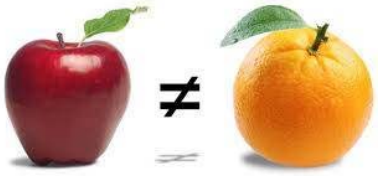
ESA

ARCADIS Design & Consultancy for natural and built assets

Towards Resilient and Sustainable Floodplains

December 19, 2017

ESA



ARCADIS Design & Consultancy for natural and built assets

How do we make flood management decisions?

We compare levees with other measures (e.g., natural floodplain functions)

Other measures (usually) have higher first costs

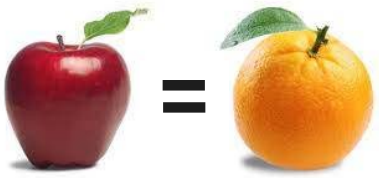
We end up comparing apples to oranges

Other measures are included to “check the box”

Result = levees (usually) win

The Challenge

ESA



ARCADIS Design & Consultancy for natural and built assets

Quantifying flood risk levels the playing field

Compare flood risk reduction using levees *vs*. flood risk reduction by other measures

Calculate the cost of flood risk reduction

Calculate the cost-effectiveness of flood risk reduction

Result = select the most cost-effective solution, not the cheapest

The Solution

ARCADIS Design & Consultancy for natural and built assets

Here's the bottom line

Current approach to floodplains

- With LOP the default is levees
  - ✓ Residual risk is not quantified
  - ✓ Other benefits are limited
  - ✓ Least first cost
- Room for the River (natural floodplain functions)
  - ✓ Other benefits may be apparent, but are difficult to monetize
  - ✓ Will likely cost more

Applying risk analysis

- Risk and residual risk is quantified
- Cost-effectiveness of actions to reduce risk can be determined
- Enables selecting the best solution based on life-cycle costs

ARCADIS Design & Consultancy for natural and built assets

Today's discussion

1. Sustainable Floodplain Management
2. Current Approaches to Floodplain Management
3. Make Room for the River (natural floodplain functions)
4. Current Approach to Flood Management
5. What is Risk?
6. Applying Tolerable Risk Guidelines
7. Why Levees?
8. Using a Risk-informed Approach

ESA

ARCADIS Design & Consultancy for natural and built assets

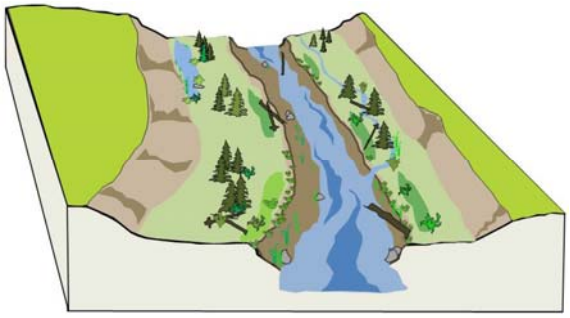
SUSTAINABLE FLOODPLAIN MANAGEMENT

ESA

ARCADIS Design & Consultancy for natural and built assets

Floodplains

A landscape feature that is periodically inundated by water from an adjacent river



Role of floodplains: Accommodate floodwaters that exceed channel capacity

ESA

ARCADIS Design & Consultancy for natural and built assets

Sustainable floodplain management

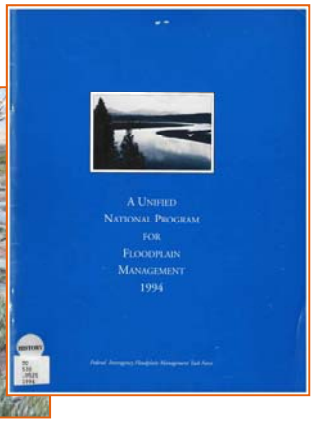
The way forward can be informed by lessons from the past

A risk-informed approach is a better way to get there

ESA

ARCADIS Design & Consultancy for natural and built assets

Floodplains provide many natural and beneficial functions



	Natural Flood and Erosion Control	*Surface Water Quality Maintenance*	*Groundwater Recharge*
Water Resources	• Provide flood storage and conveyance • Reduce flood velocities • Reduce flood peaks • Reduce sedimentation	• Filter nutrients and impurities from runoff • Process organic wastes • Moderate temperature of water	• Promote infiltration and aquifer recharge • Reduce frequency and duration of low surface flows
	Biological Productivity	*Fish and Wildlife Habitats*	
Biologic Resources	• Support high rate of plant growth • Maintain biodiversity • Maintain integrity of ecosystem	• Provide breeding and feeding grounds • Create and enhance waterfowl habitat • Protect habitats for rare and endangered species	
	Harvest of Wild and Cultivated Products	*Recreational Opportunities*	*Areas for Scientific Study and Outdoor Education*
Societal Resources	• Enhance agricultural lands • Provide sites for aquaculture • Restore and enhance forest lands	• Provide areas for active and passive uses • Provide open space • Provide aesthetic pleasure	• Contain cultural resources (historic and archaeological sites) • Provide opportunities for environmental and other studies

*Adapted from *A Unified National Program for Floodplain Management* (FEMA 1994).

