HR Wallingford
Working with water

Culvert hydraulics

Darren Lumbroso, HR Wallingford

Outline and detailed hydraulic design

Data requirements and data collection

Outline (conceptual) design

- Identify all criteria and constraints

Detailed design for new culverts

- Free & surcharged flow
- Inlet & outlet control
- Iterative process (trial size)

Assessment of existing culvert capacity

- Surcharged & free flow
- Inlet and outlet control
- Iterative process (trial flow)

Outline (conceptual) design

Identification of all constraints

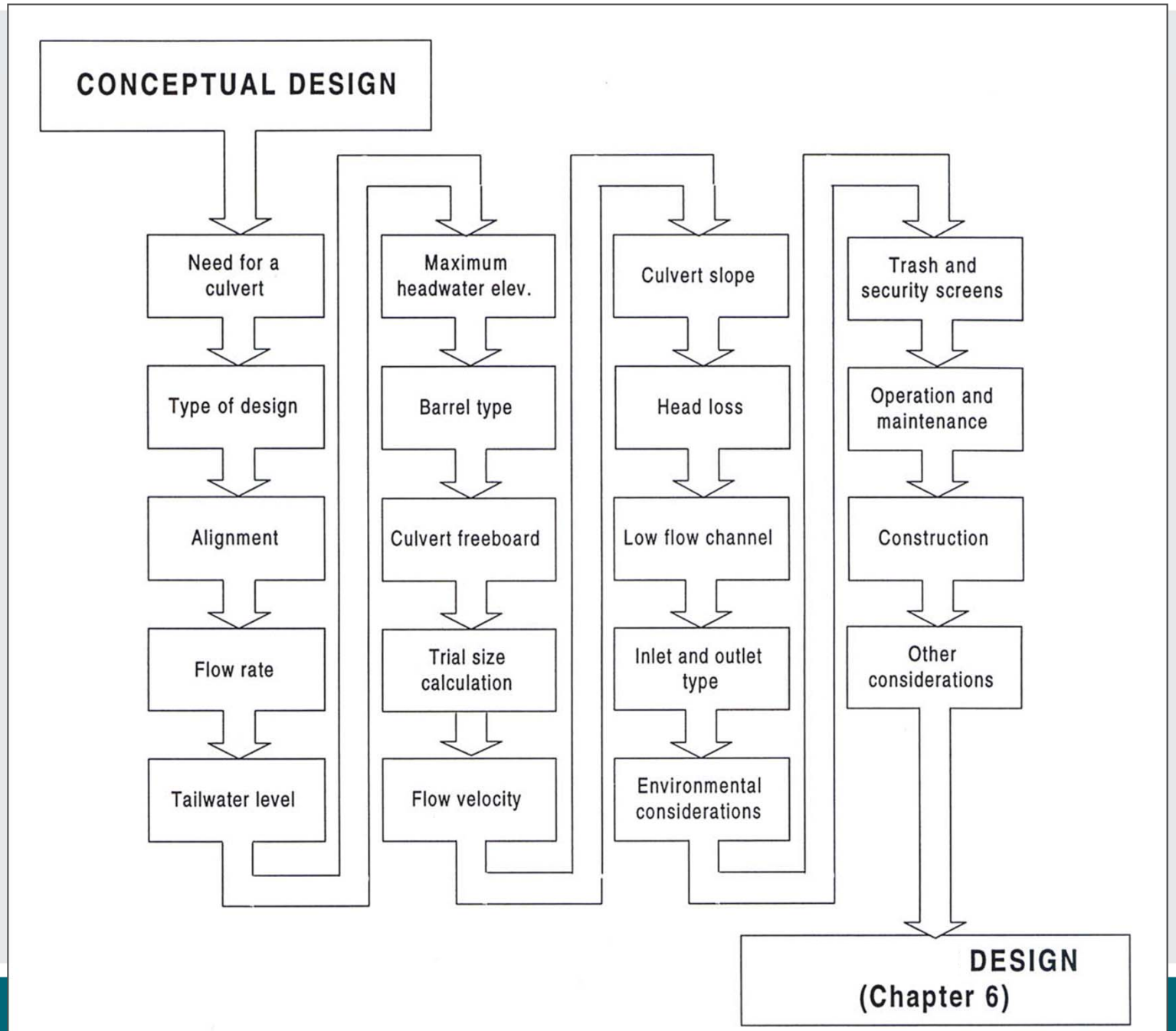
Sketch design

Leading dimensions and levels

Estimates of:

