Groundwater & Sustainable Development

Tools for Predicting Levels of Impact

Angelo Papaioannou

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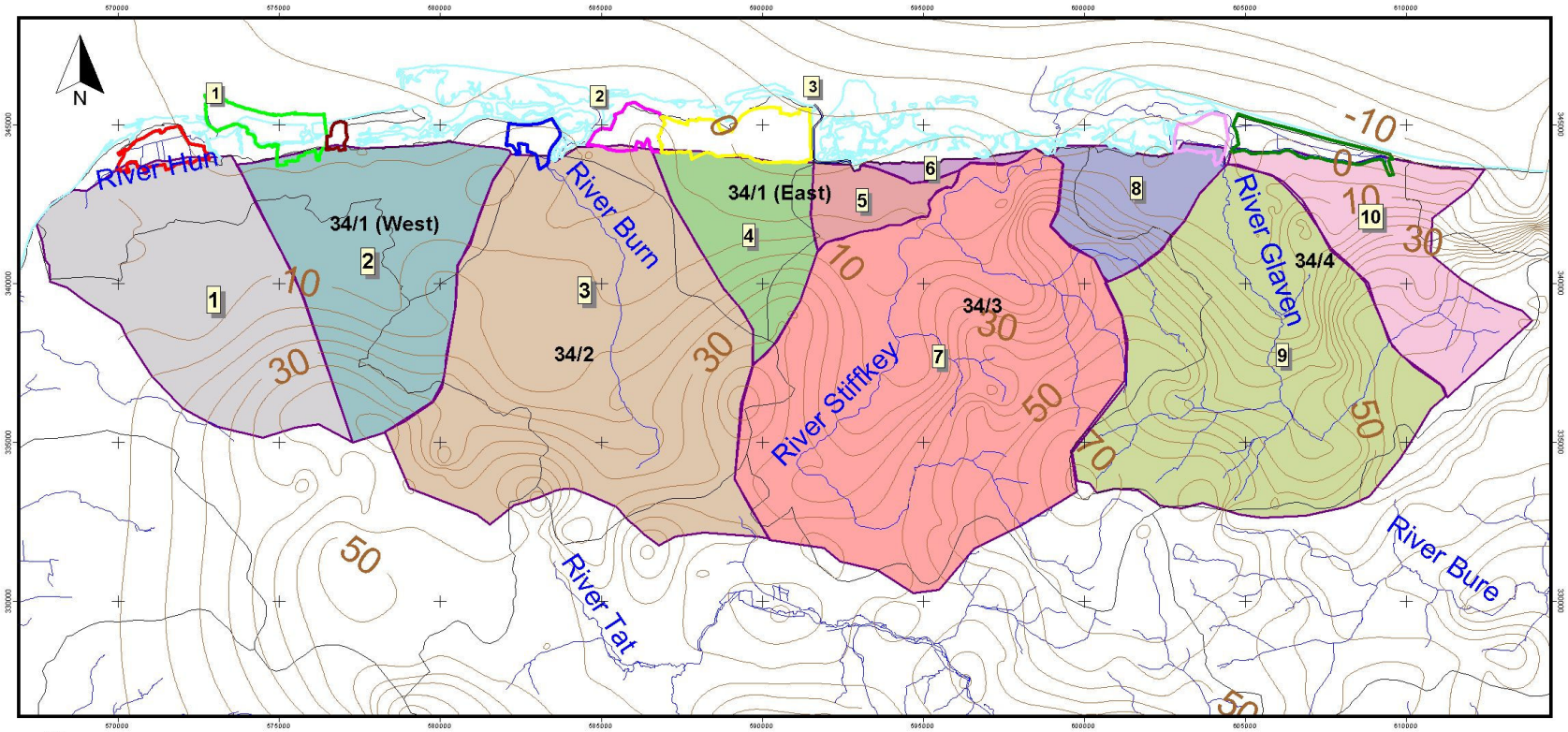


Key:

- Rivers
- 50 GW Level Contours (mAOD)
- Coast line
- Hydrometric Areas (34/1..)

WLMP (and other*) Areas

- Wells West Bank
- Holme
- Cley - Salthouse
- Burnham Overy
- Burnham Norton
- Brancaster
- Blakeney Freshes
- Titchwell Marsh*
- Chalk Groundwater Capture Zones

1 River Hun (Including Holme NNR)
2 Thornham to Deepdale (Marshes)
3 River Burn (including Burnham Noton and Overy)
4 Wells West Bank (including Holkham Marshes)
5 Wells (Harbour and Salt Marshes)
6 Warham to Stiffkey (Salt Marshes)
7 River Stiffkey
8 Morston Marshes and Blakeney Freshes
9 River Glaven
10 Cley - Salthouse Marshes

GW Level Contours & Delineation of Capture Zones

North Norfolk Coast cSAC	Zone 1	2	3	4	5	6	7	8	9	10
Coastal Lagoons	✓			✓						✓
Humid Dune Slacks	✓			✓						
Otter (probably associated predominantly with river channels and drains)	✓?	?	✓?	✓?	?	?	✓?	✓?	✓?	✓?
Petalwort	?			✓?						
Wash and North Norfolk Coast cSAC										
Atlantic Salt Meadows (refers in this table to tidal reedbed)		✓	✓						✓	
Mudflats and Sandflats not covered by seawater at low tide (of relevance because of the possible interaction between freshwater and the benthic invertebrate fauna consumed by birds)	?	?	?	?	?	?	?	✓	✓	
Other Habitats										
Creeks carrying freshwater through saltmarsh	✓	✓	✓?					✓	✓	
Freshwater Reedbed	✓	✓								✓
Freshwater/brackish Grazing Marshes and associated ditches	✓	✓	✓	✓				✓		✓

Zones are as follows and identified in Figure 4.18:

1 River Hun catchment
2 Thornham to Deepdale Marshes
3 River Burn catchment
4 Wells West Bank
5 Wells Harbour and Salt Marshes
6 Warham to Stiffkey Slat Marshes
7 River Stiffkey
8 Morston Salt Marshes and Blakeney Freshes
9 River Glaven
10 Cley-Salthouse Marshes

Distribution of European Features in Relation to Groundwater Capture/Outflow Zones

