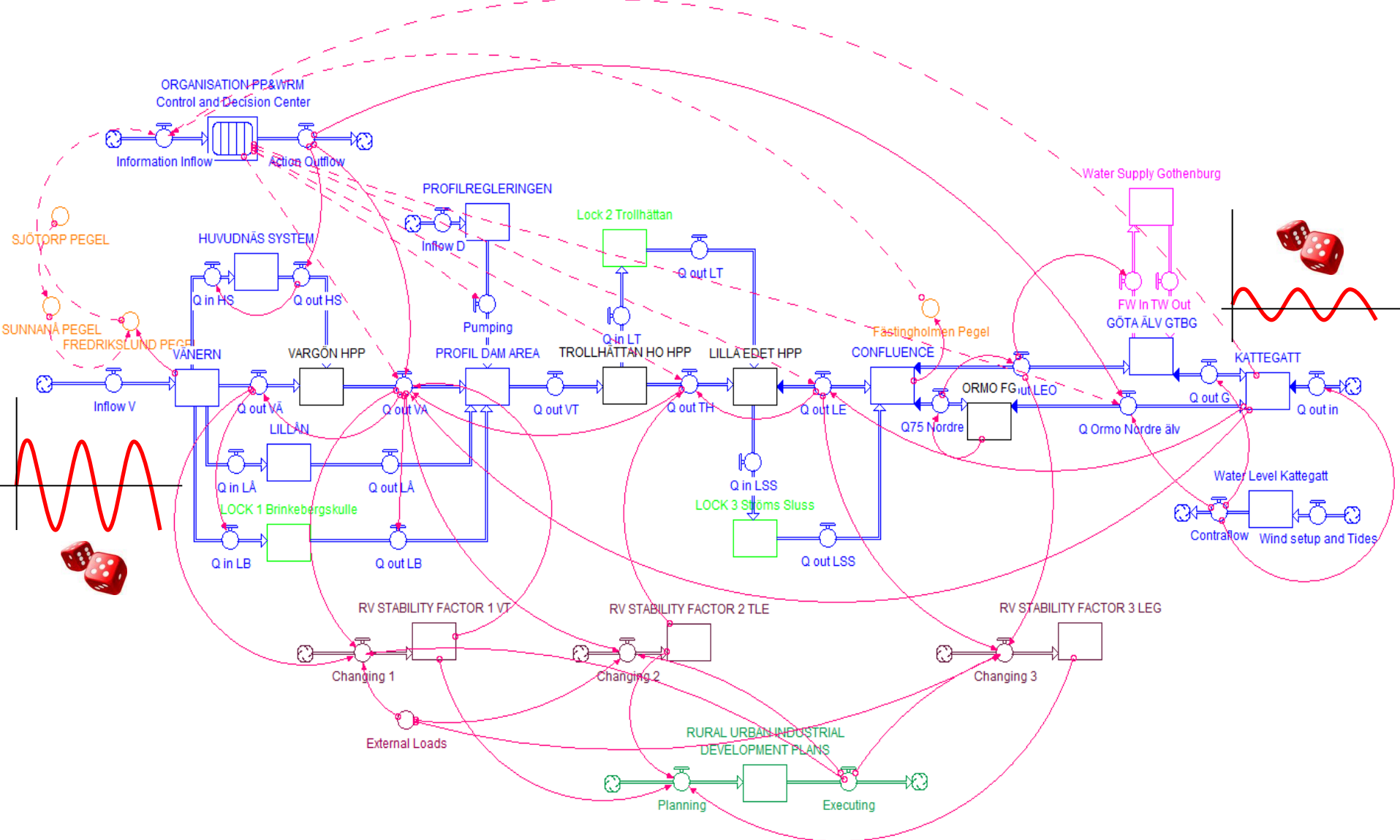
Göta River – Hydropower Plants and WI Facilities



