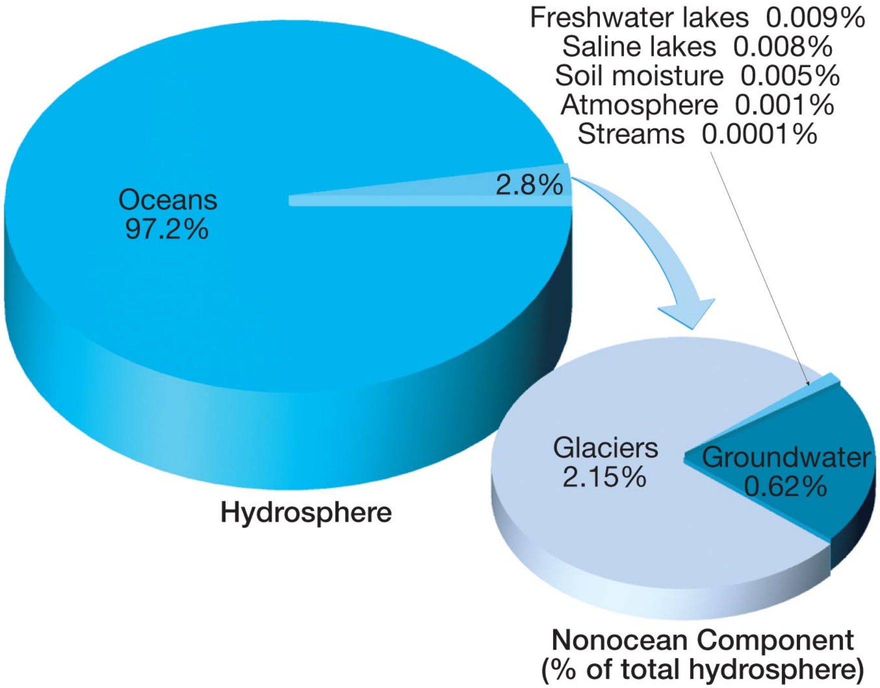
Unit 4.1: Climate and Water

Iguazu Falls: border of Argentina and Brazil

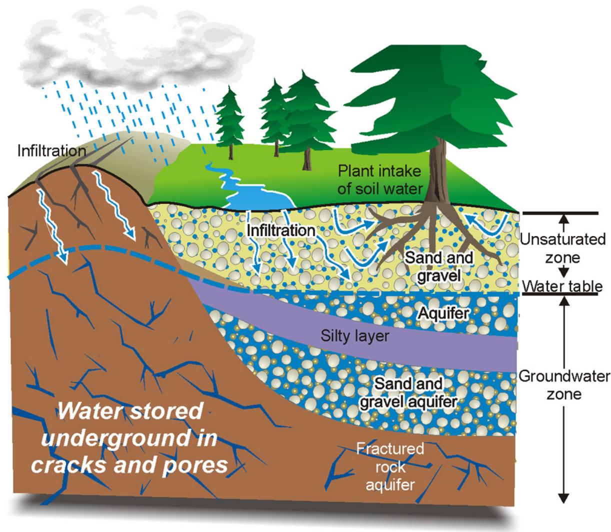
Hydrosphere

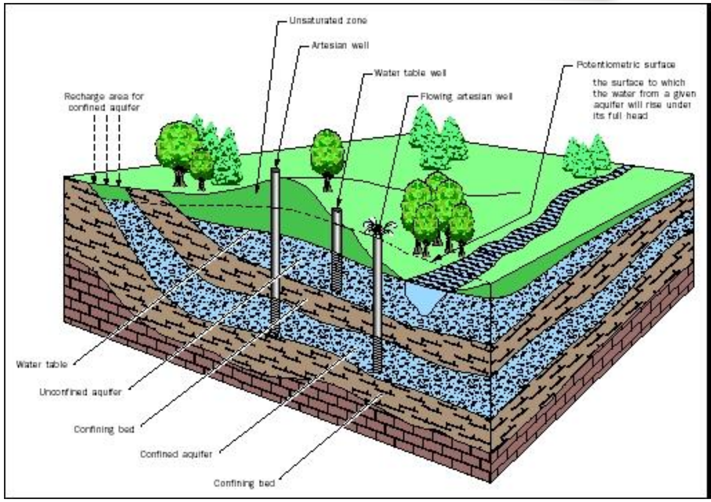
- The vast majority of the world's water (97%) is in the oceans; this is followed by the glaciers and ice caps (2.2%), ground water, surface water (rivers, lakes, etc.) and atmospheric water)
- Over land, precipitation – evaporation is positive, while over the ocean precipitation-evaporation is negative; the difference is made up by river runoff



