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ROLE OF WATERBORNE PATHOGENS IN THE FOOD SUPPLY CHAIN: IMPLICATIONS TO RISK MANAGEMENT WITH LOCAL AND GLOBAL PERSPECTIVES

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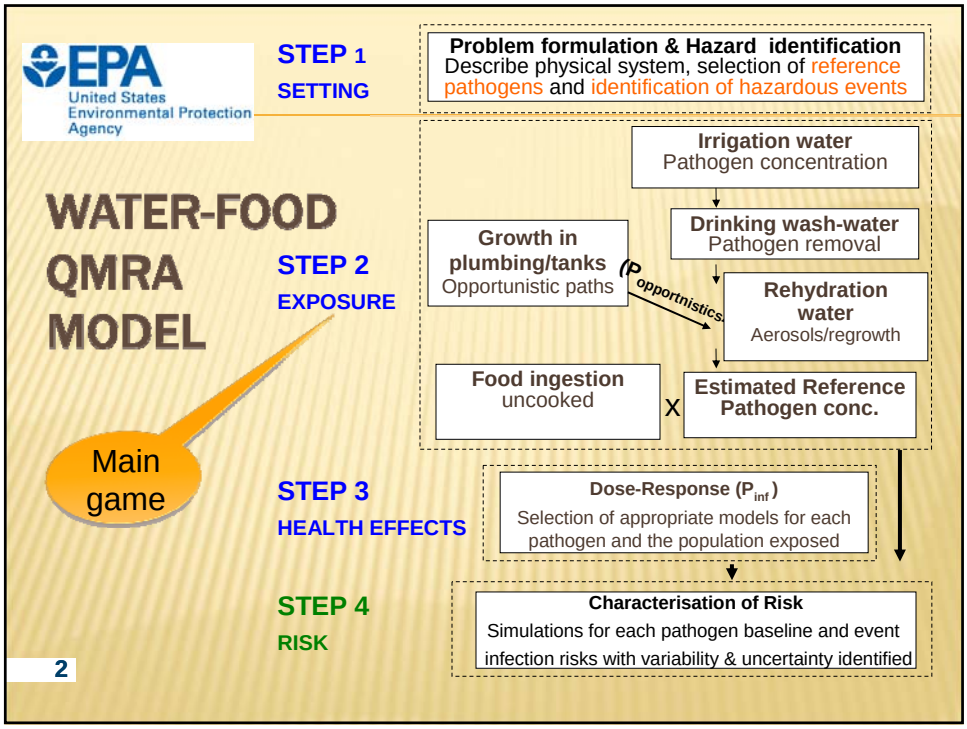
BACKGROUND

