GLM MORRIS ENGINEERING

Hydrology of Water Supply Intakes

Gregory L. Morris, P.E., Ph.D.

Consultant to DNER Water Plan Office

Topics to Discuss

- The problem of guaranteeing instream flow in island streams with a high degree of variability and very low flows.
- The problem created by multiple intakes on the same river.
- Alternative strategies available for specifying instream flow requirements in permit documents.

Gage data from Río Manatí at Ciales used as an example. This river has no upstream reservoir and still has a significant dry-season flow.

Highly Variable Annual Flows
(Río Manatí at Ciales)

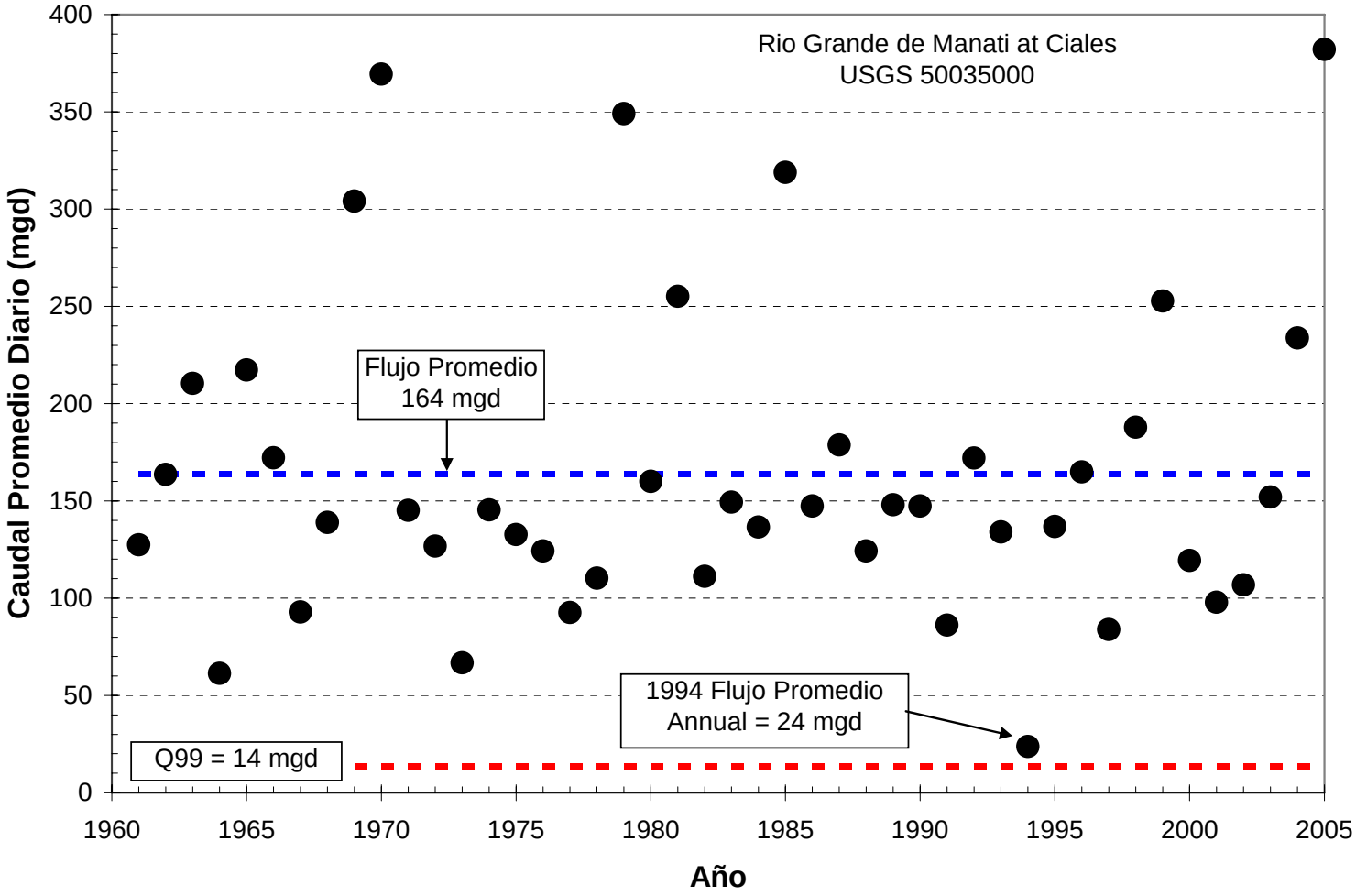


Figure 1: Variability in mean annual streamflow in Río Manatí, Ciales gage station. Notice that the mean annual flow during the entire calendaryear 1994 was close to the long term (43 year) Q99 value.