Water Cycle

- Precipitation
- Evaporation
- Runoff (snowmelt or rainfall)
- Runoff coefficient – ratio of runoff to rainfall
- Infiltration/percolation - water flow from the surface into the groundwater
- Groundwater flow
- Aquifer - a layer of rock, sand, gravel that contains a large amount of water
- Artesian well – well drilled into artesian aquifer (confined aquifer under pressure)
- Water table – level at which water is present in most interstitial spaces (not just pore water)
- Pore water – water trapped next to particles in small pores because of molecular tension
- Discharge – volume flux of water in a flowing water body
- Recharge – water that flows back into a reservoir (generally groundwater)
- Erosion – the process by which water can scour soil, rock and shape a landscape



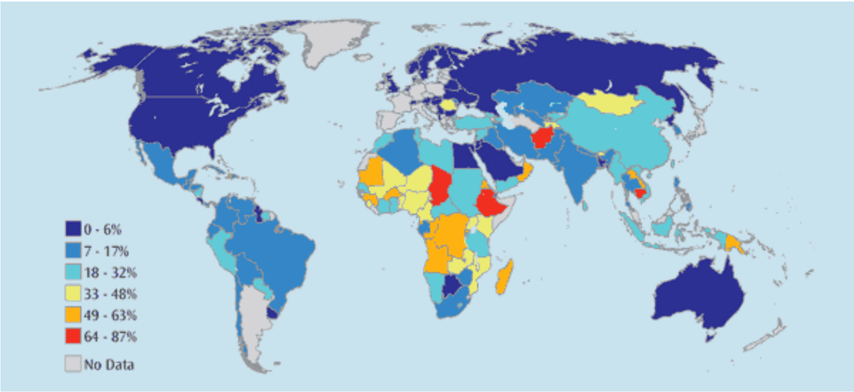


Natural surface freshwater

- Comprises only a tiny fraction of total water resources on planet, but the vast majority of water for human and terrestrial ecosystem use
- 87% of surface freshwater is in lakes (including reservoirs), 11 % in swamps, and 2% in rivers & streams
- Largest freshwater lake by volume; Baikal (23,600 km^3)
- Largest freshwater lake by surface area; Superior (82,000km^2)
- Largest swamp by area; either in Western Siberia, or the Pantanal of South America (140,000-200,000 km^2)
- Largest river by volume flux; Amazon (over 200,000m^3/s) – second on the list (Congo) has only (40,000 m^3/s)
- Longest river; Nile (only 2800 m^3/s)

Human Water Access

- Almost 800 million people globally lack reliable access to clean drinking water: http://www.water.org
- Depending on how one defines sanitation, at least 1.5 if not more than 2 billion people lack reliable access to decent sanitation infrastructure (eg. toilets and latrines)
- Access to clean water is different from access to water – note that dry areas don't necessarily have the lowest water access
- Many untreated surface water resources are contaminated with pathogens (especially in the tropics)



Map of % of population without reliable access to safe drinking water

The global population practising open defecation is slowly declining

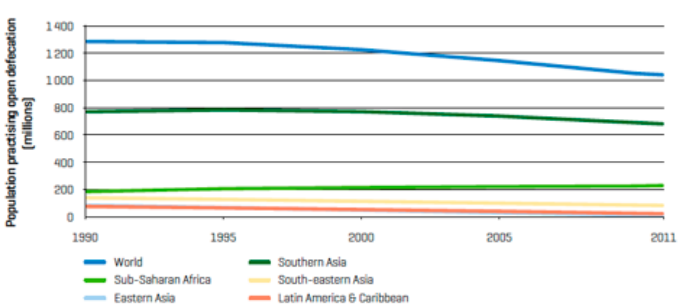
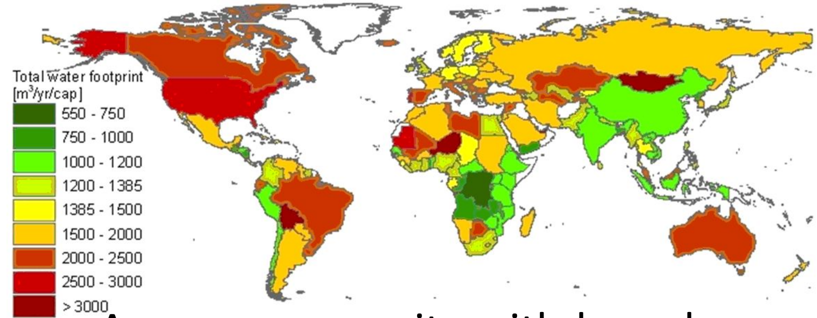