- > barrel dimensions
- > design flow
- > tailwater & headwater elevations
- > inlet & outlet invert levels
- > other requirements (screens, maintenance, etc)

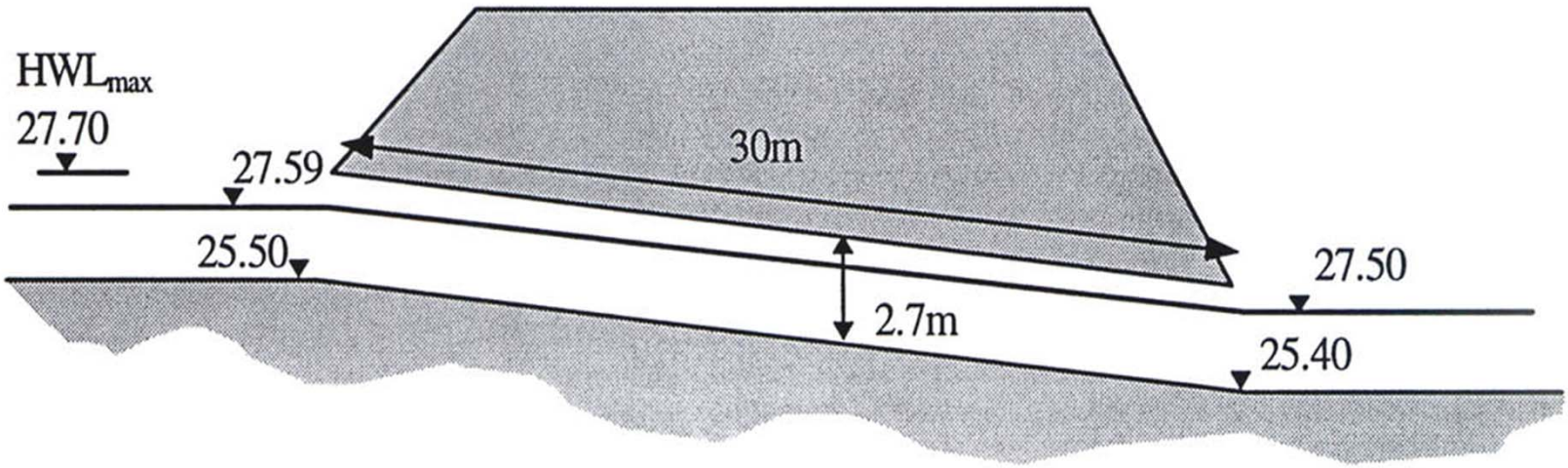
HR Wallingford
Working with water



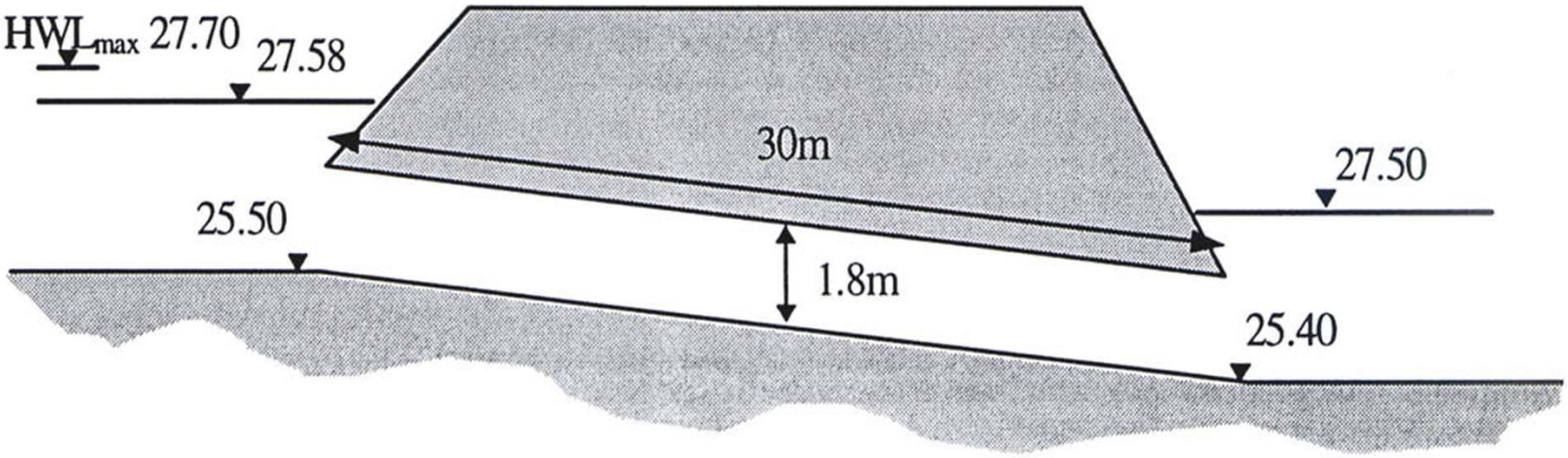
Sketch design: Longitudinal sections (not to scale)