Zonal Drought Min. Flows & Total Lic. Quantities

Zone/Catchment & Receptor		Tallied Licence Quantities				Estimated Recharge & Drought Outflow Quantities						Exceed Criteria?		Exceed Criteria (>100%)	
GW Capture Zone	Outflow Receptor	(FAQ) Full Annual Qty (Ml/d)	(FDQ) Full Daily Qty (Ml/d)	Selected Annual Qty (Ml/d)	Selected Daily Qty (Ml/d)	Average Recharge (Ml/d)	Aquifer Response Function minimum (Ml/d)	(DM_{BAR}) Mean Annual minimum (Ml/d)	(DM_5) 5 yr drought minimum (Ml/d)	(DM_{10}) 10 yr drought minimum (Ml/d)	(DM_{20}) 20 yr drought minimum (Ml/d)	Full Annual Qty > 20 yr drought minimum	Full Daily Qty > 5 yr drought minimum	100* [FAQ/DM_{20}] (%)	100* [FDQ/DM_5] (%)
Licensed Groundwater Abstractions only															
1	R. Hun (& Holme NNR)	4.87	11.01	4.87	11.01	36.54	21.68	17.08	11.86	8.29	5.14	N	N	94.6	92.8
2	Thonham to Deepdale Marsh	2.87	15.99	2.69	14.39	27.88	15.70	11.21	7.28	4.90	2.54	Y	Y	112.8	219.7
3	R. Burn (& Burnham Norton/Overy)	2.64	13.32	1.16	7.55	53.65	32.81	24.49	16.40	11.09	6.21	N	N	42.5	81.2
4	Wells West Bank	0.11	1.79	0.00	0.00	12.31	8.30	6.58	4.59	3.22	2.02	N	N	5.6	38.9
5	Wells (Harbour & Salt Marsh)	0.01	0.02	0.00	0.00	4.28	1.05	0.54	0.36	0.24	0.14	N	N	6.1	6.4
6	Warham to Stiffkey (Salt Marsh)	0.00	0.00	0.00	0.00	1.24	0.01	0.00	0.00	0.00	0.00	N	N	0.0	0.0
7	R. Stiffkey	10.30	29.44	10.05	27.91	45.41	15.08	8.85	6.28	3.90	2.16	Y	Y	477.5	468.9
8	Morston Marshes & Blakeney Freshes	0.65	4.86	0.44	1.68	6.27	2.85	1.85	1.27	0.81	0.43	Y	Y	150.3	381.7
9	R. Glaven	6.67	19.79	4.98	7.91	31.06	16.72	12.65	9.23	6.50	4.31	Y	Y	154.7	214.4
10	Cley/Salthouse Marshes	0.15	1.32	0.14	1.31	7.36	3.15	1.36	0.97	0.69	0.46	N	Y	32.9	135.8
Licensed Surface Water Abstractions only															
1	R. Hun (& Holme NNR)	0.16	1.76	0.14	1.59	36.54	21.68	17.08	11.86	8.29	5.14	N	N	3.1	14.8
2	Thonham to Deepdale Marsh	0.31	4.83	0.20	1.14	27.88	15.70	11.21	7.28	4.90	2.54	N	N	12.2	66.4
3	R. Burn (& Burnham Norton/Overy)	0.00	0.00	0.00	0.00	53.65	32.81	24.49	16.40	11.09	6.21	N	N	0.0	0.0
4	Wells West Bank	0.11	1.30	0.00	0.00	12.31	8.30	6.58	4.59	3.22	2.02	N	N	5.3	28.3
5	Wells (Harbour & Salt Marsh)	0.33	3.48	0.16	1.23	4.28	1.05	0.54	0.36	0.24	0.14	Y	Y	233.7	962.1
6	Warham to Stiffkey (Salt Marsh)	0.00	0.00	0.00	0.00	1.24	0.01	0.00	0.00	0.00	0.00	N	N	0.0	0.0
7	R. Stiffkey	1.02	5.13	0.38	1.33	45.41	15.08	8.85	6.28	3.90	2.16	N	N	47.1	81.7
8	Morston Marshes & Blakeney Freshes	0.00	0.00	0.00	0.00	6.27	2.85	1.85	1.27	0.81	0.43	N	N	0.0	0.0
9	R. Glaven	1.84	14.11	1.01	4.84	31.06	16.72	12.65	9.23	6.50	4.31	N	Y	42.7	152.8
10	Cley/Salthouse Marshes	0.03	0.87	0.00	0.00	7.36	3.15	1.36	0.97	0.69	0.46	N	N	6.0	89.6
Licensed Surface & Groundwater Abstractions combined															
1	R. Hun (& Holme NNR)	5.02	12.77	5.00	12.60	36.54	21.68	17.08	11.86	8.29	5.14	N	Y	97.7	107.7
2	Thonham to Deepdale Marsh	3.18	20.82	2.89	15.52	27.88	15.70	11.21	7.28	4.90	2.54	Y	Y	125.0	286.0
3	R. Burn (& Burnham Norton/Overy)	2.64	13.32	1.16	7.55	53.65	32.81	24.49	16.40	11.09	6.21	N	N	42.5	81.2
4	Wells West Bank	0.22	3.09	0.00	0.00	12.31	8.30	6.58	4.59	3.22	2.02	N	N	10.9	67.2
5	Wells (Harbour & Salt Marsh)	0.33	3.50	0.16	1.23	4.28	1.05	0.54	0.36	0.24	0.14	Y	Y	239.8	968.5
6	Warham to Stiffkey (Salt Marsh)	0.00	0.00	0.00	0.00	1.24	0.01	0.00	0.00	0.00	0.00	N	N	0.0	0.0
7	R. Stiffkey	11.32	34.57	10.44	29.24	45.41	15.08	8.85	6.28	3.90	2.16	Y	Y	524.6	550.6
8	Morston Marshes & Blakeney Freshes	0.65	4.86	0.44	1.68	6.27	2.85	1.85	1.27	0.81	0.43	Y	Y	150.3	381.7
9	R. Glaven	8.51	33.90	5.99	12.75	31.06	16.72	12.65	9.23	6.50	4.31	Y	Y	197.4	367.2
10	Cley/Salthouse Marshes	0.18	2.20	0.14	1.31	7.36	3.15	1.36	0.97	0.69	0.46	N	Y	38.9	225.4