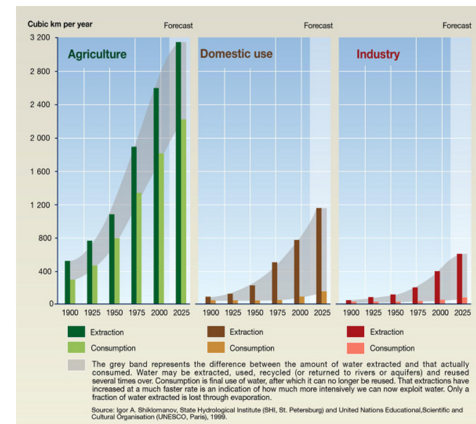
Figure 5. Open defecation trends in developing regions and the world, 1990–2011.

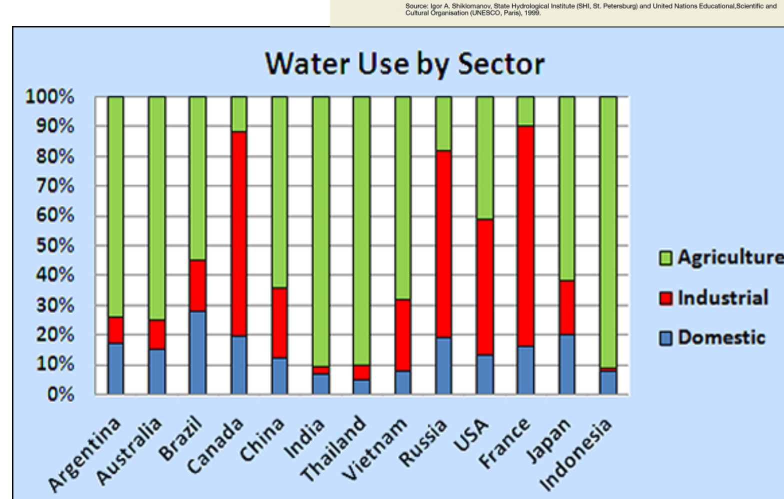
Human Water Use

- Developed countries consume much more water per capita than do developing countries
- Water consumption often has little to do with natural water supply and a lot to do with wealth
- Globally, agriculture comprises the largest share of human water use, followed by domestic and industrial usage
- But water usage varies significantly from country to country



Average per capita withdrawals 1996-2005





Water Supply issues: managing for drought

- when reservoirs are managed for drought risk and water supply shortfall, they are kept at a high level
- this is also good management practice for hydropower generation
- evaporation can be quite significant over large lake or reservoir areas, especially during hot dry conditions
- If surprise heavy precipitation occurs, overtopping and dam failure can occur
- If drought is very prolonged, inflow into reservoirs may need to be reduced to reduce evaporation losses and preserve upstream flow