- *Microbial risk assessment (MRA) in the food industry is used to support HACCP – which largely focuses on bacterial pathogen control in processing foodstuffs*
- *Potential role of microbially-contaminated water used in food production is not as well understood*
- *Emergence of Quantitative MRA as a tool for assessing & informing waterborne pathogen risks internationally*
  - *WHO: water safety plans (2004), wastewater reuse (2006)*
- *Primary point of this paper is to highlight potential risks from water in food production*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WATER-FOOD QMRA MODEL
Main game
STEP 1
SETTING
Problem formulation & Hazard identification
Describe physical system, selection of reference pathogens and identification of hazardous events
STEP 2
EXPOSURE
Irrigation water
Pathogen concentration
Drinking wash-water
Pathogen removal
Growth in plumbing/tanks
Opportunistic paths
(P opportnistics)
Rehydration water
Aerosols/regrowth
Food ingestion
uncooked
X
Estimated Reference Pathogen conc.
STEP 3
HEALTH EFFECTS
Dose-Response (P inf)
Selection of appropriate models for each pathogen and the population exposed
STEP 4
RISK
Characterisation of Risk
Simulations for each pathogen baseline and event infection risks with variability & uncertainty identified
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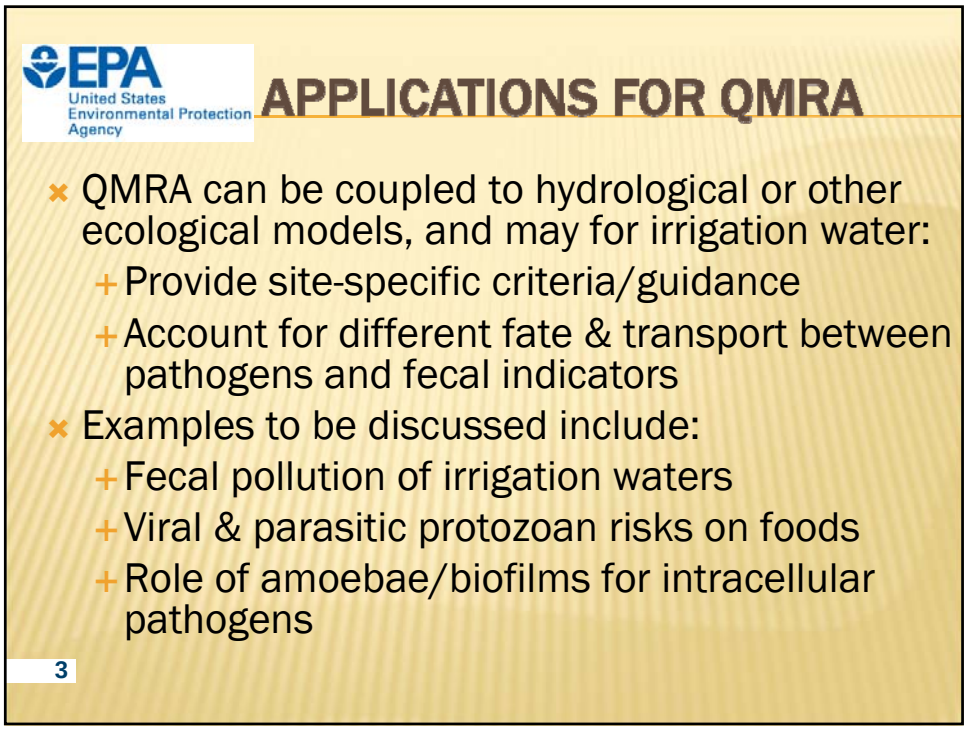
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APPLICATIONS FOR QMRA
QMRA can be coupled to hydrological or other ecological models, and may for irrigation water:
Provide site-specific criteria/guidance
Account for different fate & transport between pathogens and fecal indicators
Examples to be discussed include:
Fecal pollution of irrigation waters
Viral & parasitic protozoan risks on foods
Role of amoebae/biofilms for intracellular pathogens
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IRRIGATION PATHOGENS

- Hazardous events need to be assessed
  - Rain-induced pathogen run-off
  - Septic seepage to river waters
  - Waterfowl aggregation

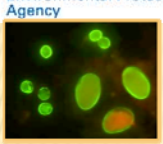
- Inadequacy of fecal indicators
  - Viral and parasitic protozoa present when < 1 *E. coli* per 100 mL drinking water
  - How protective is <35 enterococci / 100 mL recreational water for irrigation purposes?
    - Use of *Bacteroidales* microbial source tracking

EPIDEMIOLOGIC EVIDENCE: ENTERIC VIRUSES

- Recent epidemiological evidence indicates that enteric viruses, in particular noroviruses (but also hepatitis A virus & rotavirus [bovine too]), are the leading cause of foodborne illness
  - E.g. viruses implicated in U.S. foodborne diseases increased from 4.7% in 1997 to 52% in 2004
    - Mostly due to increased virus analyses/understanding

Butot *et al*. (2007) Appl. Environ. Microbiol. 73:186–192
Vega *et al*. (2008) J. Fd Prot. 71:522-9

EPIDEMIOLOGIC EVIDENCE: PARASITIC PROTOZOA



- A number of *Cyclospora, Cryptosporidium, Giardia* & *Toxoplasma* outbreaks from fresh berries from central America and also dairy products generally

Rose & Slifko (1999) *Giardia, Cryptosporidium, and Cyclospora and their impact on foods: A review. J. Fd Prot. 62:1059-1070*
Smith & Nichols (2006) Zoonotic protozoa - food for thought. Parasitologia 48:101-4.