Potential Risks and Level of Confidence in the Assessment

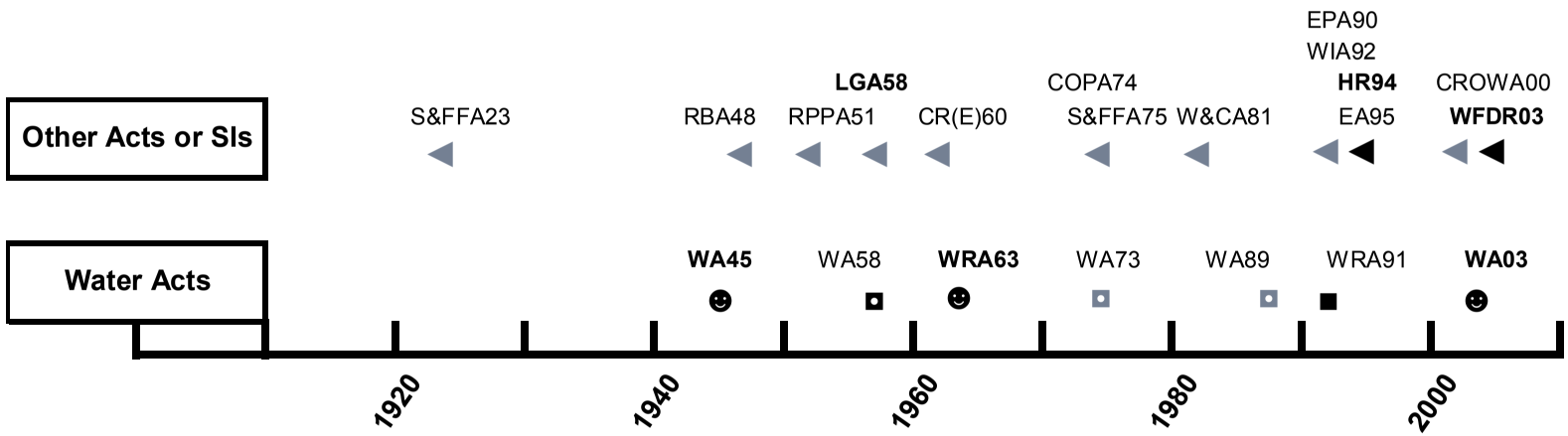
Source of Risk	Potential Risk to European Features	Level of Confidence
Environment Agency Water Resources Consents		
Zone 1	**Hun (including Holme NNR)**	
GW Abstractions	Low	Low
SW Abstractions	Negligible	Medium
All Abstractions	Low	Low
Zone 2	**Thornham to Deepdale Marshes**	
GW Abstractions	Medium	Low
SW Abstractions	Very Low	Medium
All Abstractions	Medium	Low
Zone 3	**Burn (including Bunham Norton & Overy)**	
GW Abstractions	Low	Medium
SW Abstractions	Negligible	High
All Abstractions	Low	Medium
Zone 4	**Wells West Bank**	
GW Abstractions	Negligible	Low
SW Abstractions	Negligible	Low
All Abstractions	Very low	Low
Zone 5	**Wells Harbour & Salt Marsh**	
GW Abstractions	Low	Low
SW Abstractions	Medium	Low
All Abstractions	Medium	Low
Zone 6	**Warham to Stiffkey Salt Marshes**	
GW Abstractions	Negligible	Medium
SW Abstractions	Negligible	High
All Abstractions	Negligible	Medium
Zone 7	**Stiffkey Estuary**	
GW Abstractions	Low/Medium	Low
SW Abstractions	Low	Low
All Abstractions	High	Low
Zone 8	**Morston Salt Marsh & Blakeney Freshes**	
GW Abstractions	Low	Medium
SW Abstractions	Low	Low – Medium
All Abstractions	Low -Medium	Medium
Zone 9	**Glaven Estuary**	
GW Abstractions	Medium	Low
SW Abstractions	Low	Low
All Abstractions	High	Low
Zone 10	**Cley/Salthouse Marshes**	
GW Abstractions	Low - Medium	Low - Medium
SW Abstractions	Very low	High
All Abstractions	Low - Medium	Low - Medium

Conclusion of Stage 2 for the NNC site

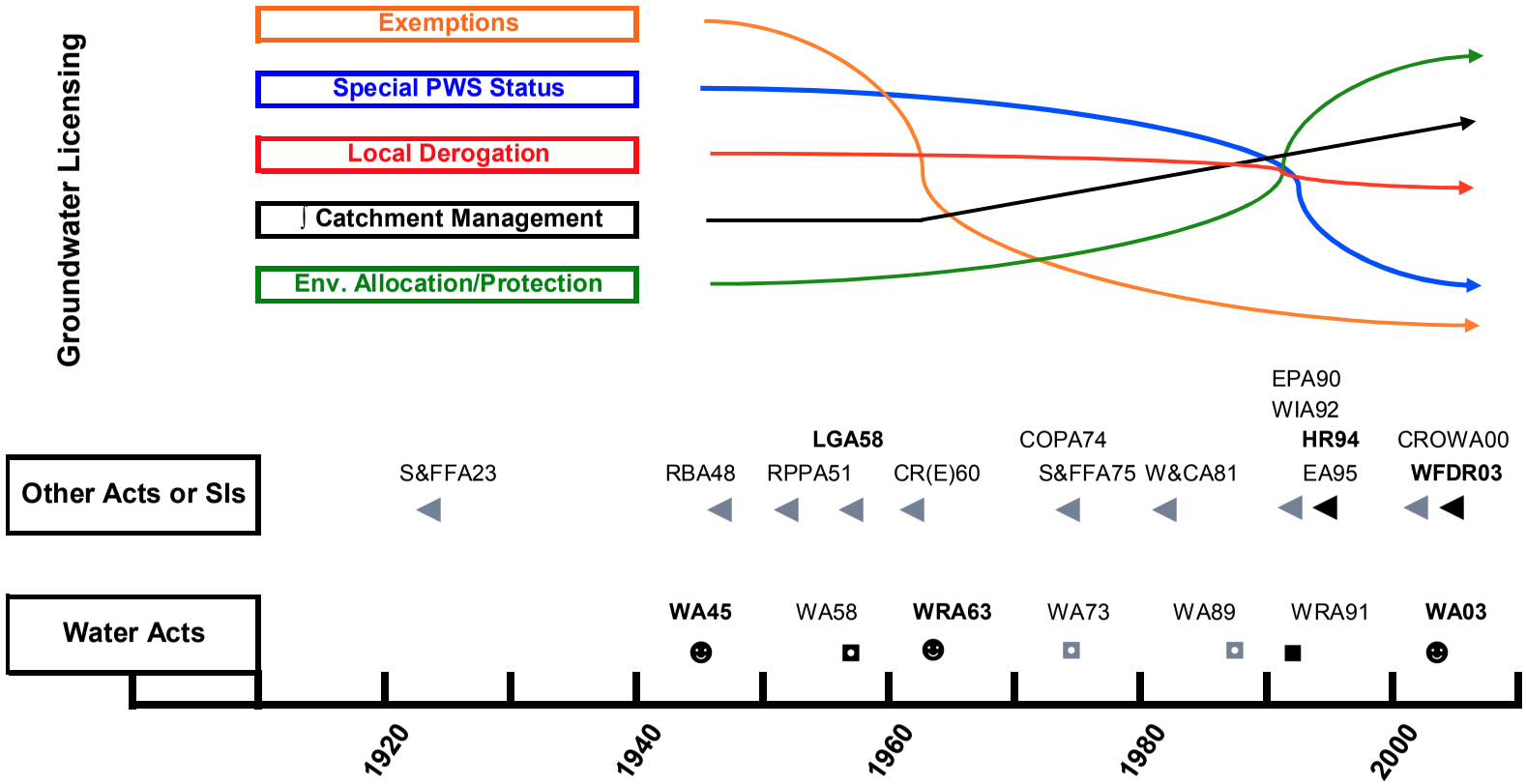
- The whole site will progress to Stage 3 (Appropriate Assessment)
- For the two Zones considered to be at Very Low (or lesser) Risk no further assessment is required. This includes:
  - Zone 4 (Wells West Bank (part of Holkham NNR))
    Due to insignificant levels of abstraction.
  - Zone 6 (Wareham to Stiffkey Salt Marshes)
    Due to the absence of any significant freshwater pathway.
- For all other Zones, at Low (or higher) Risk, within the site Stage 3 entails more Investigations and Assessments