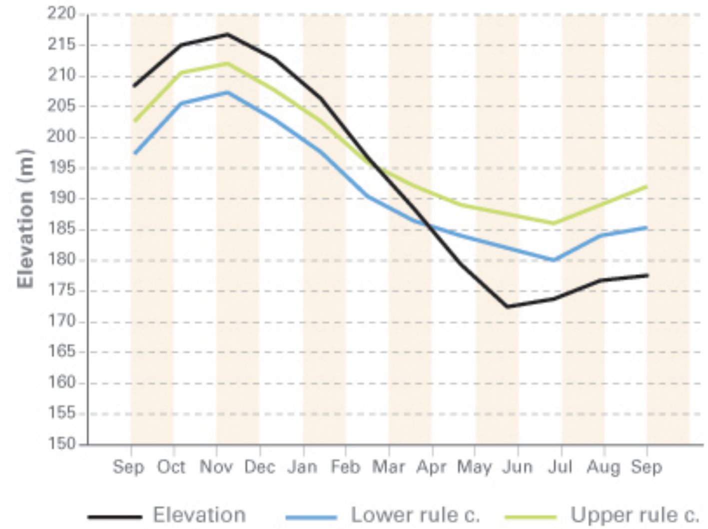
Hoover Dam and Lake Mead, NV/AZ

Water Supply issues: managing for floods

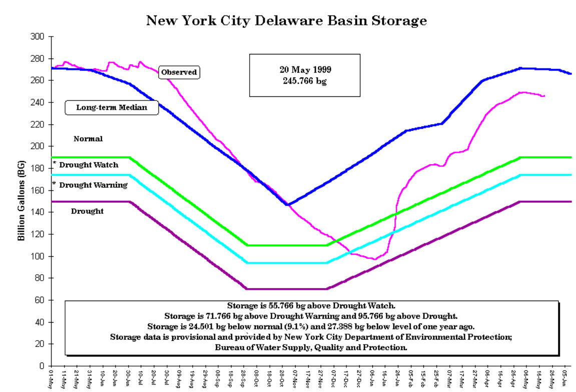
- Reservoir level must be lowered to accommodate increase in water levels from wet season, snowmelt and/or coming storm
- If large influx of water fails to come, the reservoir can be in danger of being poorly provisioned if drought conditions prevail
- But if reservoir level is not lowered enough to accommodate influx of water, overtopping and structural failure may result

Rule Curves

- Operating principles for reservoir to account for seasonal variation of precipitation, inflows, outflows and evaporation
- Lowest levels when P-E is largest and highest levels when P-E is lowest
- In the middle and high latitudes, P-E is lowest in the summer
- In the tropics, P-E is lowest in the dry season, which may be the "winter"



Rule Curves for Angat Reservoir in the Philippines



NYC Delaware Basin water supply

Impacts of Reservoirs and hydropower

- Sediment/silt buildup in reservoirs and deprivation downstream (can lead to more downstream erosion)
- Alteration of streamflows with impacts on human and ecosystems (river ecosystem disruption)
- Potential for inundation of downstream communities
- Excessive dams can cause rivers (in arid, drought prone regions) to run dry

Figure 6. Erosion on left bank of Neosho River just downstream from riprap at Oswego overflow dam. Location of Oswego overflow dam shown in figure 2.

Water Quality and Hydrological extremes

- Both extremely low and extremely high precipitation can have adverse consequences on water quality
- Extreme drought reduces the dilution potential with respect to any impurities in the water supply
- Extreme heavy rainfall can cause heavy sediment accumulation and turbidity in reservoirs

Competing Interests

- Urban versus rural
- Rich versus poor
- Upstream versus downstream
- Other locational tensions – proximity to water resources
- Competing sectoral interests/needs – especially during times of drought and flooding – who faces what adverse impact?

Allocation Schemes

- Some examples include:
  - Prior use/historical
  - Egalitarian
  - property ownership
- Sectoral allocations are often made by government and/or water management officials
- Power asymmetries within and across sectors
- Who makes prioritization decisions?

Domestic River Basin Management

- Agricultural, industrial (including power generation), domestic, ecological needs
- Some tensions can arise between states on upstream versus downstream or prior use versus adaptive management lines
- Tennessee Valley Authority
- http://www.tva.gov

Transnational River Basin Management

- Issues of federal sovereignty
- Agricultural, domestic and industrial needs
- Ecological needs
- International Commission on the Protection of the Danube River
- https://www.icpdr.org/main/icpdr/about-us
- Downstream/upstream conflicts; Egypt and Ethiopia with regard to Nile River resources
- http://www.bbc.com/news/world-africa-22696623
- How are international water treaties constructed?
- Opportunity for cooperation; Friends of the Earth Middle East (trilateral Israeli, Jordanian and Palestinian collaborative on Jordan River's dwindling supply) http://foeme.org/www/?module=home
- Niger Basin Authority - http://www.abn.ne