Daily flows are highly variable

Variability of daily flows, 1960-2003

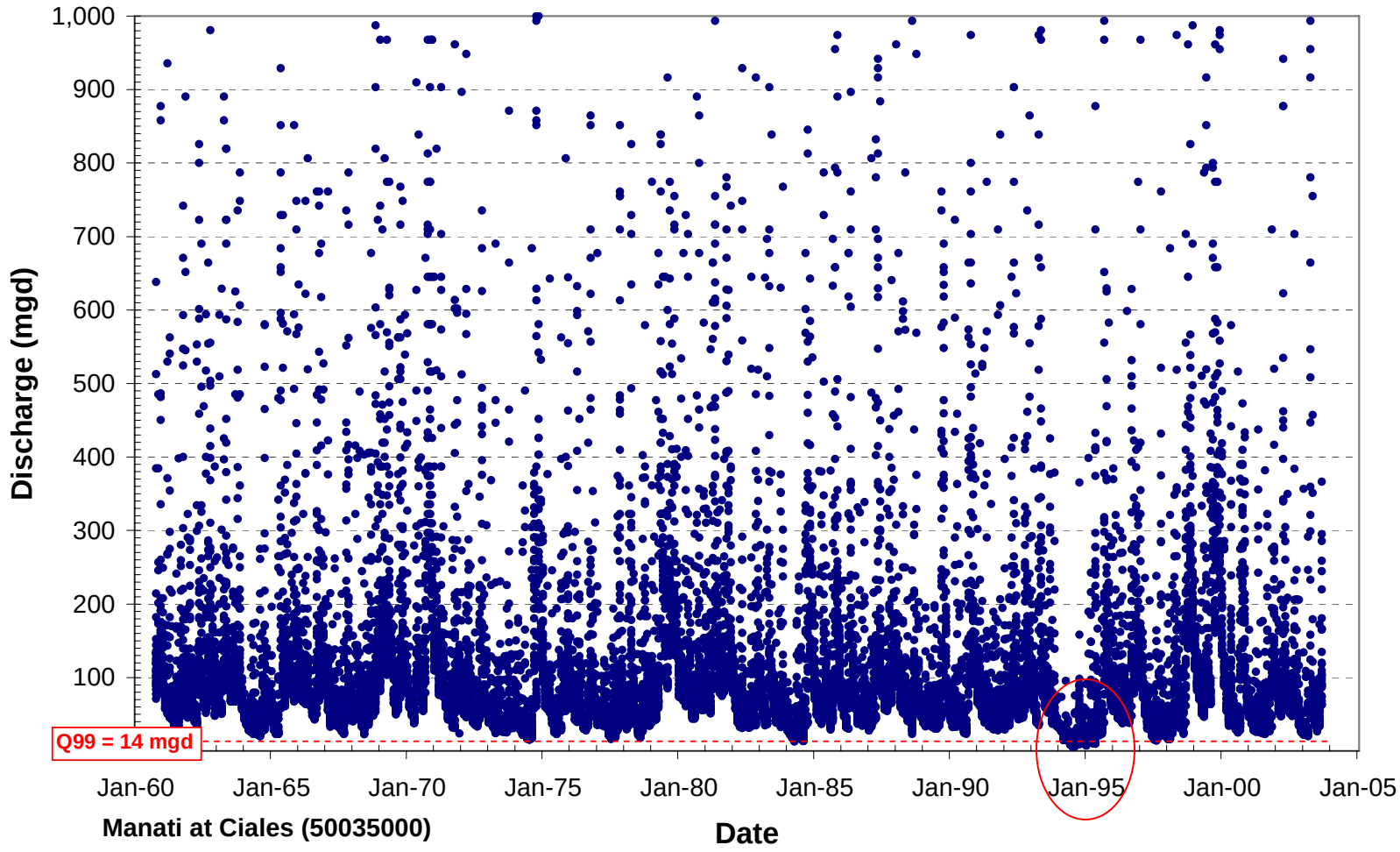


Figure 2: Variability in mean daily streamflow for Río Manatí, Ciales. Most of the flows below Q99 occurred during the 1994-95 drought.