EPIDEMIOLOGIC EVIDENCE: AMOEBA/BIOFILM PATHOGENS

- Presence of amoebae on leafy vegetables & biofilms and their sequestration of enteric bacteria in vesicles indicate that they may play an important role in the ecology of human pathogens (*E. coli* O157, *Salmonella, Listeria…*) on produce

Gourabathini *et al*. (2008) Interactions between food-borne pathogens and protozoa isolated from lettuce and spinach. Appl. Environ. Microbiol. 74:2518-25

RISK-BASED APPROACH

- Australian Drinking Water Guidelines – HACCP-like
  - As in the UK, largely directed to control *Cryptosporidium*
- World Health Organization - Guidelines for drinking water quality, 3rd edition, September 2004
  - New approach based on risk assessment / risk management
  - Tools: Water Safety Plan, Quantitative Microbial Risk Assessm
- ISO 22000 standard, October 2005
  - Possibility to certify water safety plans
- European Union / WHO working group, May 2006 – March 2
  - Develop a harmonized regulatory framework for WSP
  - Introduction expected in the European legislation in 2009-2010

• Implementation of WSPs now in many water companies

•Some ISO 22000 certificates delivered

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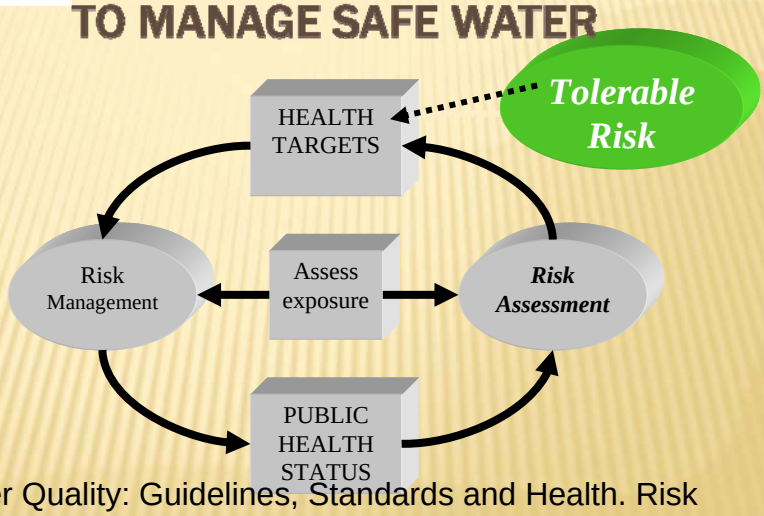
WHO RISK-BASED FRAMEWORK TO MANAGE SAFE WATER



Water Quality: Guidelines, Standards and Health. Risk Assessment and Management for Water Related Infectious Diseases. IWA Publishing, London (WHO website)