ESA

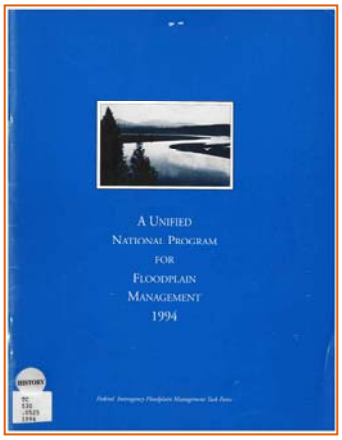
ARCADIS Design & Consultancy for natural and built assets

Goals for floodplain management

Reduce by half

- Risk to life and property
- Risk to natural resources

What strategies can we use to help achieve the goals for floodplain management?



ESA

ARCADIS Design & Consultancy for natural and built assets

CURRENT APPROACHES TO FLOODPLAIN MANAGEMENT

ESA

ARCADIS Design & Consultancy for natural and built assets

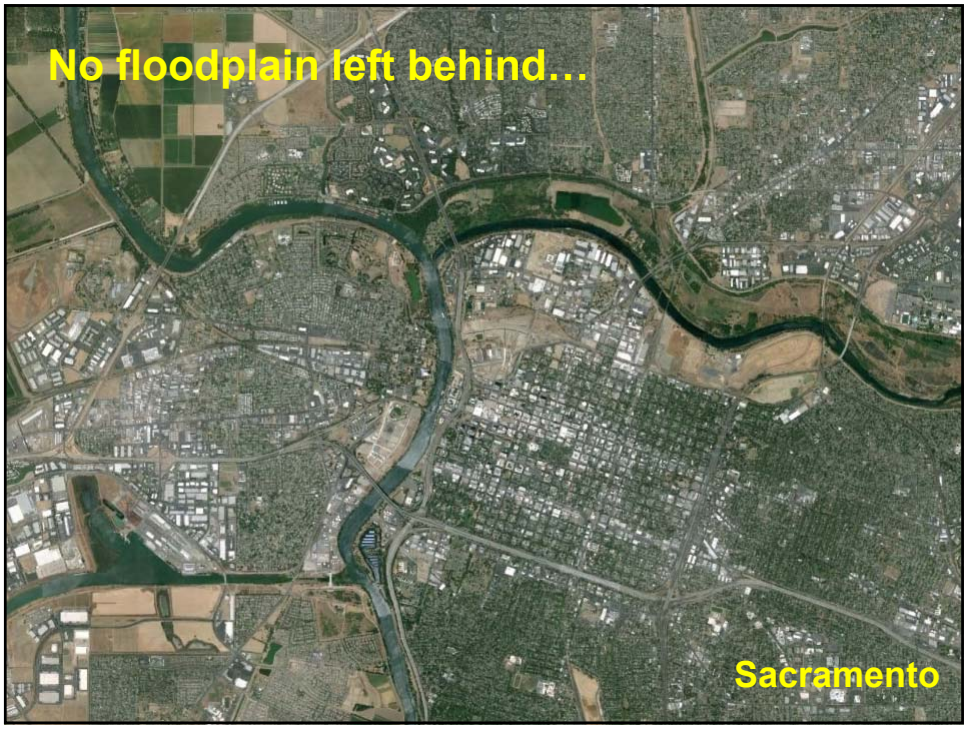
Other (beneficial) uses of floodplains

ESA

ARCADIS Design & Consultancy for natural and built assets

The result, levees prevail

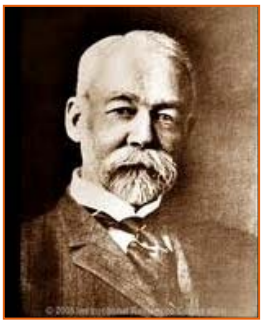
>30,000 miles of riverine levees in the U.S.