Coverage

Key Legislative Drivers in England & Wales



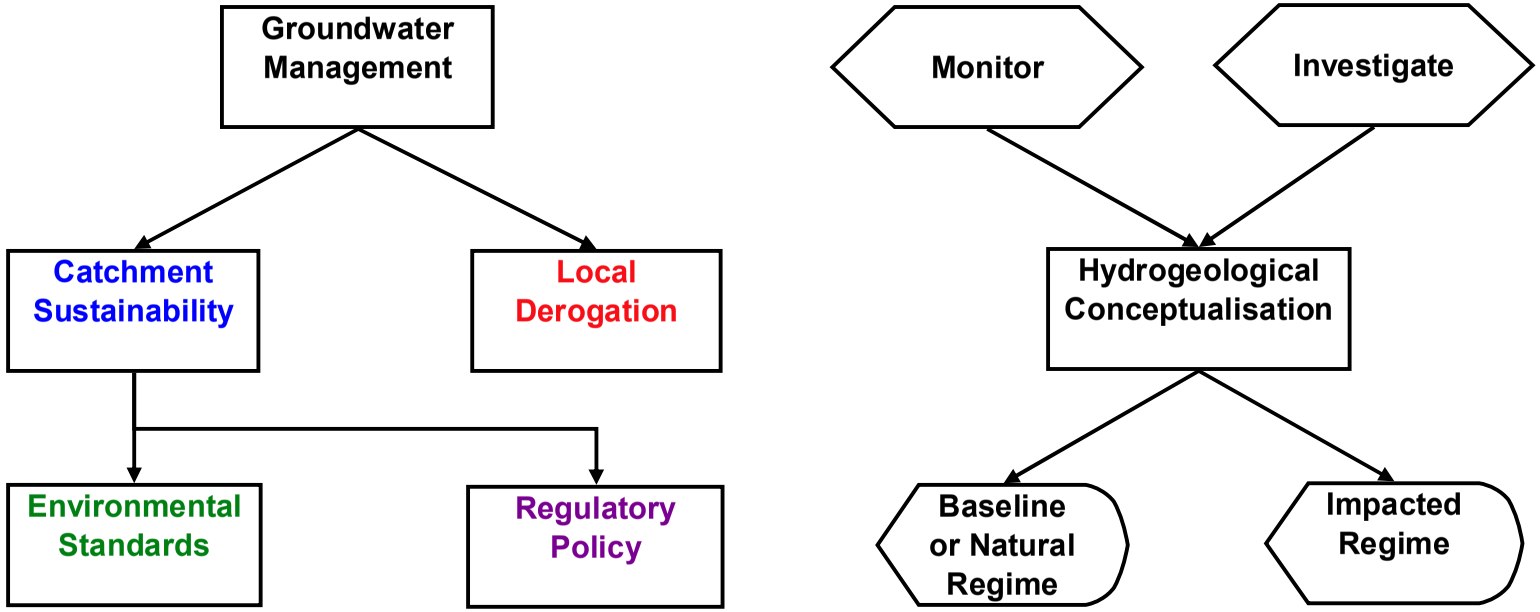
GW Licensing/Management Trends in E & W



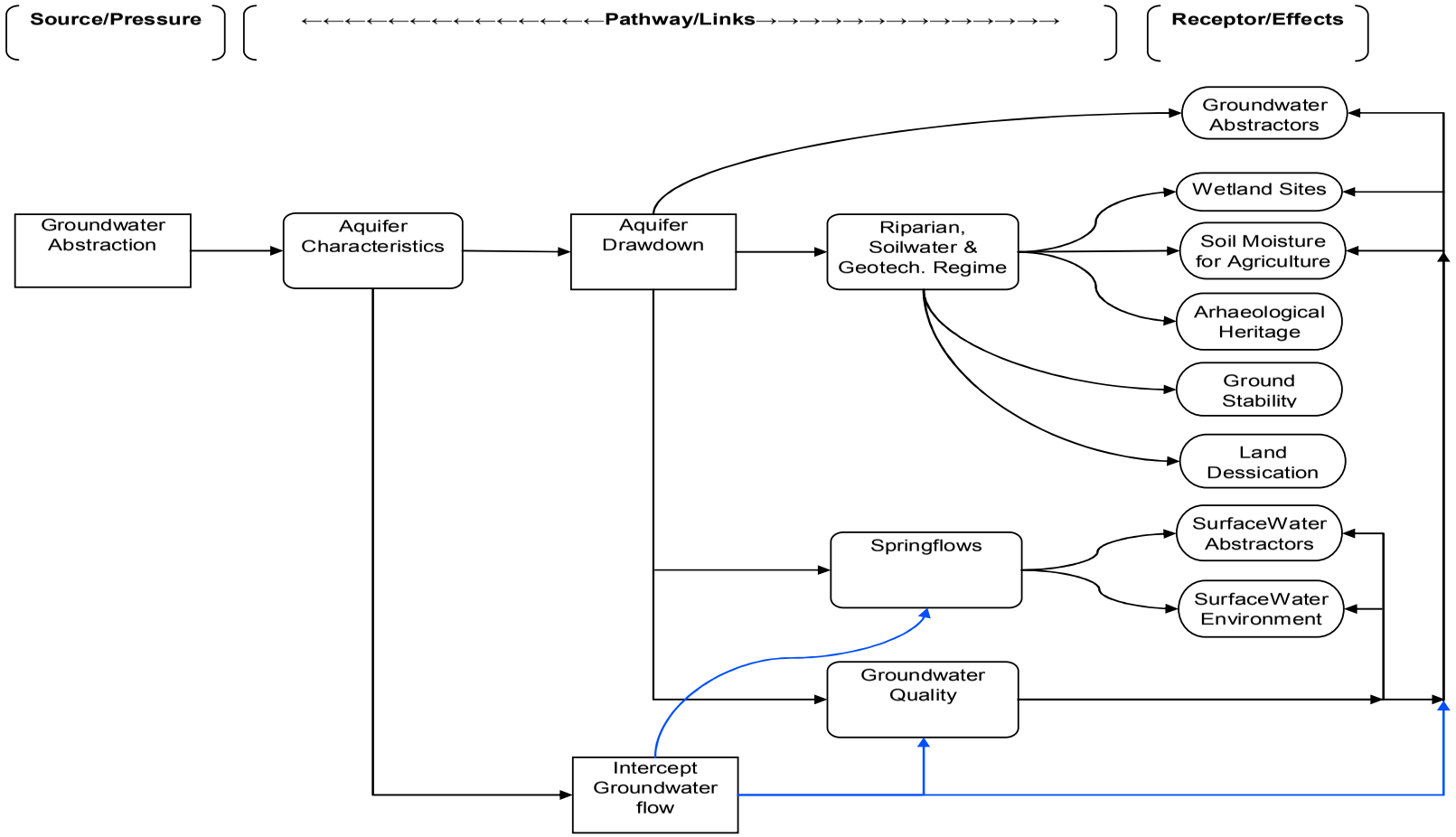
Groundwater Licensing in Scotland

1. Restricted to few selective & significantly aquifers prior to WEWS/CAR.
2. Water Environment & Water Services (Scotland) Act – 2003 (WEWS) *primary legislation enactment for the Water Framework Directive.*
3. Water Environment (Controlled Activities) (Scotland) Regs. – 2005 (CAR) *CAR (along with 2007 Amendment) now includes water