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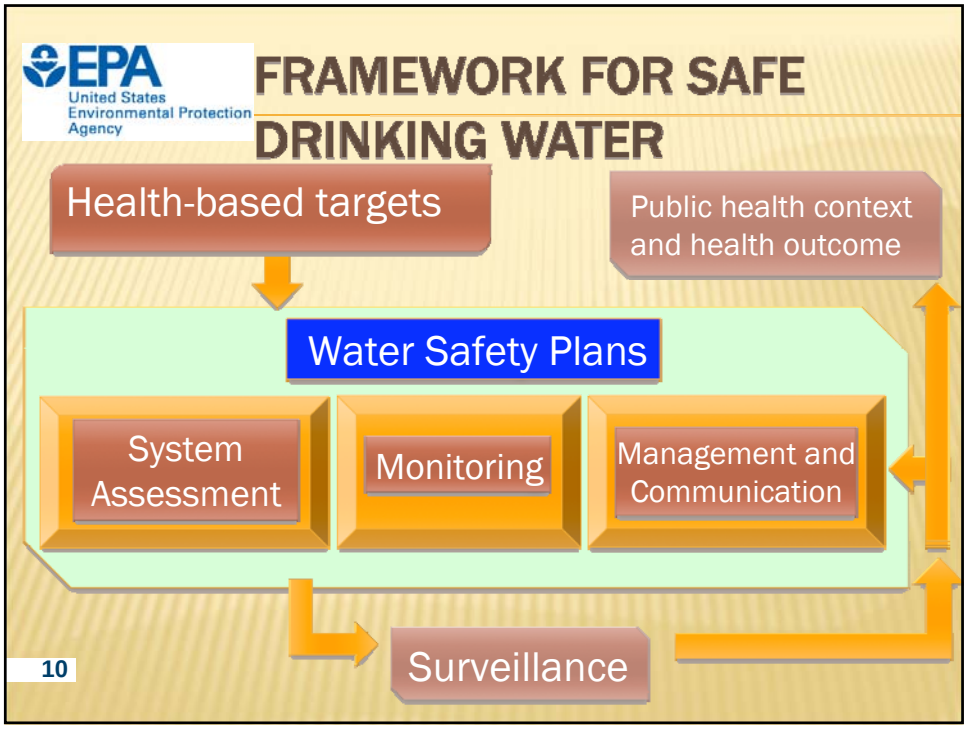
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FRAMEWORK FOR SAFE DRINKING WATER
Health-based targets
Public health context and health outcome
Water Safety Plans
System Assessment
Monitoring
Management and Communication
Surveillance
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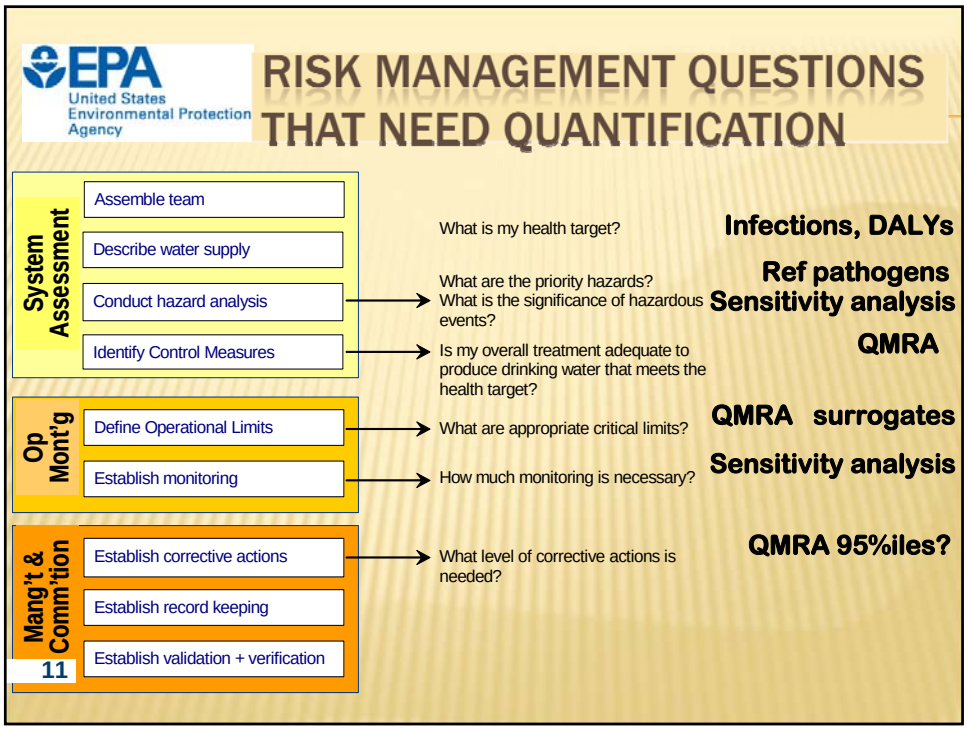
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RISK MANAGEMENT QUESTIONS THAT NEED QUANTIFICATION
System Assessment
Assemble team
Describe water supply
Conduct hazard analysis
Identify Control Measures
Op Mont'g
Define Operational Limits
Establish monitoring
Mang't & Comm'tion
Establish corrective actions
Establish record keeping
Establish validation + verification
What is my health target?
Infections, DALYs
What are the priority hazards?
What is the significance of hazardous events?
Ref pathogens
Sensitivity analysis
Is my overall treatment adequate to produce drinking water that meets the health target?
QMRA
What are appropriate critical limits?
QMRA surrogates
How much monitoring is necessary?
Sensitivity analysis
What level of corrective actions is needed?
QMRA 95%iles?
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MONITORING REQUIRED TO VERIFY AT THE 95% CONFIDENCE LEVEL THAT FAILURE EVENTS DO NOT SIGNIFICANTLY ADD TO RISK