ESA

ARCADIS Design & Consultancy for natural and built assets

When it comes to levees, there are two types:



Those that have been overtopped by floodwaters

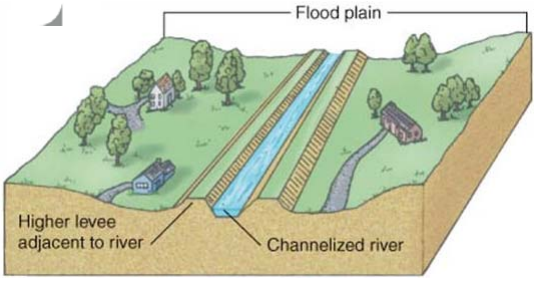
And those that will be overtopped by floodwaters

... It should be fully understood then, that floods will occasionally come which must be allowed to spread

William Hammond Hall, 1895

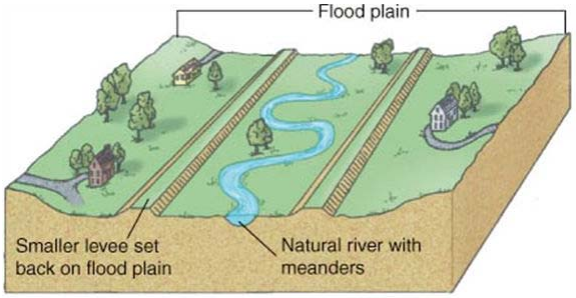
ESA

ARCADIS Design & Consultancy for natural and built assets



This?

Or, this?



ESA

ARCADIS Design & Consultancy for natural and built assets

This?

Or, this?

ESA

ARCADIS Design & Consultancy for natural and built assets

MAKING ROOM FOR THE RIVER

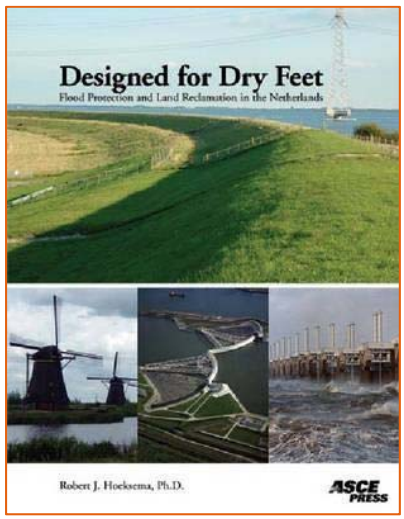
ESA

ARCADIS Design & Consultancy for natural and built assets

Goals in the Netherlands

Prevent floods and keep the water out

- "Never Again"
- "Dry Feet"



ESA

ARCADIS Design & Consultancy for natural and built assets

Adapting to change

Close calls in 1993, 1995

Recognition of climate change

ESA

ARCADIS Design & Consultancy for natural and built assets

Ruimte voor de Rivier

Program Goals

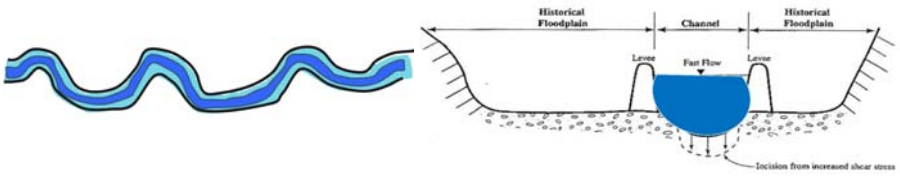
- Improve flood safety
- Enhance scenic quality

ESA

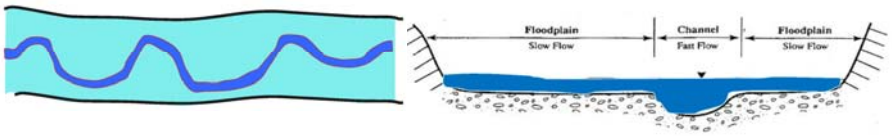
ARCADIS Design & Consultancy for natural and built assets