environment activities including Groundwater Abstractions which came in to effect in April 2006.*
4. Includes General Binding Rules plus 3 Tiers of Licensing (two of which extended to drilling & testing phases of new abstraction development).
5. SEPA/SNIFFER have developed extensive guidance (some still ongoing) for groundwater investigation & management and some are referred to later.

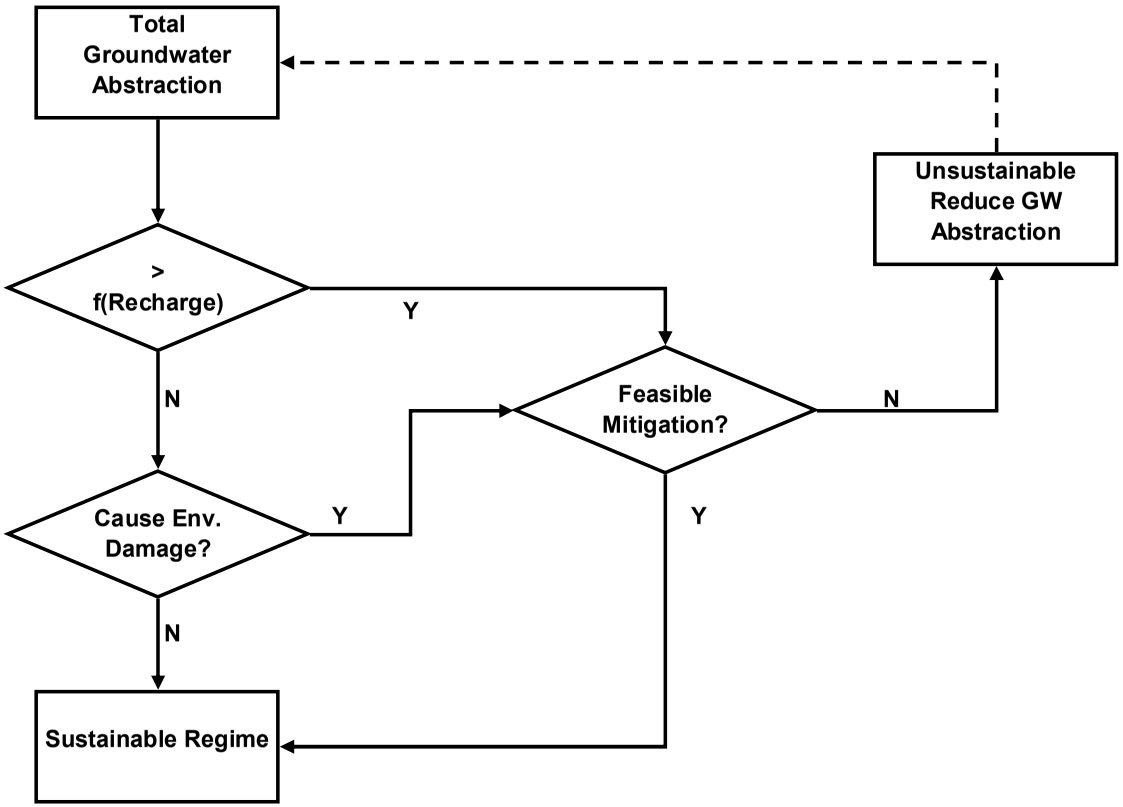
Groundwater Quantity Management



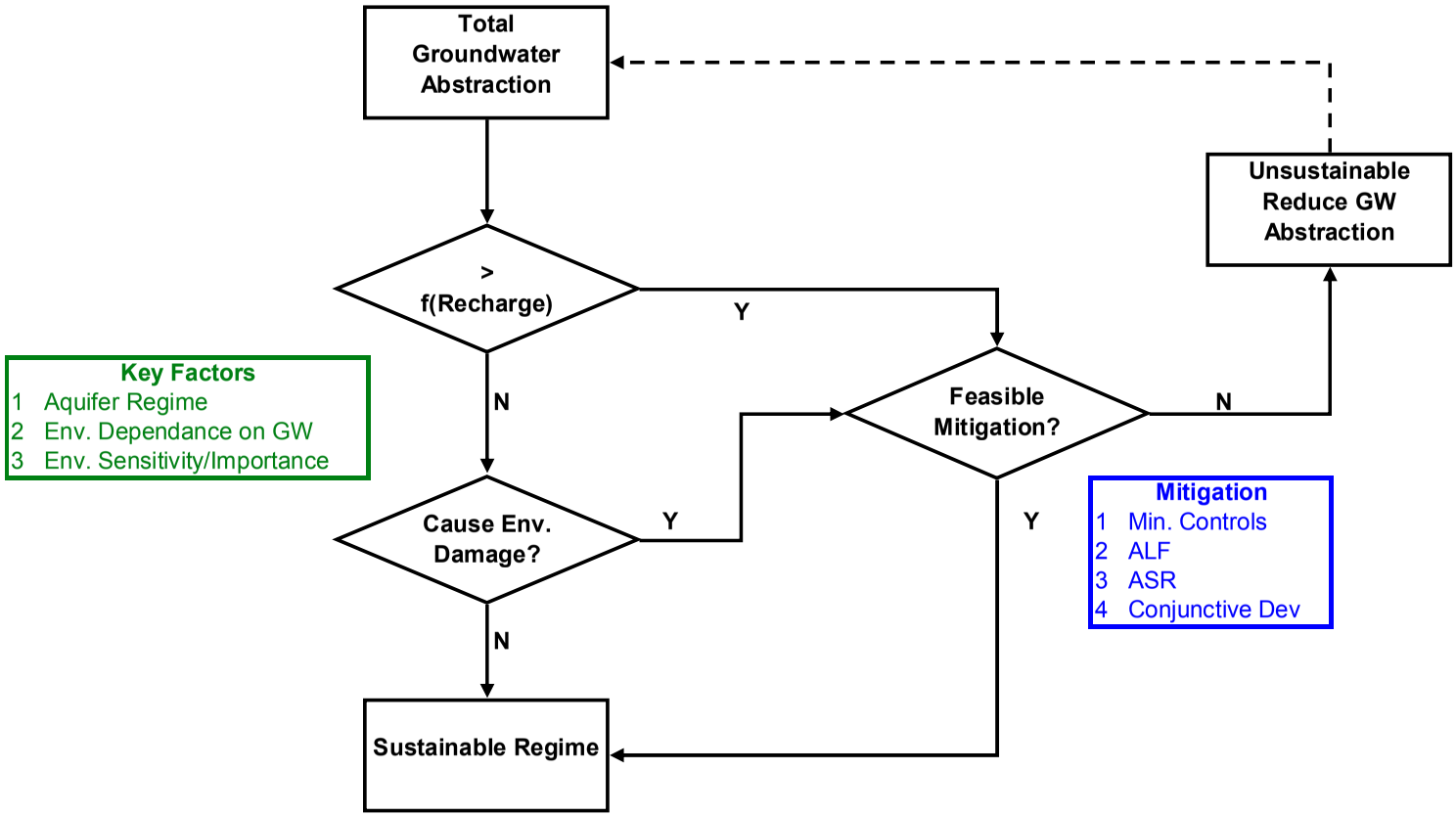
S-P-R Local Derogation Conceptualisation