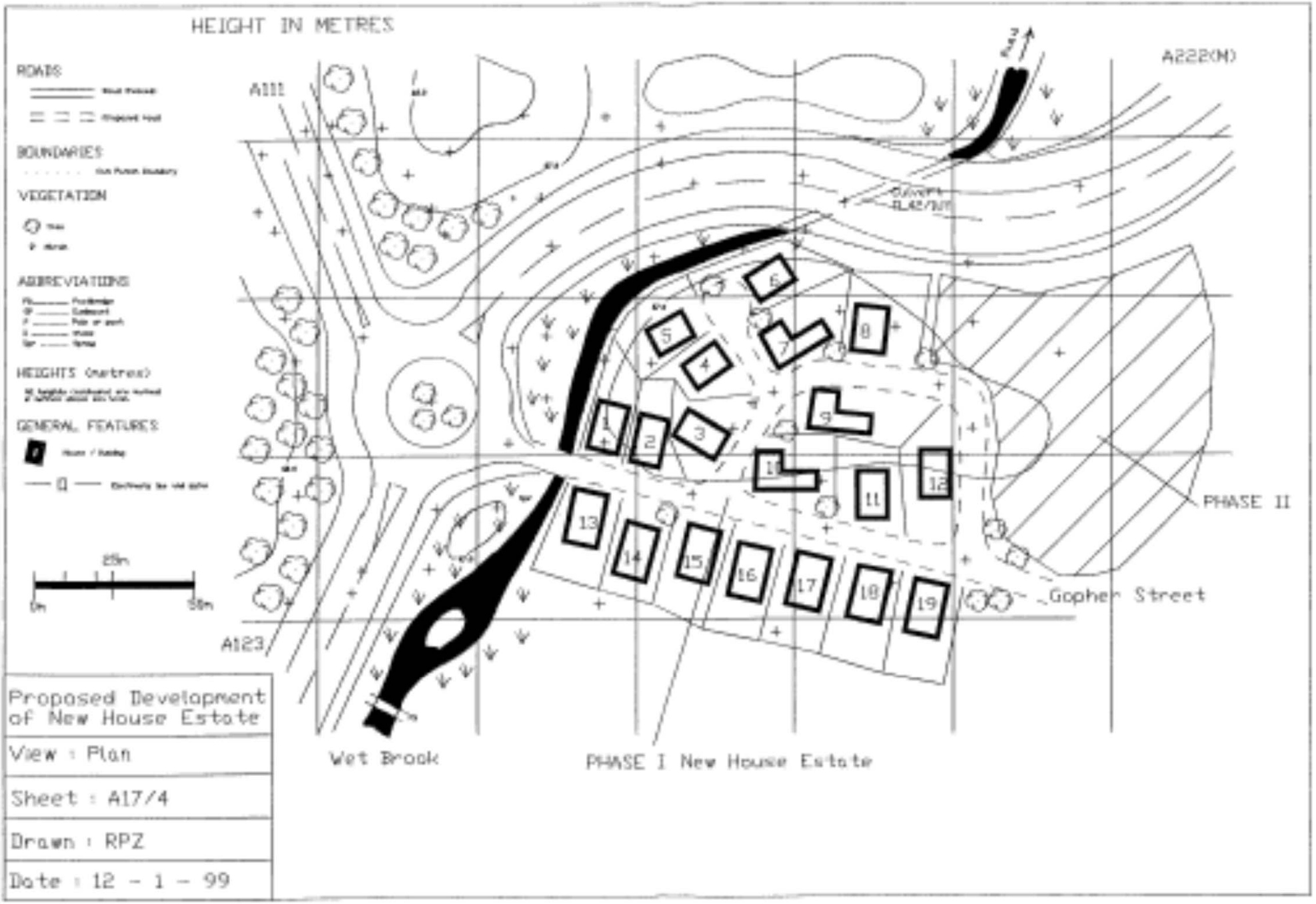
Levels in mAD

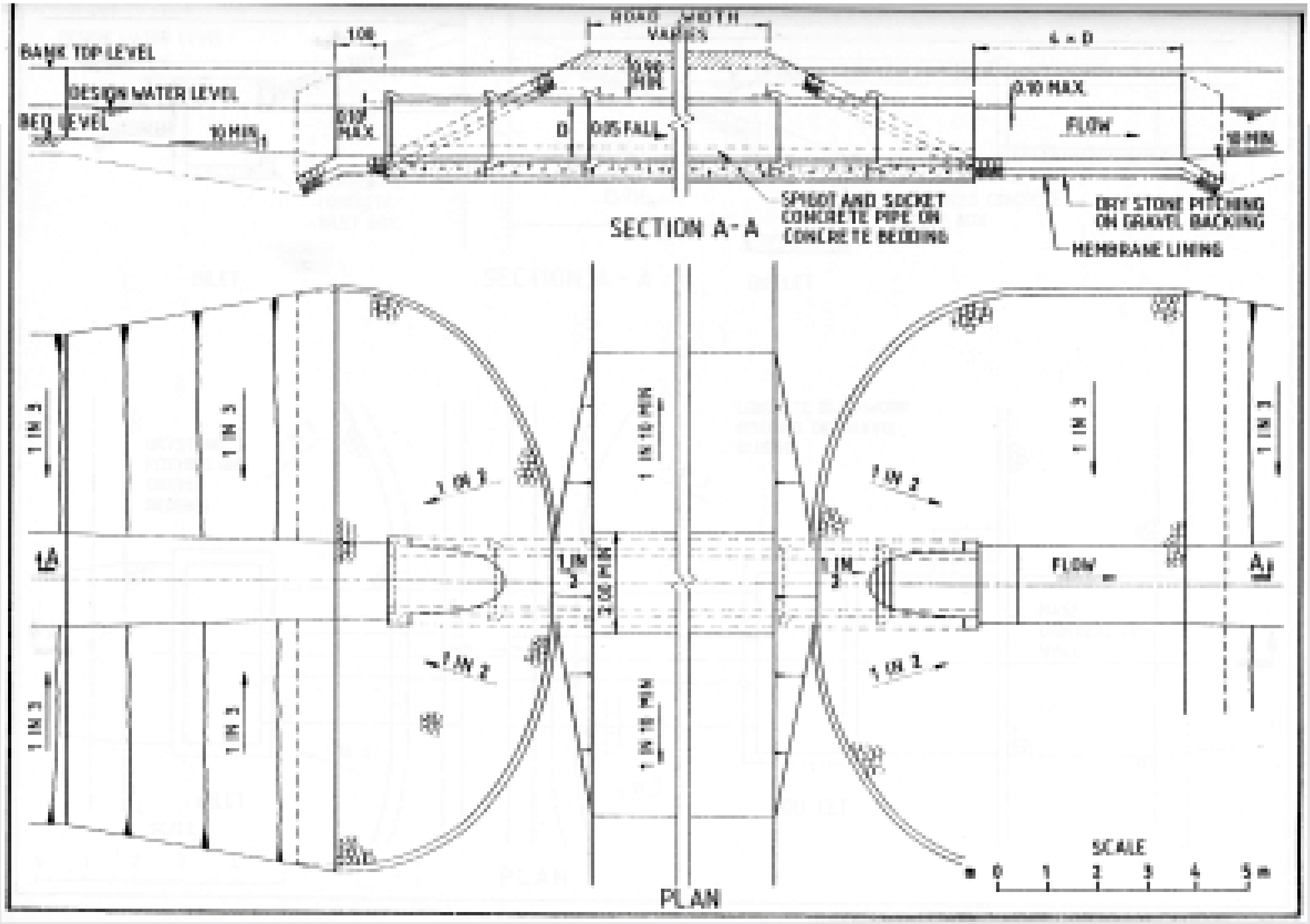
Free flow culvert



Surcharged culvert




HEIGHT IN METRES
ROADS
BOUNDARIES
VEGETATION
ABBREVIATIONS
HEIGHTS (metres)
GENERAL FEATURES
25m
0m
50m
A111
A222(M)
A123
PHASE II
Gopher Street
Wet Brook
PHASE I New House Estate
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Proposed Development of New House Estate
View : Plan
Sheet : A17/4
Drawn : RPZ
Date : 12 - 1 - 99