Making room for the river

Existing floodway



Expanded floodway



ESA

ARCADIS Design & Consultancy for natural and built assets

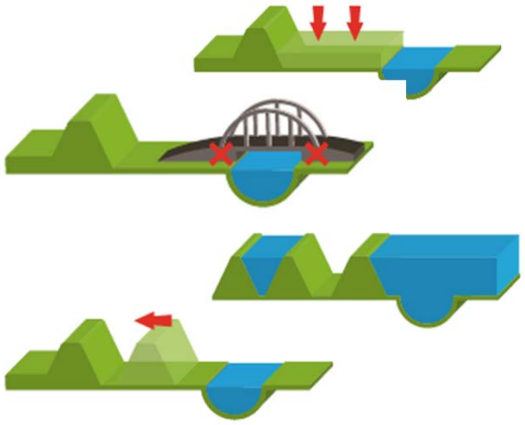
Measures

Depress floodplains

Remove obstacles

Add bypasses

Setback levees

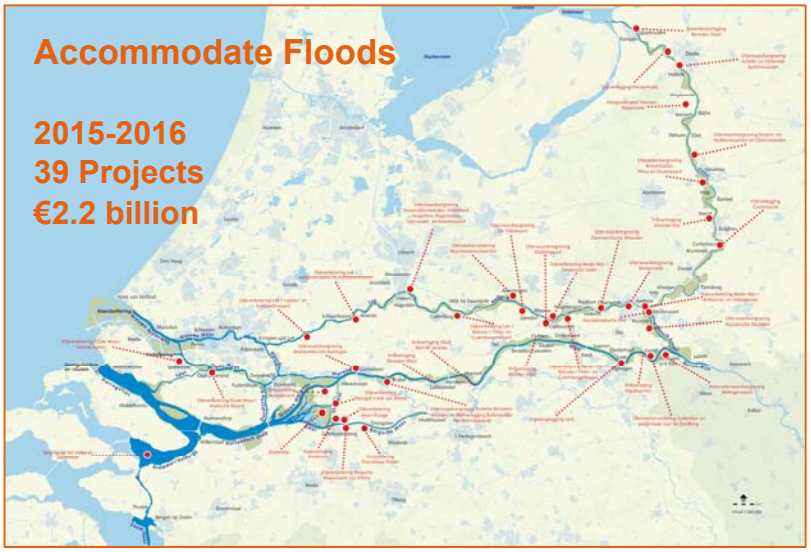


ESA

ARCADIS Design & Consultancy for natural and built assets

Accommodate Floods

2015-2016
39 Projects
€2.2 billion



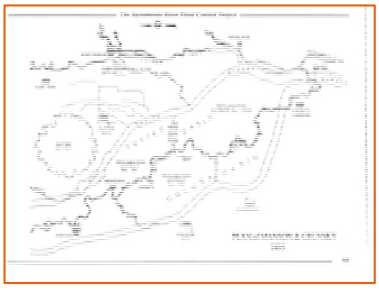
ESA

ARCADIS Design & Consultancy for natural and built assets

Where have we seen this before?

Min River, China, 256 BCE

California, 1917



Mississippi River, 1928

ESA

ARCADIS Design & Consultancy for natural and built assets

Han Dynasty, 206 BCE

Commission to investigate catastrophic floods

- Do not rely on levees
- Build bypasses and floodways

Yellow River Flood 1887

Do not fight against water for land

ESA

ARCADIS Design & Consultancy for natural and built assets

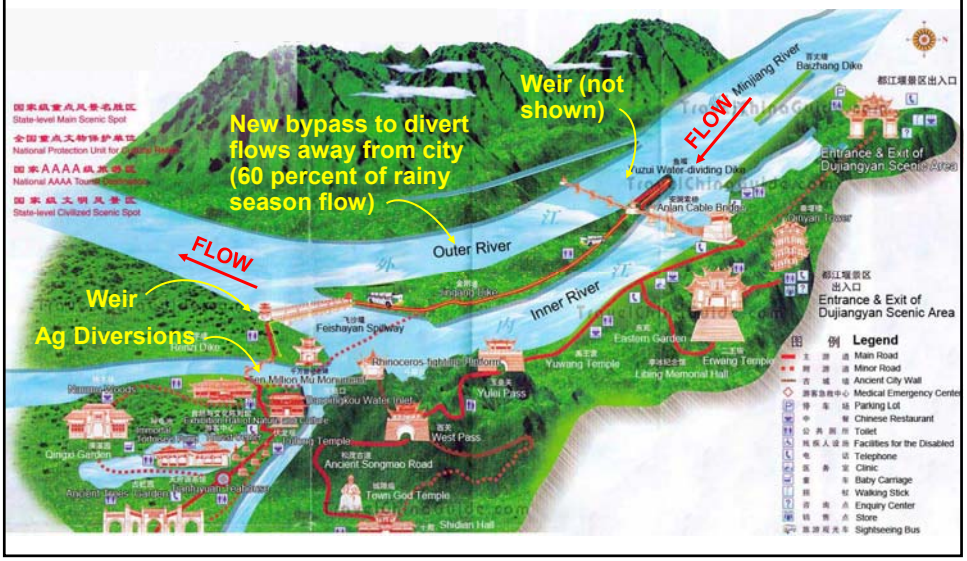
Trouble in the Chengdu Plain, 256 BCE

Floods and ***drought*** on the Min River, Sichuan Province

ESA

ARCADIS Design & Consultancy for natural and built assets

Li Bing: Governor, Engineer



ESA

ARCADIS Design & Consultancy for natural and built assets

ESA

ARCADIS Design & Consultancy for natural and built assets

OUTER RIVER DIVERSION
(LOOKING UPSTREAM)