Sustainable GW Abstraction Regime



Sustainable GW Abstraction Management



Predicting Impacts & Sustainable Yield

1. **Simple Approaches**
   - ➢ Recharge Estimation
   - ➢ Water Balance Assessments
   - ➢ Analytical Drawdown Estimation
   - ➢ Estimating Stream-flow Reduction
2. **Catchment Based Analytical Assessments**
   - ➢ GW Resource Sustainable Yield/Management
   - ➢ EA Resource Assessment & Management (RAM) Framework
3. **Distributed Groundwater Modelling**

Simple/Analytical Approaches

1. **Recharge Estimation/Routing**
   - MOSES/MORECS (+ routing factors)
   - EA R&D Technical Report W6-057/TR
   - http://www.sniffer.org.uk/results.asp (see WFD12 & WFD31)
   - Rainfall routing to runoff and recharge for regional groundwater resource models QJEGH 37, 113 – 130
2. **Water Balance Assessments**
   - EA RAM Framework (R&D W6-066M)
3. **Analytical Drawdown Estimation**
   a. **Borehole/Well Abstractions**
      - EA Science Report SC040020/SR2
      - Aquifer Win32 User Manual (ESI)

   b. **Dewatering Abstractions**
      - EA Science Report SC040020/SR1
4. **Estimating Stream-flow Reduction**
   - EA (R&D W6-046M) *IGARF2*

   $Q_{minBF} = R * f(S_Y * L_E^{**2} / T_E)$
5. **GW Resource Sustainable Yield/Management**
   - EA (R&D W6/i544/7) *SPRW6-I544-7-E-E*
   - JoH – Vol 202 (1997), The Use of Aquifer Response Rate in the Assessment of GW Resources
   - http://www.sniffer.org.uk/results.asp (see WFD53)
6. **EA Resource Assessment & Management (RAM) Framework**
   - EA RAM Framework (R&D W6-066M)
   - http://www.sniffer.org.uk/results.asp (see WFD48 which draws upon the RAM framework as a key WFD indicator)