Class activity

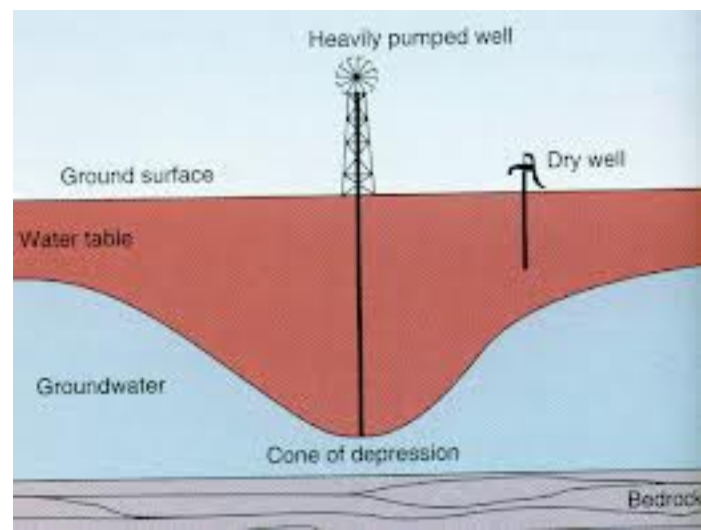
- A river system in the low latitudes has three reservoirs with specified volumes
- There are two major cities – one at the mouth (population 2 million) and one at a major confluence (population 1 million) and the rest of the watershed is peri-urban to rural with a total combined watershed population of 5 million
- Allocations have been 65% agriculture, 20% domestic, 15% industrial
- Respond to specific climate forecasts and changes

Water Privatization

- much of the water consumed around the world is available in the public domain
- But in some instances, there is a concerted effort to privatize water
- This often has the effect of benefiting multinational corporate elites at the expense of poor citizens
- Cochabamba water riots in Bolivia
- Blue Gold
- https://www.youtube.com/watch?v=B1a3tjqQiBI

Groundwater Storage and Groundwater Mining

- In many arid to semi-arid regions with limited natural surface water resources, a great deal of the water resources used are from the ground
- While groundwater resources are vast, intensity of use often exceeds natural replenishment making it effectively a mined resource
- Compaction and ground settling
- Cone of depression
- This being said, if used responsibly, groundwater can be a good supplemental water resource



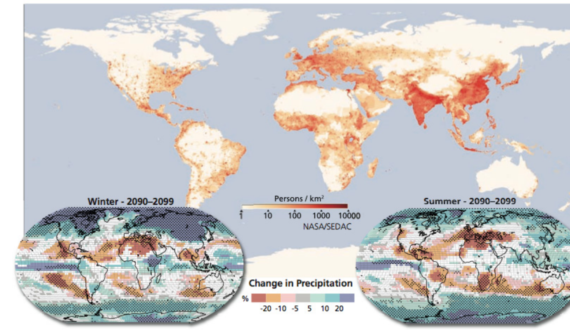
Land Cover and surface runoff

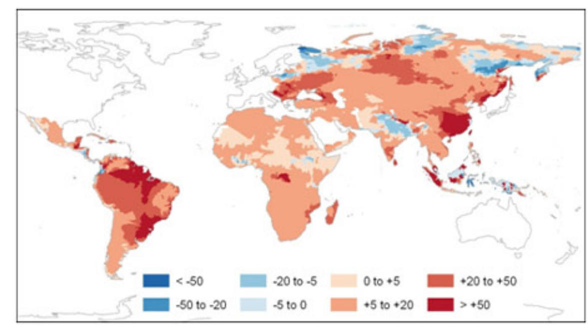
- Different types of land surface have different characteristics with regard to infiltration
- Built environments and heavily denuded field environments tend to cause a lot of runoff
- Natural forest or grassland cover with deep soil tends to lead to more infiltration, more reliable groundwater resources

Intensive gully erosion in grassland

Projected Changes to the Hydrological Cycle: Implications for Water Supply

- Water supply most effected by hydrological drought and total basin rainfall (in the case of flooding)
- Intensification of hydrologic cycle arguably poses greater risks for both water deficit and reservoir overtopping/structural failure/flooding
- Loss of snowcover will reduce spring inflows and make summers more prone to drought
- Projected changes to hydrological cycle are highly geographically differentiated
- Complex, nonlinear interactions between rainfall and actual surface water levels effected by
  - human activity,
  - land surface and runoff characteristics,
  - intensity, timing and duration of storms,
  - upstream water budget
  - groundwater flow





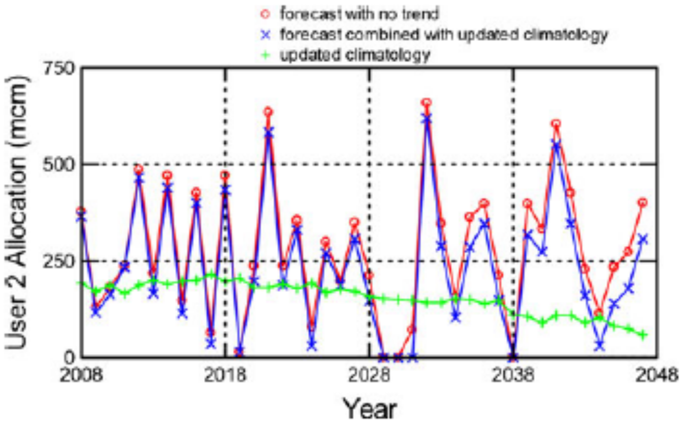
World Bank projected changes to water deficit index