ESA

ARCADIS Design & Consultancy for natural and built assets

Bridge to temple for Li Bing

ESA

ARCADIS Design & Consultancy for natural and built assets

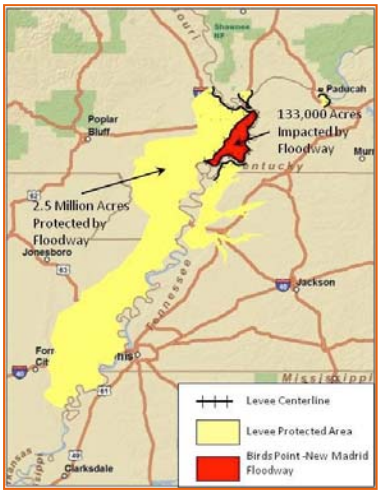
On the Mississippi

Before and after the Great Flood of 1927, engineers warned against a “levees-only” policy

ESA

ARCADIS Design & Consultancy for natural and built assets

Bird’s Point – New Madrid Floodway



Impact 133,000 acres to protect 2,500,000 acres

Prevented $110 billion in damages

ESA

ARCADIS Design & Consultancy for natural and built assets

Ecological, water quality, and recreational benefits

50,000 acres of floodplain and wetland

Improved fish spawning and rearing

Protection for migrating waterfowl

Recreation benefits

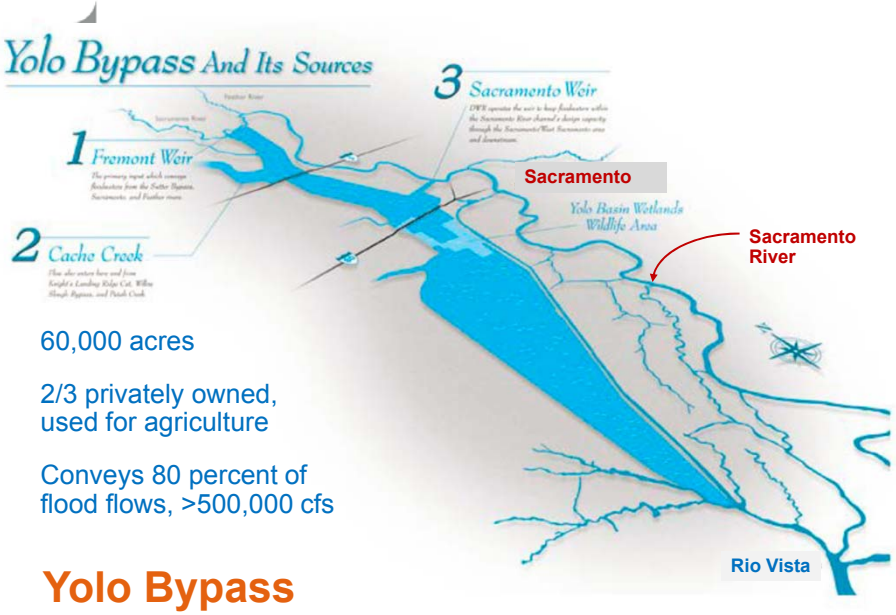
ESA

ARCADIS Design & Consultancy for natural and built assets

Yolo Bypass

ESA

ARCADIS Design & Consultancy for natural and built assets



60,000 acres

2/3 privately owned, used for agriculture

Conveys 80 percent of flood flows, >500,000 cfs

Yolo Bypass

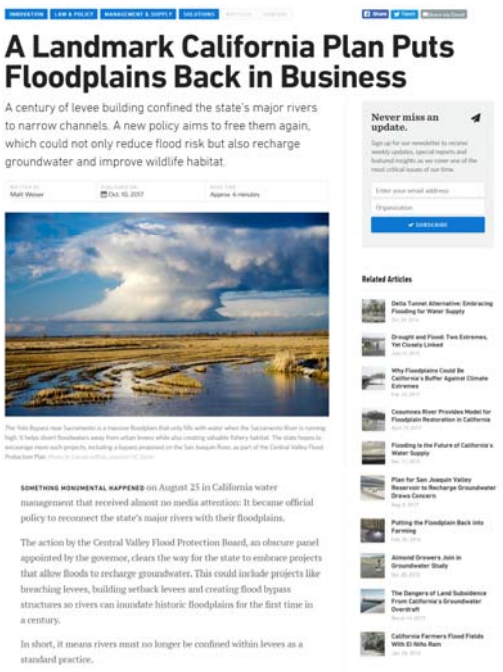
ESA

ARCADIS Design & Consultancy for natural and built assets

Yolo Bypass

Floods every 2-3 years

Critical habitat for migratory salmon and birds



A Landmark California Plan Puts Floodplains Back in Business

A century of levee building confined the state's major rivers to narrow channels. A new policy aims to free them again, which could not only reduce flood risk but also recharge groundwater and improve wildlife habitat.