Nominal $\log_{10}$ reduction	#/year	Monitoring interval
0.05	1	1 year
1	30	1 week
2	300	1 day
3	3,000	3 hours
4	30,000	15 min
5	300,000	2 min
6	3,000,000	10 sec
7	30,000,000	1 sec

i.e. a 100,000 m^3/d plant treatment designed for 4 log inactivation of viruses, must monitored every 3000 liters to be 95% confident that all water was sufficiently treated

Smeets (2008)

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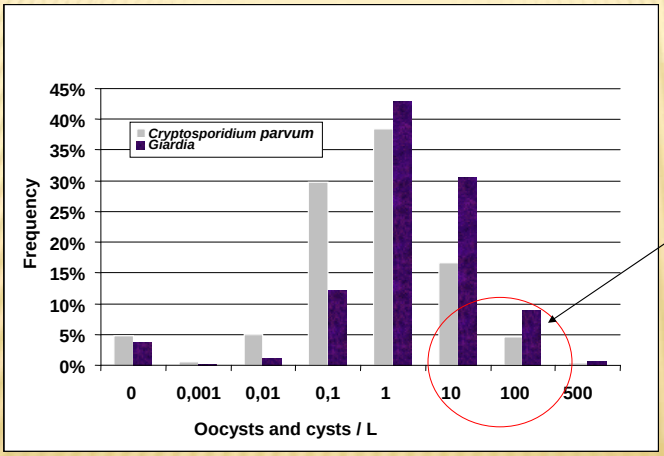
WATER SAFETY PLAN PATHOGEN (HAZARD) RESEARCH

E. COLI O157:H7 (RAIN & MANURE ? AMOEBAE)

- From 1995–2006, 22 produce outbreaks were documented in the US, with nearly half traced to lettuce or spinach grown in California
- Rain events in the Salinas and San Juan valleys CA, reported to transport EHEC up to 32 km
- *E. coli* O157 isolated from carrots 168 days after application of contaminated manure

Cooley *et al*. (2007) Incidence and tracking of *Escherichia coli O157:H7 in a major produce production region in California. PLoS ONE 2:e1159*

RESEARCH TO IDENTIFY VARIABILITY OF SOURCE WATER CONTAMINATION

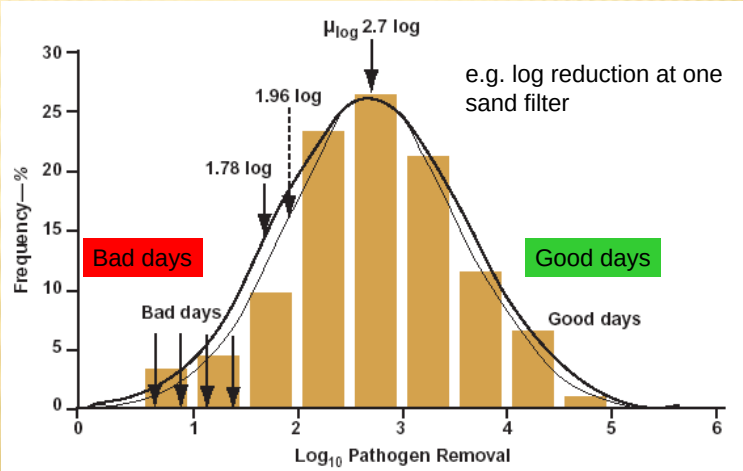


> 100 times the average conc., 5-10% of the time

Ex.: *Cryptosporidium* and *Giardia* in the Seine water (1991 – 2005)

www.MicroRisk.com

RESEARCH TO ID BY-PASSES IN TREATMENT
(E.G. PARTICLE COUNT SURROGATE)



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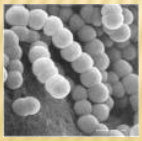
Gale (2002) JAWWA **94**(9):30-38

WSP MONITORING

- Validation monitoring
  - Challenge testing
  - Operational parameters
- Verification monitoring
  - 30-day providing period
  - Operational monitoring