Case Study of Western US – climatology changing

- The American West (particularly Southwest) has been facing a significant drought for most of the 21st century
- Paleoclimate records indicate that the region may have a tendency towards decadal or multidecadal scale "megadrought" and that we may be in such a phase now
- Many of the water rights and much of the development (especially in places like Las Vegas and Phoenix) were formulated on the basis of historical hydroclimatology (in the 20th century)

Adaptive and Maladaptive Management

- Assumption of stationarity is often predominant
  - Assumption that the mean, variability and shape of the streamflow and rainfall distributions are relatively temporally invariant
  - it's the way it's always been done; bureaucratic inertia
- More adaptive assumption would be that statistics are nonstationary
  - would require an acknowledgement of climate change, but would also require choice of particular models of change and justification for choice
  - can be more politically/professionally costly
  - greater potential for extremes can induce more strain on the infrastructure even if the best science is used in the management decisions



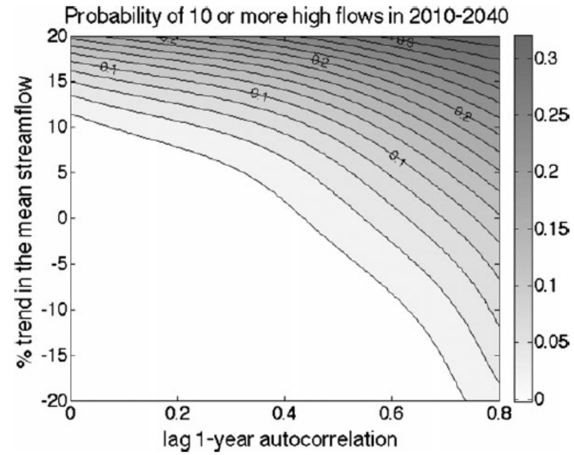
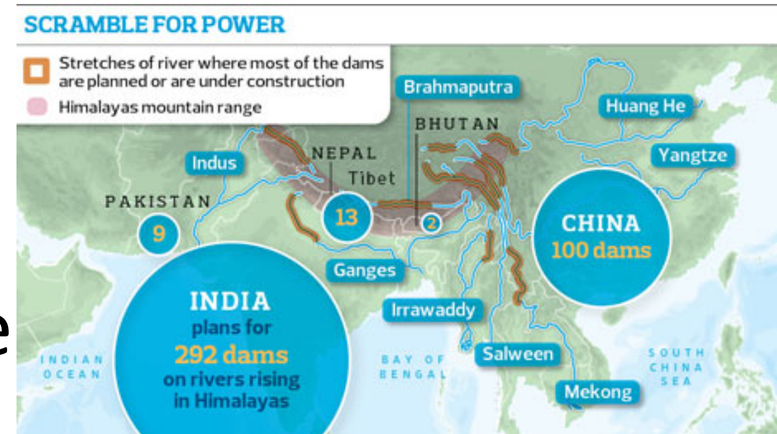
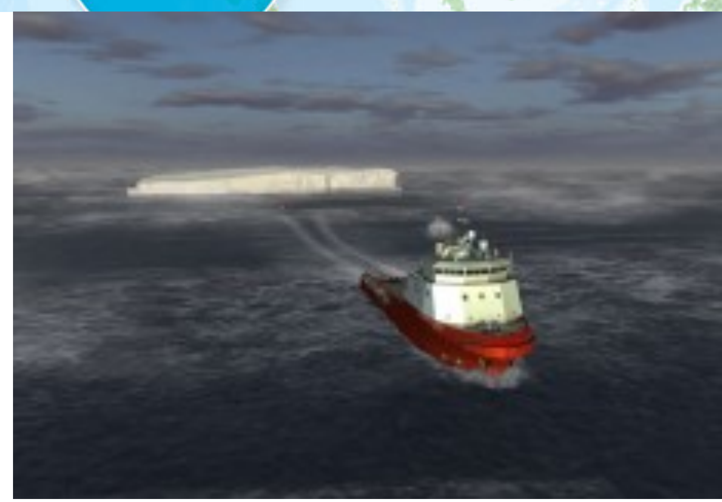


Figure 11(a). Probability of 10 or more threshold crossing high flows in 2010–2040 with specified trends in mean streamflow (*y*-axis) and autoregression coefficient for the MDV in the streamflow (*x*-axis). These results are for Koulikoro/Niamey.