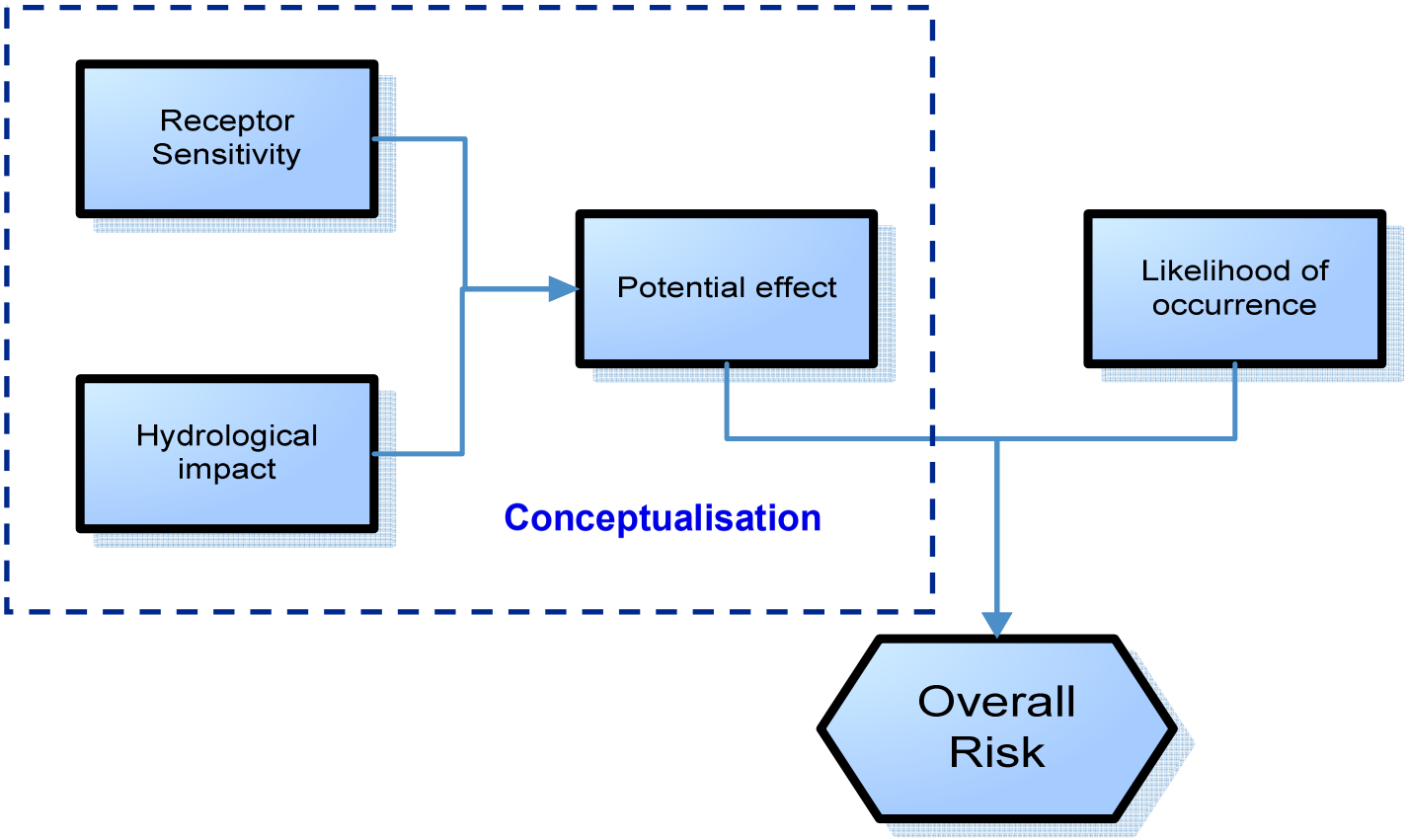
Distributed Groundwater Modelling

1. **Generic**
   - **EA R&D W213** ***Guidance-Briefing (GEHO0505BJEN-E-E*** **)**
   - **EA R&D W214 (Technical Report)**
2. **MODFLOW**
3. **MIKE-SHE**
4. ***Many Others!***

Hydro-ecological Prescriptions

- http://www.english-nature.org.uk/lifeinukrivers/summary/summary.html
  for in-river Natura 2000 species
- http://www.naturalengland.org.uk/search.asp?cx=010476233810196394646%3Aj3joeevl72k&q=eco-hydrological+guidelines&sa=Search&cof=FORID%3A11#662
  for; Lowland Wetland Plants; alluvial forest and bog woodlands; bog restoration - Peatland Ecosystems; basin fens; & dune habitats.
- http://www.snh.org.uk/publications/samples/naturalHeritageManagement/bogssamples.asp
  for Ombrotrophic Mires (Bog Habitats)
- http://publications.environment-agency.gov.uk/epages/eapublications.storefront/46fcbcbc00229ffa273fc0a8029606e7/Product/View/GEAN0205BIPZ&2DE&2DE
  for Eco-hydrological Guidelines for Lowland Wetland Plant Communities
- http://publications.environment-agency.gov.uk/epages/eapublications.storefront/46fcbcbc00229ffa273fc0a8029606e7/Search/Run
  for various wetland/hydrology publications
- http://www.sniffer.org.uk/results.asp
  for imminent publications; WFD35 Wetland Framework; WFD84 Groundwater Classification Framework; & WFD83 Freshwater Flows to Transitional Waters.