Ormo flip gates against salt water intrusion



Systems Dynamics Model of Göta River



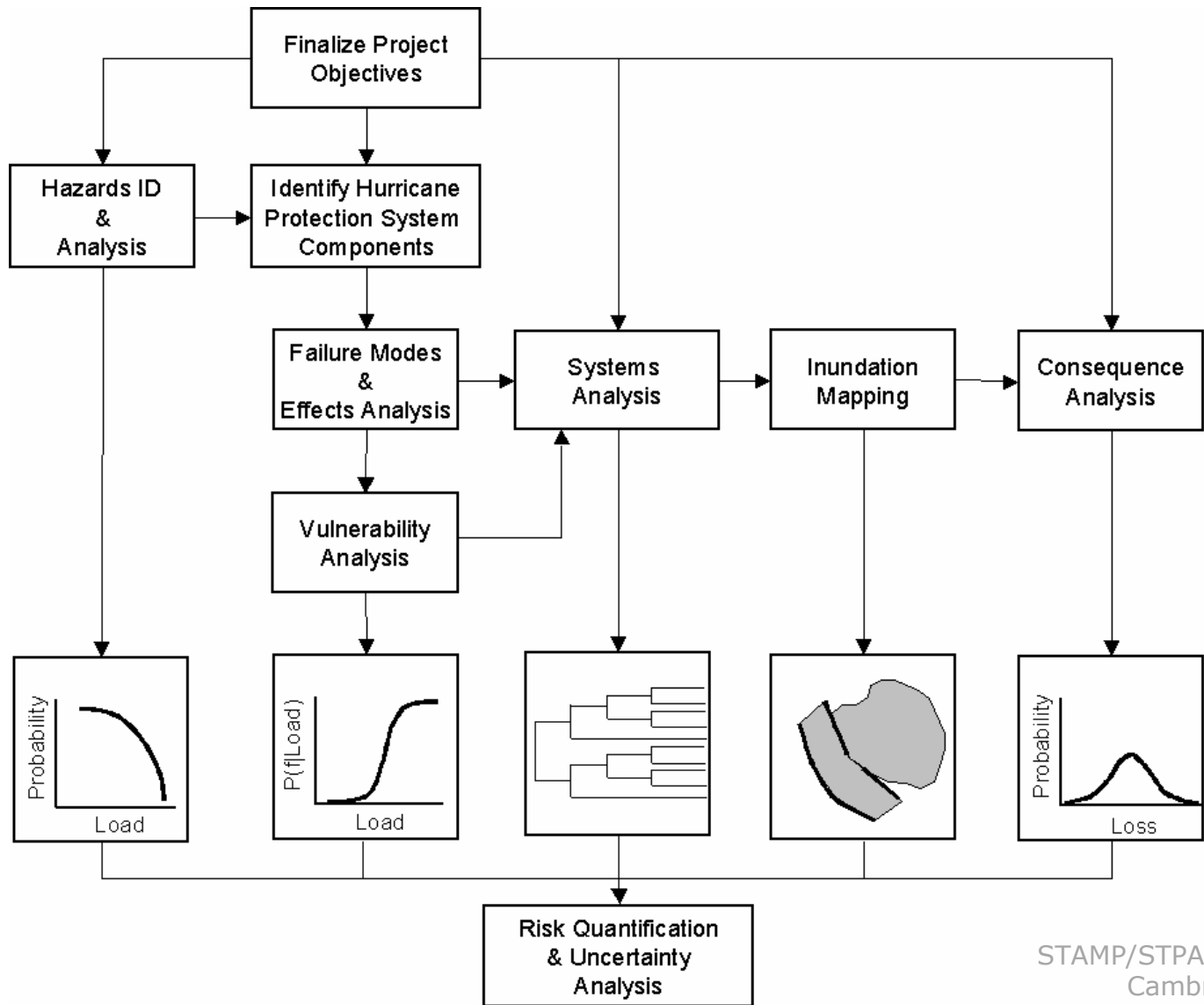
Thank you.



Discussion slides ...

Courtesy, OPG

IPET/DRMS (T-V-C) Risk Model



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Courtesy, Patrick Regan, FERC

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