BANK TOP LEVEL
DESIGN WATER LEVEL
BED LEVEL
10 MIN
0.10 MAX
D
0.05 FALL
ROAD WIDTH VARIES
4 × D
0.10 MAX
FLOW
10 MIN
SPIGOT AND SOCKET CONCRETE PIPE ON CONCRETE BEDDING
DRY STONE PITCHING ON GRAVEL BACKING
MEMBRANE LINING
SECTION A-A
1 IN 3
1 IN 2
1 IN 10 MIN
3 OR MIN
FLOW
SCALE
0 1 2 3 4 5 m
PLAN

Detailed design for new culverts

Design flow rates (high and low)

Tailwater elevation

Trial size

> conceptual design

> review

Iterative process

> vary trial size

> maximum upstream level

Free and surcharged flow

HR Wallingford
Working with water

Analysis steps

1. Normal depth method
2. Backwater method
3. Inlet control
   - design table and charts
4. Head loss due to trash screen
5. Outlet head loss
6. Head loss due to bend
7. Inlet head loss
8. Head loss due to friction
9. Compound roughness
10. Scour check

High flow estimation

Peak flow required for culvert design

How to estimate this?

Tailwater elevation

Normal depth calculation (single cross-section)

Backwater method (several cross-sections)

> Calculation

> Hydraulic model

Observations

Combine methods

Free flow design

Inlet control

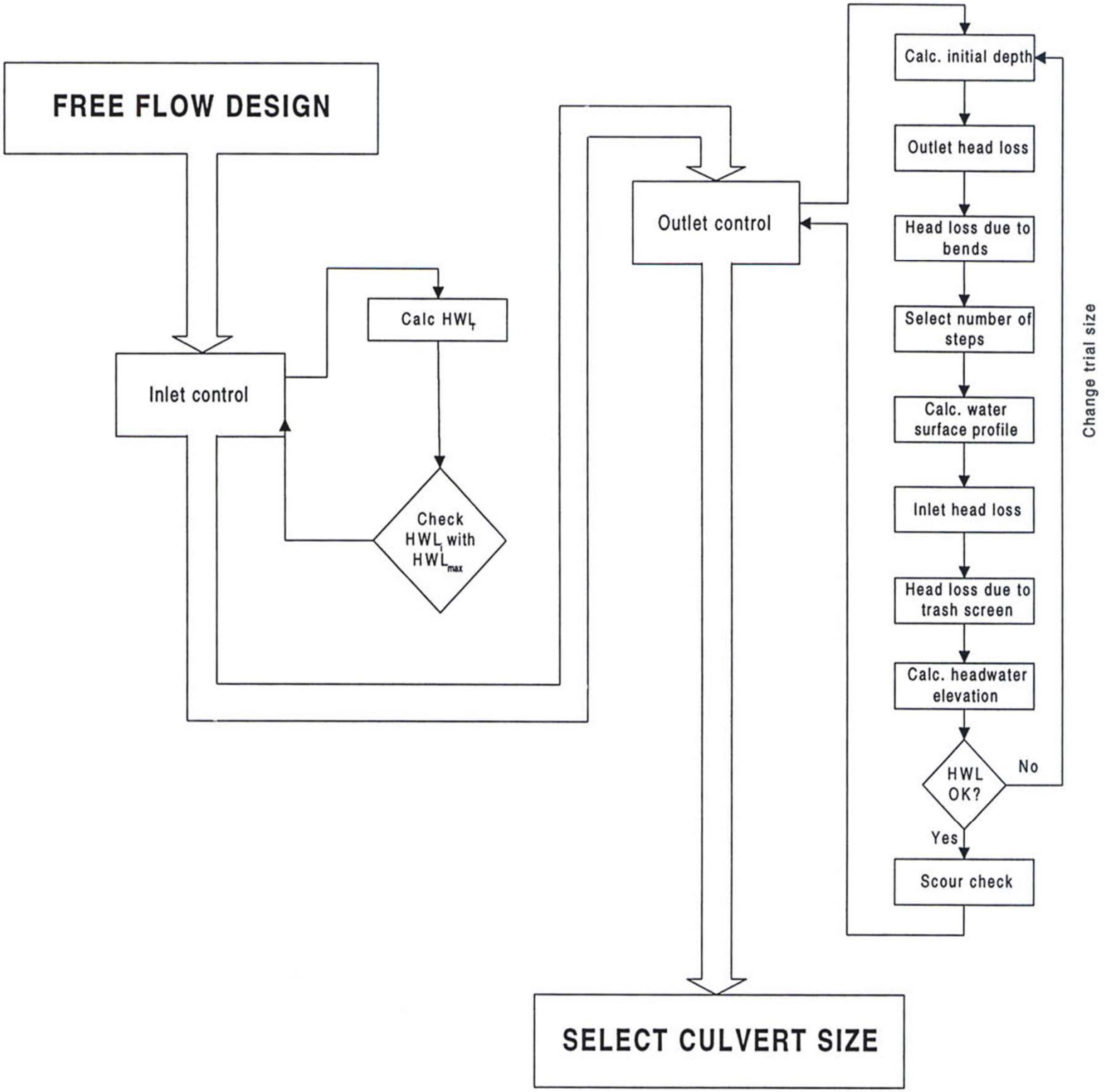
> Critical depth near inlet

Outlet control

> Critical depth at outlet or downstream of outlet

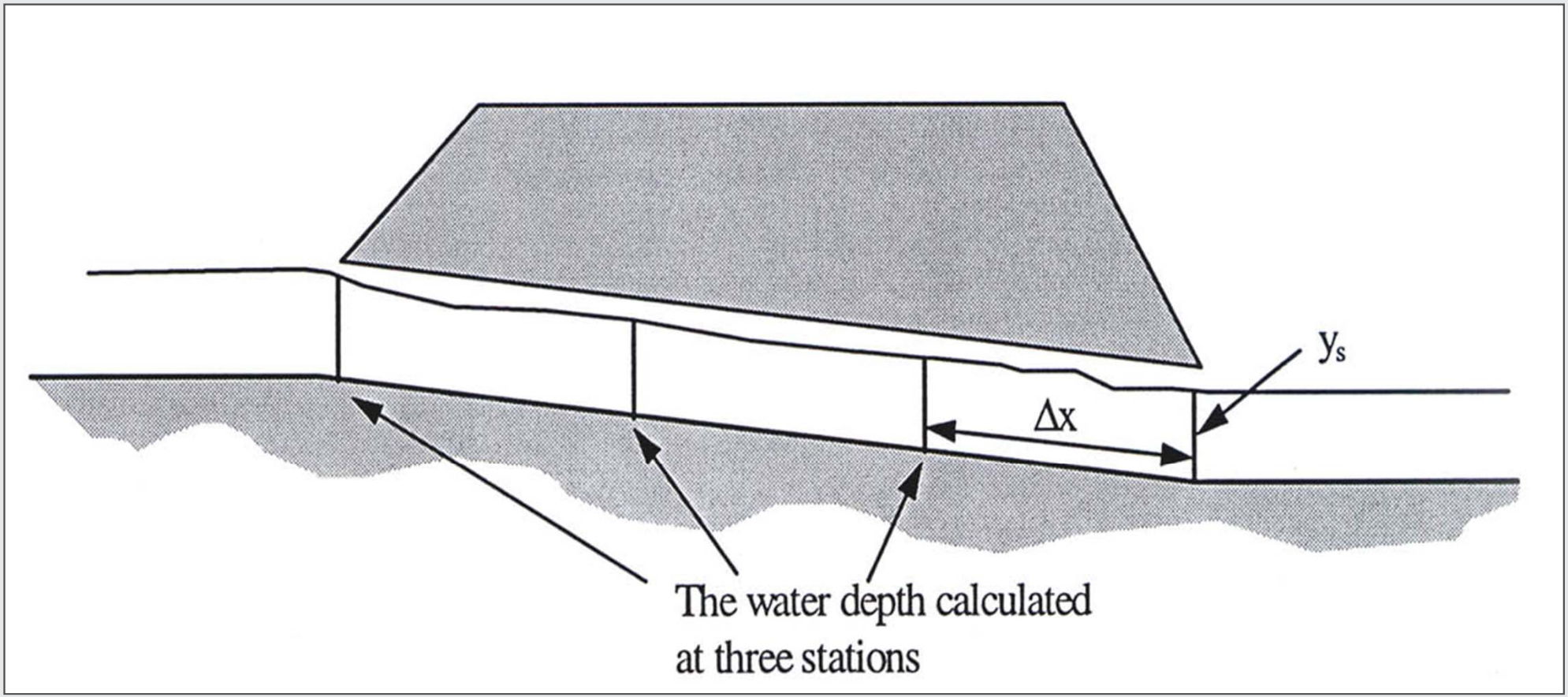
> Backwater calculation through culvert for upstream water level