Phage surrogate

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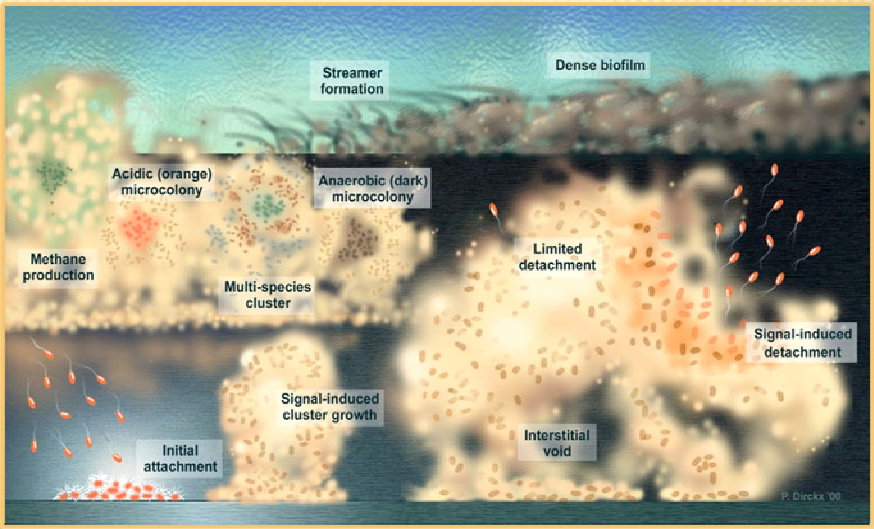
Clostridium perfringens spore surrogates

EXAMPLE OPERATIONAL/ CRITICAL LIMITS

Operational and critical limits allowing to meet (>95%) an objective of 1 case of infection / 10 000 consumers . Year

CCP	Operational Limits	Critical limits	Conditions
Clarification	T < 0.2 NTU 95% T < 0.5 NTU 100%	T < 1 NTU	
Ozonation	0.15<O_3< 0.5 95% 0.05<O_3<1 100%	O_3 <0.05 (<35days)	O_3 >0.15 mg/L
Chlorination	0.2<Cl_2<0.5 95% 0.05<Cl_2<0.8 100%	Cl_2 < 0.05 mg/L	NTU < 0.2 Cl_2 > 0.20 mg/L

NEED TO UNDERSTAND (SURFACE) BIOFILM ECOLOGY



ROLE OF FREE-LIVING AMOEBAE IN PIPE BIOFILMS

- Still (last 28 years) controversial whether *L. pneumophila* can just persist or indeed competitively grows in piped water biofilms without amoebae
- Up to 40% of various hospital water and dental system biofilms positive for *Acanthamoeba* spp. & other (host) general
- Many intracellular pathogens grow in biofilms

CONCLUSIONS

- Uses of water in the food production chain provides a number of ways for microbial contamination – currently under-recognized
  - Enteric viruses and parasitic protozoa poorly addressed by traditional fecal indicators and are under-rated foodborne pathogens via water
  - Water-biofilm food interface becoming more recognized as important for the development of intracellular bacterial pathogens via amoebae
    - And sig. reduce disinfection efficacy

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- U.S. EPA
  - Dr. Schoen, John Ravenscroft (Dr. Soller)

Views expressed are not necessarily those of the U.S. EPA

Impact Level	Source	Dry Weather/ Baseline	Baseline Event- Small Event	Large Event - Extreme Event
Low - protected catchment	Large Reservoir	Very Low [0]*	Low [1]	Moderate [3-4]
	Small Reservoir	Low [0]	Moderate [2-3]	High [5]
	River/ Stream	Low [2-3]	Moderate-High [3-4]	High [5]
Moderate-partly impacted catchment	Large Reservoir	Low [1]	Moderate-High [2-3]	High [4]
	Small Reservoir	Low [1-2]	High [3-4]	High-Very High [5-6]
	River/ Stream	Moderate [2-3]	High [3-5]	Very High [5-6]
High - heavily impacted catchment	Large Reservoir	Low-Moderate [1-2]	High [2-3]	Very High [5-6]
	Small Reservoir	Moderate [1-2]	Very High [5-6]	Extreme [6-7]
	River/ Stream	High [3-4]	Very High-Extreme [5-6]	Extreme [6-7]

CRC-WQT *[magnitude of effect to fully-protected, 1=10 fold, 2=100 fold etc.]