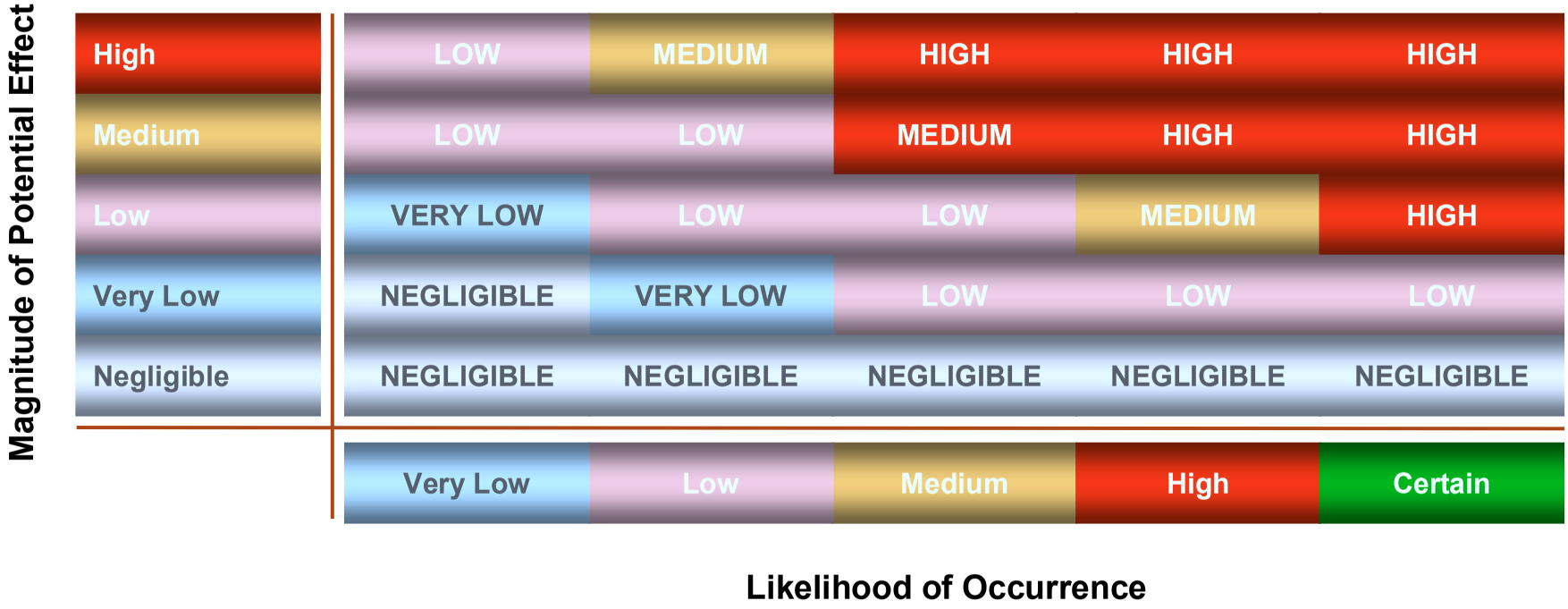
Risk Based Screening Assessments

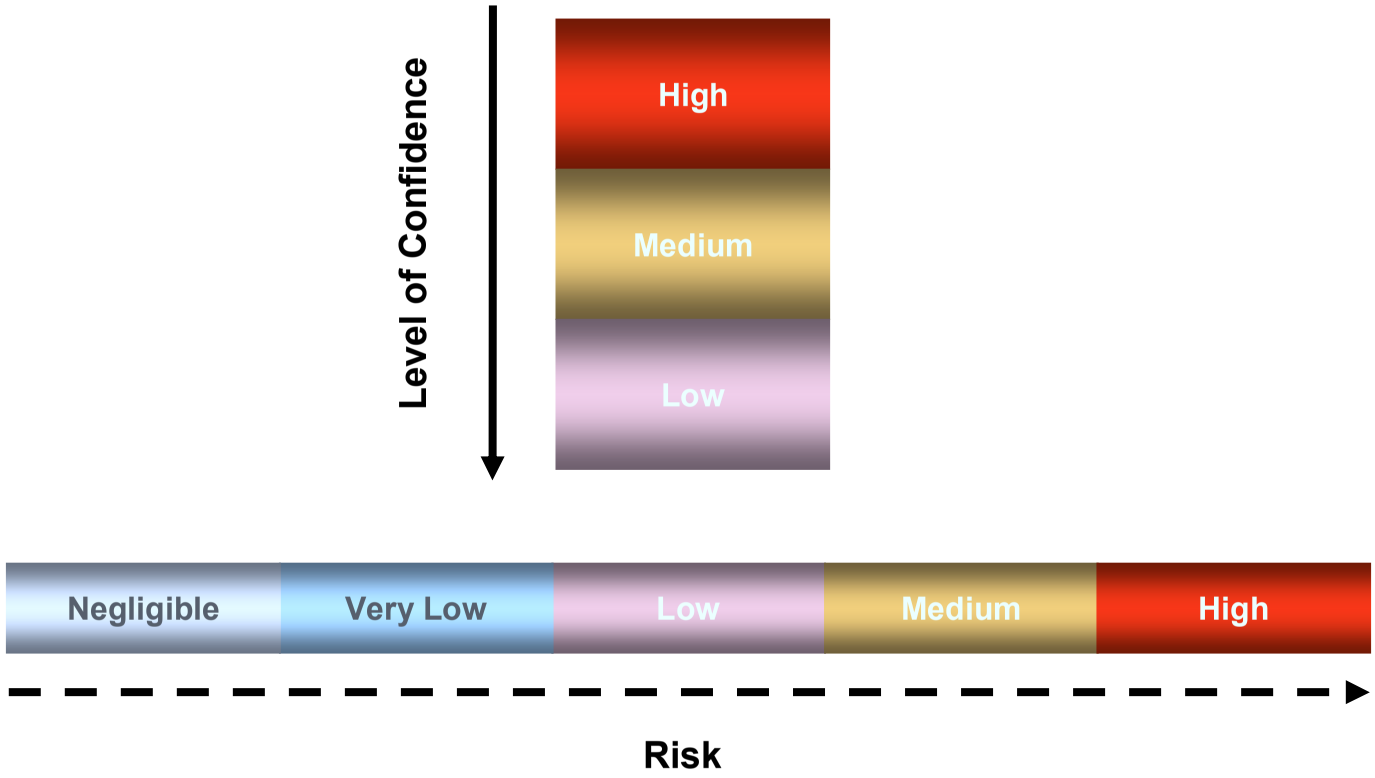


Freshwater Lagoon - Holme NNR

Fresh Groundwater Inflow to Thornham 'Salt' Marsh

Assigning Overall Risk

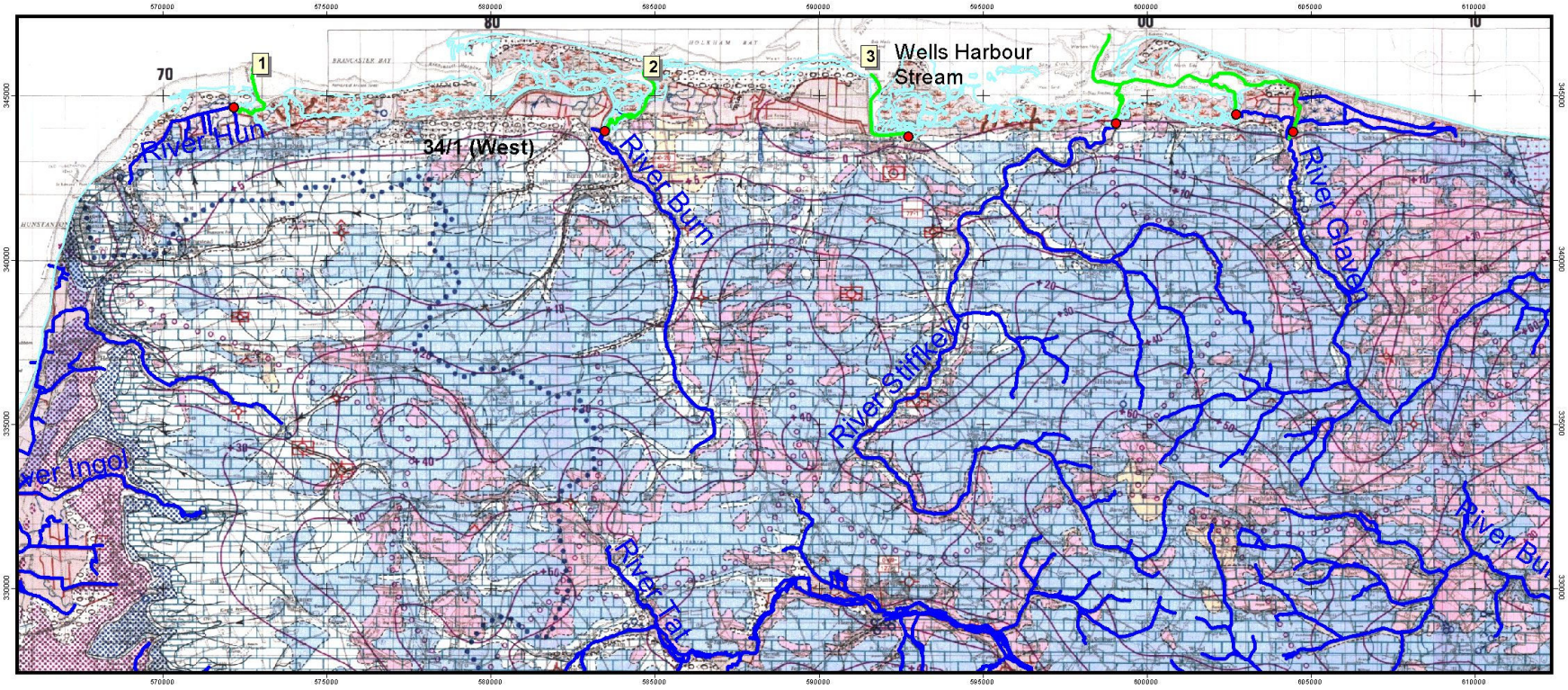




Managing Uncertainty

Case Example
Stage 2 – Review of Consents for the North Norfolk Coast SAC/SPA/Ramsar under the Habitats Regulations/Directive

Hydrological Regime of North Norfolk Coast



NNC Designations/Characteristics

Designations

- SSSI
- North Norfolk Coast cSAC
- Wash and North Norfolk Coast cSAC
- North Norfolk Coast SPA
- Ramsar Site

What is different about this site?

- It occupies 40km of coastline (between Hunstanton and Weybridge)
- It includes a full spectrum of transitional habitats from marine to reclaimed freshwater marsh
- It includes both distinct estuarine and groundwater freshened inter-tidal (salt marsh and tidal creek) habitats

Therefore, the approach to assessment is tailored to suit the hydro-ecological regime. The flow regime (gw & river) is critical and level regimes are of secondary significance in terms of risk.

The flow regime is critical in terms of:

- freshening/flushing
- abating saline intrusion