Matt Weiser — Oct. 10, 2017 — Approx. 4 minutes

SOMETHING MONUMENTAL HAPPENED on August 25 in California water management that received almost no media attention: It became official policy to reconnect the state's major rivers with their floodplains.

The action by the Central Valley Flood Protection Board, an obscure panel appointed by the governor, clears the way for the state to embrace projects that allow floods to recharge groundwater. This could include projects like breaching levees, building setback levees and creating flood bypass structures so rivers can inundate historic floodplains for the first time in a century.

In short, it means rivers must no longer be confined within levees as a standard practice.

Never miss an update.

Related Articles

ARCADIS Design & Consultancy for natural and built assets

"Spread it out, slow it down, sink it in, give the river more room."

California Natural Resources Agency

ESA

ARCADIS Design & Consultancy for natural and built assets

CURRENT APPROACH TO FLOOD MANAGEMENT

ESA

ARCADIS Design & Consultancy for natural and built assets

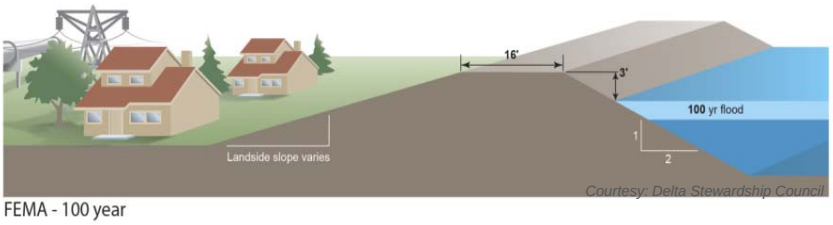
Current guidance

One percent AEP—NFIP (44CFR 65.10)

- "100-year" level-of-protection (LOP)
- Basis for FEMA accreditation

On the land-side of levee

- No insurance is required
- No special mitigation is required



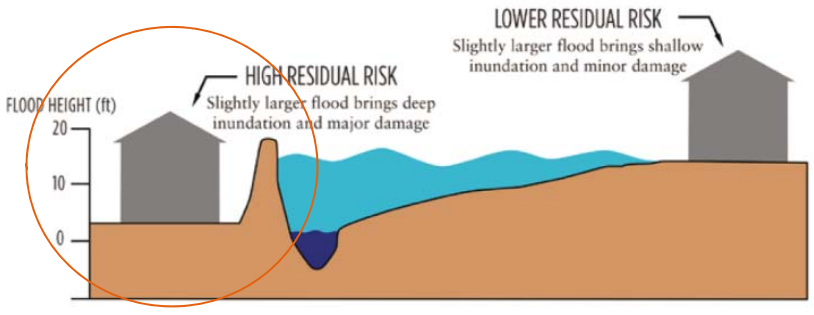
FEMA - 100 year

ESA

ARCADIS Design & Consultancy for natural and built assets

Using LOP ignores residual risk

Residual risk is the flood risk that remains *after actions have been taken* to reduce that risk



Adapted from Eisenstein et al (2007)

ESA

ARCADIS Design & Consultancy for natural and built assets

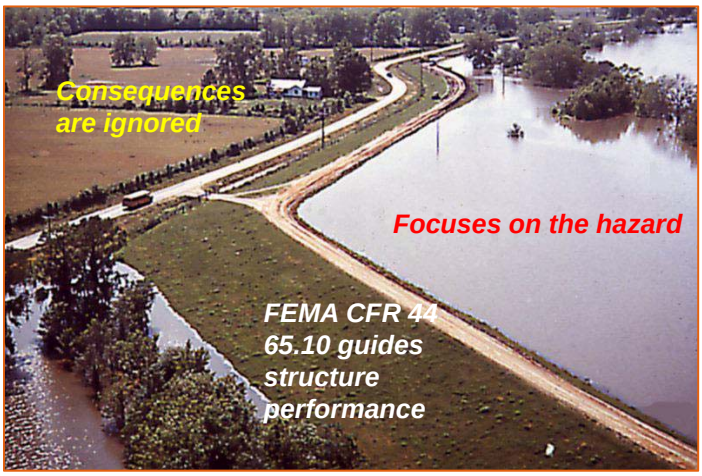
Ignoring risk has adverse consequences

- Public safety
- Land use
- Infrastructure development
- Personal preparedness

ESA

ARCADIS Design & Consultancy for natural and built assets

Limitations of the LOP approach



ESA

ARCADIS Design & Consultancy for natural and built assets

WHAT IS RISK?

ARCADIS Design & Consultancy for natural and built assets

What is risk?