Extreme adaptation measures

- Large scale dams and diversions
- Long distance interbasin transfer – building large scale infrastructure to transport water from one watershed to another
- Towing an iceberg to drought stricken region?



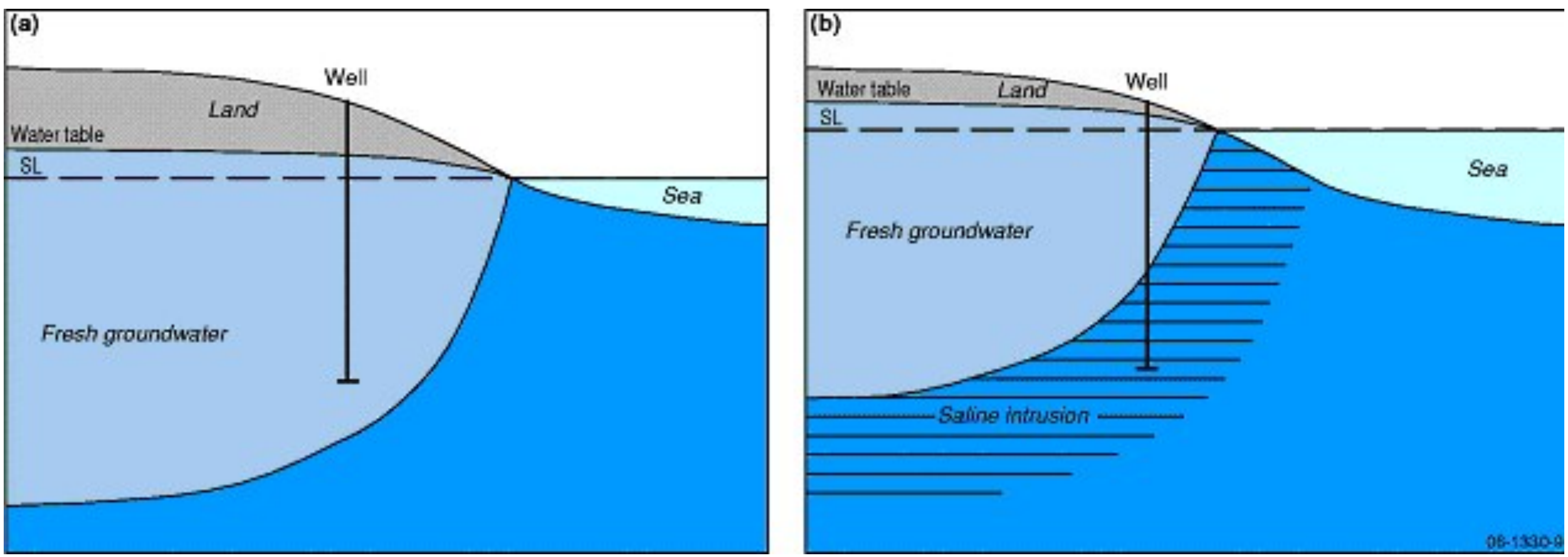


Wastewater treatment, recycling and reclamation

- Through multiple stages of evaporation/condensation and filtration, much of the crud in wastewater can be removed
- Very politically socially controversial because of the "yuck" factor
- Can be expensive and require a lot of energy depending on how polluted the water is

Saline intrusion

- In aquifers near the ocean, higher sea levels can bring salty water into what was formerly fresh water supply and can significantly limit freshwater supplies in such regions
- Significant and soon to be growing problem, especially in tropical low lying areas



Desalination

- On a very small scale, can be done with minimal energy inputs and a simple solar still (can be sustainable)
- Passive solar desalination is a very slow process with low efficiency and limited yield of freshwater
- On an industrial scale, the process is often expensive and very energy intensive (often contributing more to climate change)
- Nevertheless, for arid coastal regions with a reasonably large amount of capital (California, Saudi Arabia, etc.), large scale desalination may be very beneficial

Simple, portable water cone

Reverse osmosis desal plant