Select control with highest upstream level


FREE FLOW DESIGN
Inlet control
Calc HWL$_i$
Check HWL$_i$ with HWL$_{max}$
Outlet control
Calc. initial depth
Outlet head loss
Head loss due to bends
Select number of steps
Calc. water surface profile
Inlet head loss
Head loss due to trash screen
Calc. headwater elevation
HWL OK?
No
Yes
Scour check
Change trial size
SELECT CULVERT SIZE

HR Wallingford
Working with water

Points for water surface profile calculation



Surcharged flow design

Inlet control

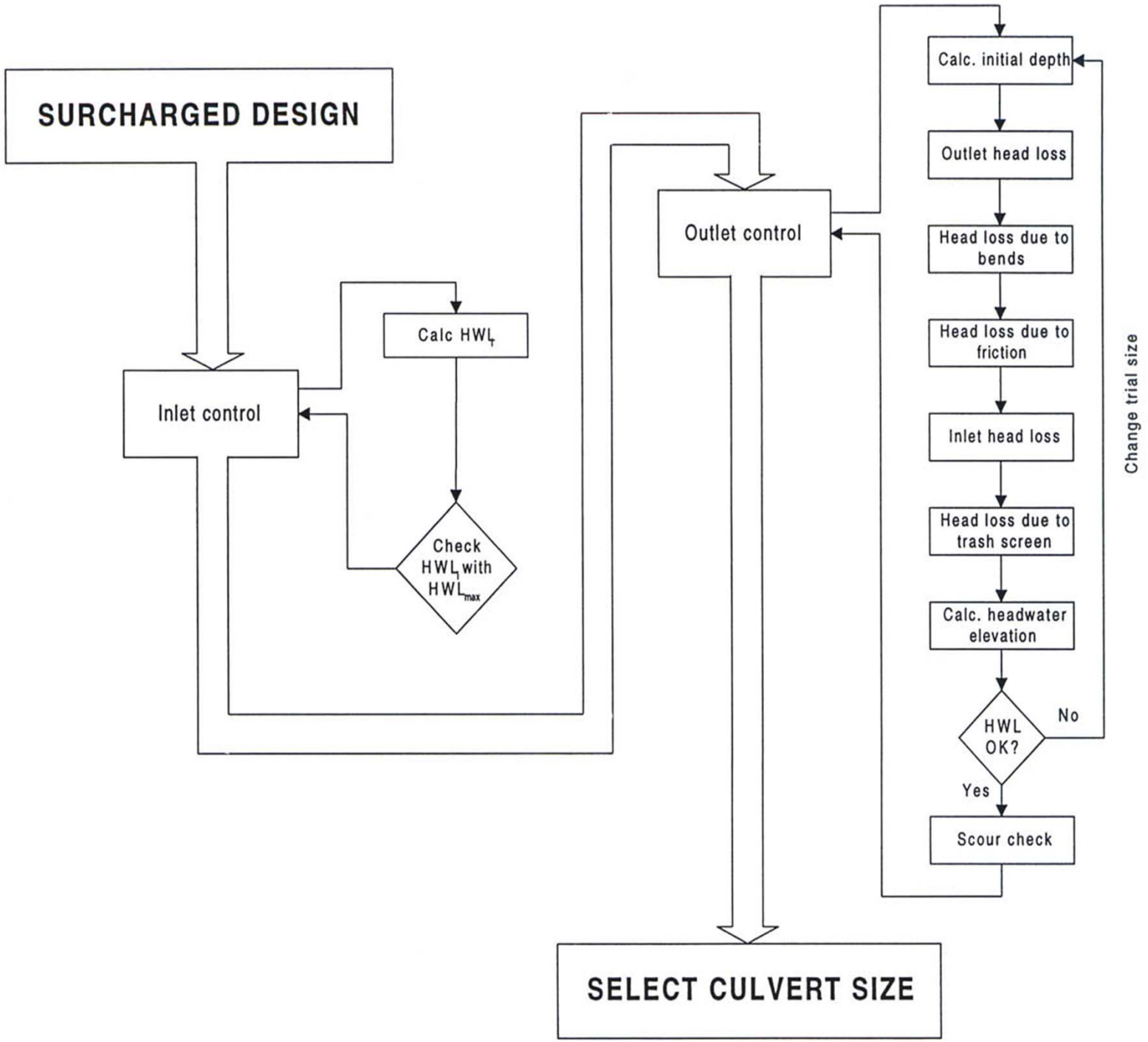
> Critical depth near inlet

Outlet control

> Critical depth at outlet or downstream of outlet

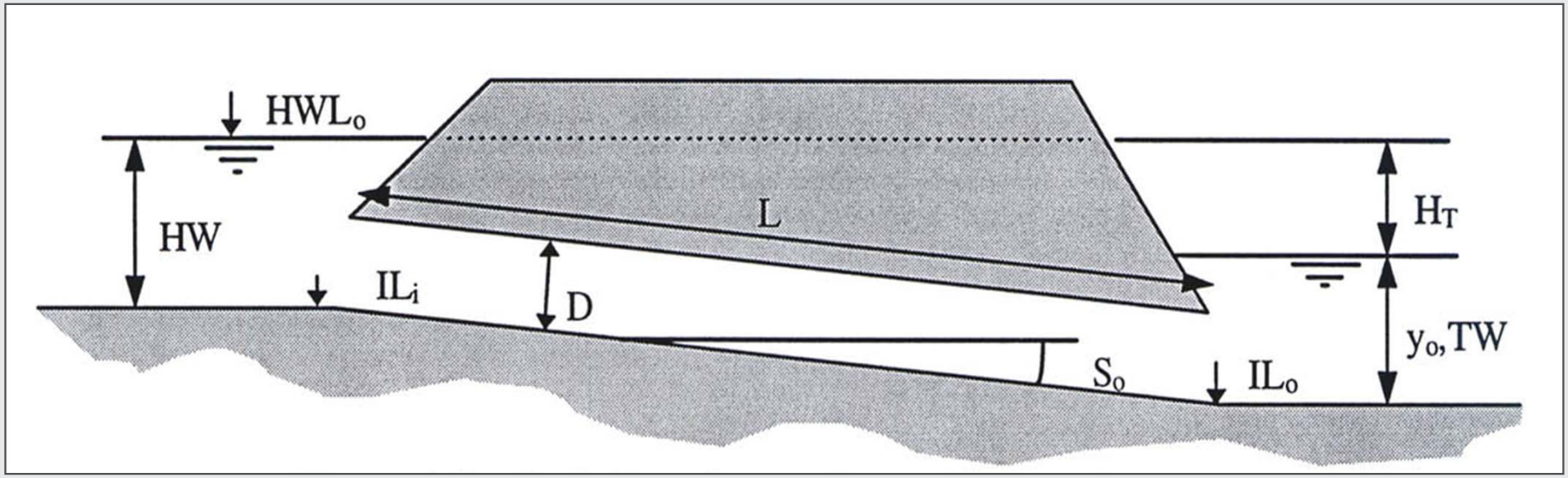
> Sum of headlosses through culvert for upstream water level

Select control with highest upstream level


SURCHARGED DESIGN
Inlet control
Calc HWL$_t$
Check HWL$_t$ with HWL$_{max}$
Outlet control
Calc. initial depth
Outlet head loss
Head loss due to bends
Head loss due to friction
Inlet head loss
Head loss due to trash screen
Calc. headwater elevation
HWL OK?
No
Yes
Change trial size
Scour check
SELECT CULVERT SIZE

HR Wallingford
Working with water

Definitions for surcharged flow under outlet control



Assessment of existing culvert capacity

Dimensions fixed

Flow unknown

Sketch of culvert

Initial flow estimate

Tailwater depth

> rating curve

Surcharged and free flow analysis

Iterative process (vary flow)

Surcharged flow analysis

Inlet control and outlet control

Select control with highest upstream level

Outlet control method calculates sum of headlosses through culvert for upstream water level

Use of analysis modules

Free flow analysis

Inlet control and outlet control

Select control with highest upstream level

Outlet control method uses backwater calculation through culvert for upstream water level

Use of analysis modules

HR Wallingford
Working with water

Any questions?

HR Wallingford
Howbery Park, Wallingford, Oxfordshire OX10 8BA, United Kingdom
tel +44 (0)1491 835381 fax +44 (0)1491 832233 email info@hrwallingford.com