Sacramento 1862

Common definitions of *risk*

- The possibility that something bad will happen
- Threats that can be identified, evaluated, and mitigated

Risk = Probability x Consequences

ESA

ARCADIS Design & Consultancy for natural and built assets

What is risk?

ESA

ARCADIS Design & Consultancy for natural and built assets

Risk cannot be ignored


Katrina, 2005


Mississippi River, 2011


Sandy, 2012


Houston, 2015


Louisiana, 2016


Houston, 2017

ESA

ARCADIS Design & Consultancy for natural and built assets

Quantifying risk enables

Understanding and communicating risk (and residual risk)

Deciding if more risk reduction warranted

Identifying actions to address most urgent risks

How do we decide whether risks are tolerable?

ESA

ARCADIS Design & Consultancy for natural and built assets

We make decisions everyday on what level of risk is tolerable to us

ESA

ARCADIS Design & Consultancy for natural and built assets

What risk is tolerable?

Unacceptable — **Broadly acceptable**

Range of Tolerability

Risk cannot be justified except under extraordinary circumstances

No further actions required. Risk regarded as insignificant

Tolerable Risk **is the level of risk people are willing to live with in order to secure certain benefits**

ESA

ARCADIS Design & Consultancy for natural and built assets

Principles of Tolerable Risk

- Life safety is paramount
- Risk cannot be ignored
- Absolute safety cannot be guaranteed
- Goal = ***As Low As Reasonably Practicable (ALARP)***

ALARP **is what can be reasonably done without spending an inordinate amount of time, money, or resources relative to the risk reduction benefits.**

ESA

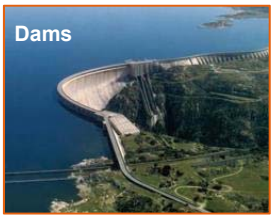
ARCADIS Design & Consultancy for natural and built assets

APPLYING TOLERABLE RISK GUIDELINES

ESA

ARCADIS Design & Consultancy for natural and built assets

How do we measure risk?



Guidance from Other Settings

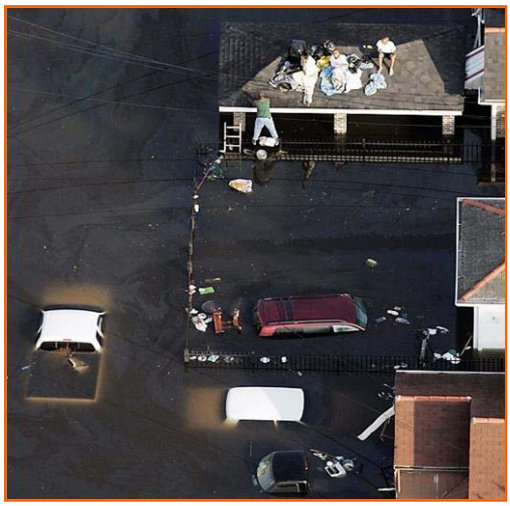
ESA

ARCADIS Design & Consultancy for natural and built assets

How do we measure risk?

Expected Annual Fatalities (EAF)

Expected Annual Damages (EAD)



ESA

ARCADIS Design & Consultancy for natural and built assets

Applying Tolerable Risk

Characterize Risk
- Inventory assets
- Identify Hazards
- Assess vulnerabilities
- Calculate risk

Identify Options to Reduce Risk
- Structural
- Non-structural
- Calculate risk reduction

Evaluate Options
- Do measures reduce risk to tolerable levels?
- Compare cost-effectiveness measures, trade-offs
- Assess residual risk

Continuously Review
- Communicate risks
- Adapt to change
- Perform robust OMRR&R*

*Operations, maintenance, repair, replacement, and rehabilitation

ESA

ARCADIS Design & Consultancy for natural and built assets

WHY LEVEES?

ESA

ARCADIS Design & Consultancy for natural and built assets

"If floodplains are so beneficial, why do levees prevail?"

Here's why

People want to live near water

Historically, commerce thrives near water

Developers want to, well, develop

Local governments want to increase the tax base

But, more development and more infrastructure increases the cost of flood risk management and emergency preparedness

Levees are usually lowest in first cost

ESA

ARCADIS Design & Consultancy for natural and built assets

Comparison of flood management benefits

	Levees	Room for the River
Sustainability	Low	Moderate to High
Resilience	Low	Moderate to High
Multiple Benefits	Very Low	Moderate to High
Financial	High	Moderate
Environmental	Low	High
Social	Low	High

ESA

ARCADIS Design & Consultancy for natural and built assets

Here's why

Levees	Room for the River
100-yr LOP	>100-yr LOP
Less first cost	Higher first cost
Limited environmental benefits	Enhanced environmental benefits
Less resilient	Improved resiliency

Guess what wins!

ESA

ARCADIS Design & Consultancy for natural and built assets

USING A RISK-INFORMED APPROACH

ESA

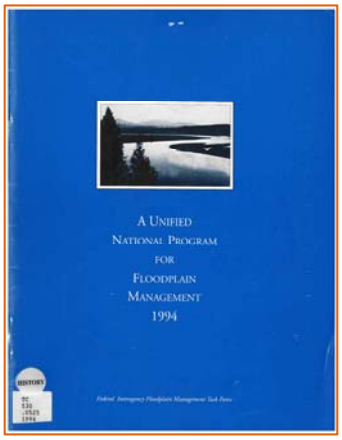
ARCADIS Design & Consultancy for natural and built assets

Goals for floodplain management

Reduce by half

- Risk to life and property
- Risk to natural resources

Can we use principles of tolerable risk to quantify costs and benefits?



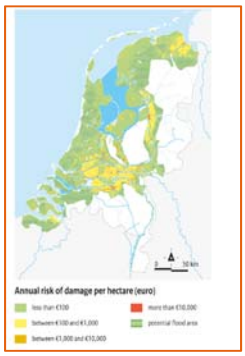
ESA

ARCADIS Design & Consultancy for natural and built assets

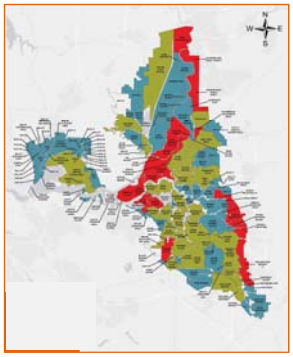
Risk = probability x consequences

ARCADIS Design & Consultancy for natural and built assets

Risk Maps

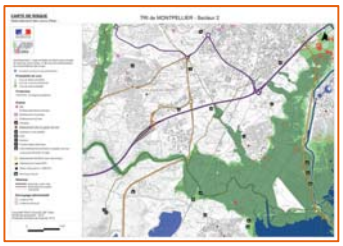


The Netherlands



California Delta

France



UK

ESA

ARCADIS Design & Consultancy for natural and built assets

Can we quantify floodplain benefits?

	LOP	Risk
Cost	YES	YES
Residual Risk	NO	YES
Risk Reduction	NO	YES
Cost effectiveness	NO	YES
Other Benefits	?	?

ESA

ARCADIS Design & Consultancy for natural and built assets

Decision based on risk, not LOP

Levees	Room for the River
Less first cost	Higher first cost
Limited environmental benefits	Enhanced environmental benefits
Less resilient	Improved resiliency
Single purpose	**Multi-benefits**
Higher residual risk	**Lower residual risk**
Higher life-cycle costs	**Lower life-cycle costs**
Less cost effective	**More cost effective**

Now what wins?

ESA

ARCADIS Design & Consultancy for natural and built assets

EVALUATING FLOOD RISK MANAGEMENT OPTIONS	LOP	TOLERABLE RISK
COST	✓	✓
ADVANTAGES	✓	✓
DISADVANTAGES	✓	✓
CURRENT RISK	NA	✓
RISK REDUCTION ACHIEVED	NA	✓
COST – EFFECTIVENESS	NA	✓

ESA

ARCADIS Design & Consultancy for natural and built assets

Advantages of Tolerable Risk

Facilitates

- Understanding risk
- Communicating risk
- Managing risk

Recognizes

- Risk cannot be eliminated
- Absolute protection is not possible

Enables

- Evaluation of trade-offs and cost-effectiveness
- Efficient use of resources
- Establishing priorities
- Fair treatment

Accounts for both Structural and non-structural options

If you can measure risk, you can measure the cost-effectiveness of efforts to reduce risk

ARCADIS Design & Consultancy for natural and built assets

Here's the bottom line

Current approach to floodplains

- With LOP the default is levees
  - ✓ Residual risk is not quantified
  - ✓ Other benefits are limited
  - ✓ Least first cost
- Room for the River (natural floodplain functions)
  - ✓ Other benefits may be apparent, but are difficult to monetize
  - ✓ Will likely cost more

Applying risk analysis

- Risk and residual risk is quantified
- Cost-effectiveness of actions to reduce risk can be determined
- Enables selecting the best solution based on life-cycle costs

ESA

ARCADIS Design & Consultancy for natural and built assets

ESA

ARCADIS Design & Consultancy for natural and built assets

Contacts:

LARRY ROTH, PE, GE, ENV SP
Vice President, Arcadis
Phoenix, AZ
c 916.740.0930
e larry.roth@arcadis.com

JESSICA LUDY, CFM
Water Resources Planner, ESA
San Francisco, CA
c 734.604.0282
e jludy@esassoc.com