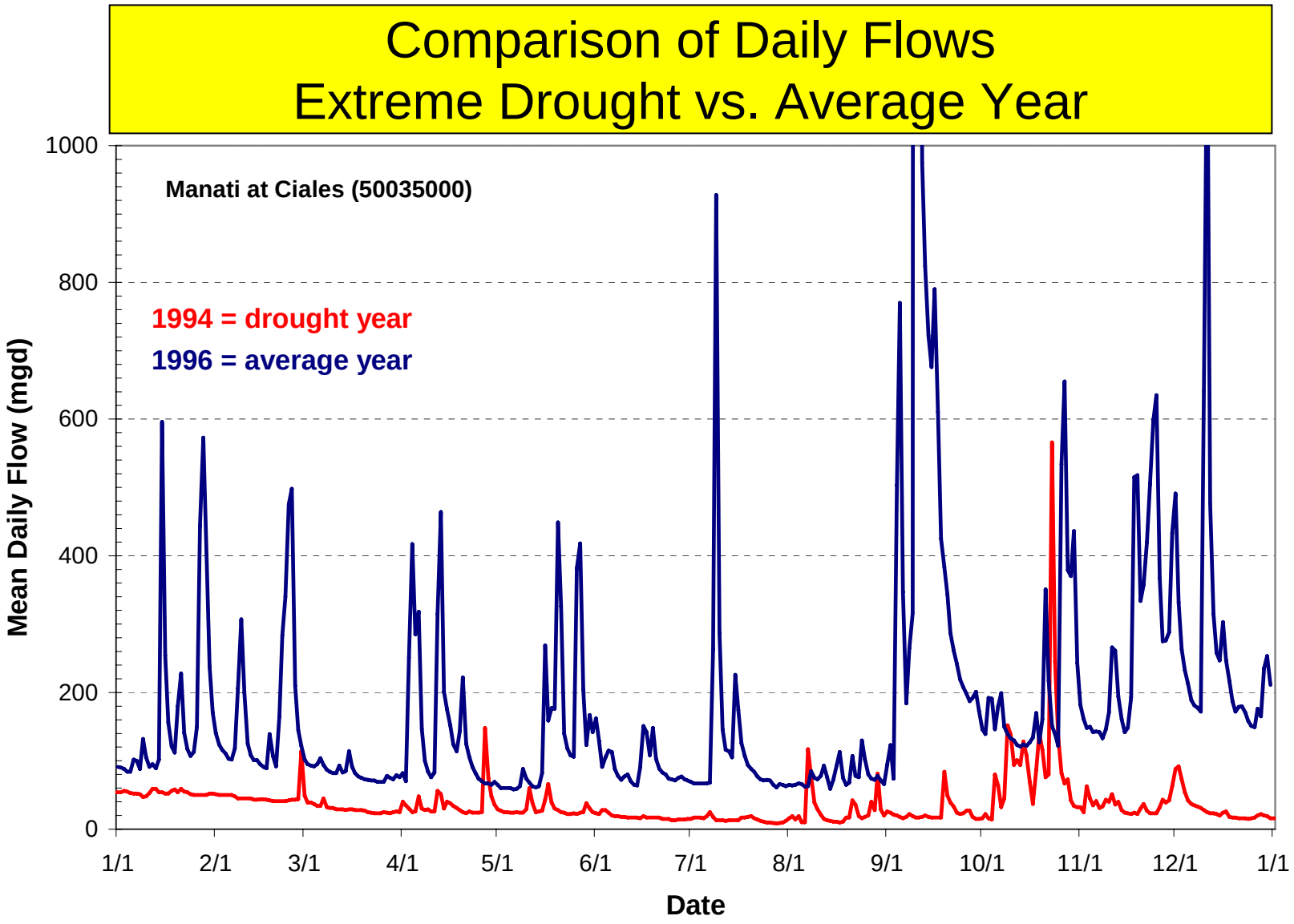


Figure 3: Comparison of daily streamflow for the most severe drought year (1994) with a year of average discharge.

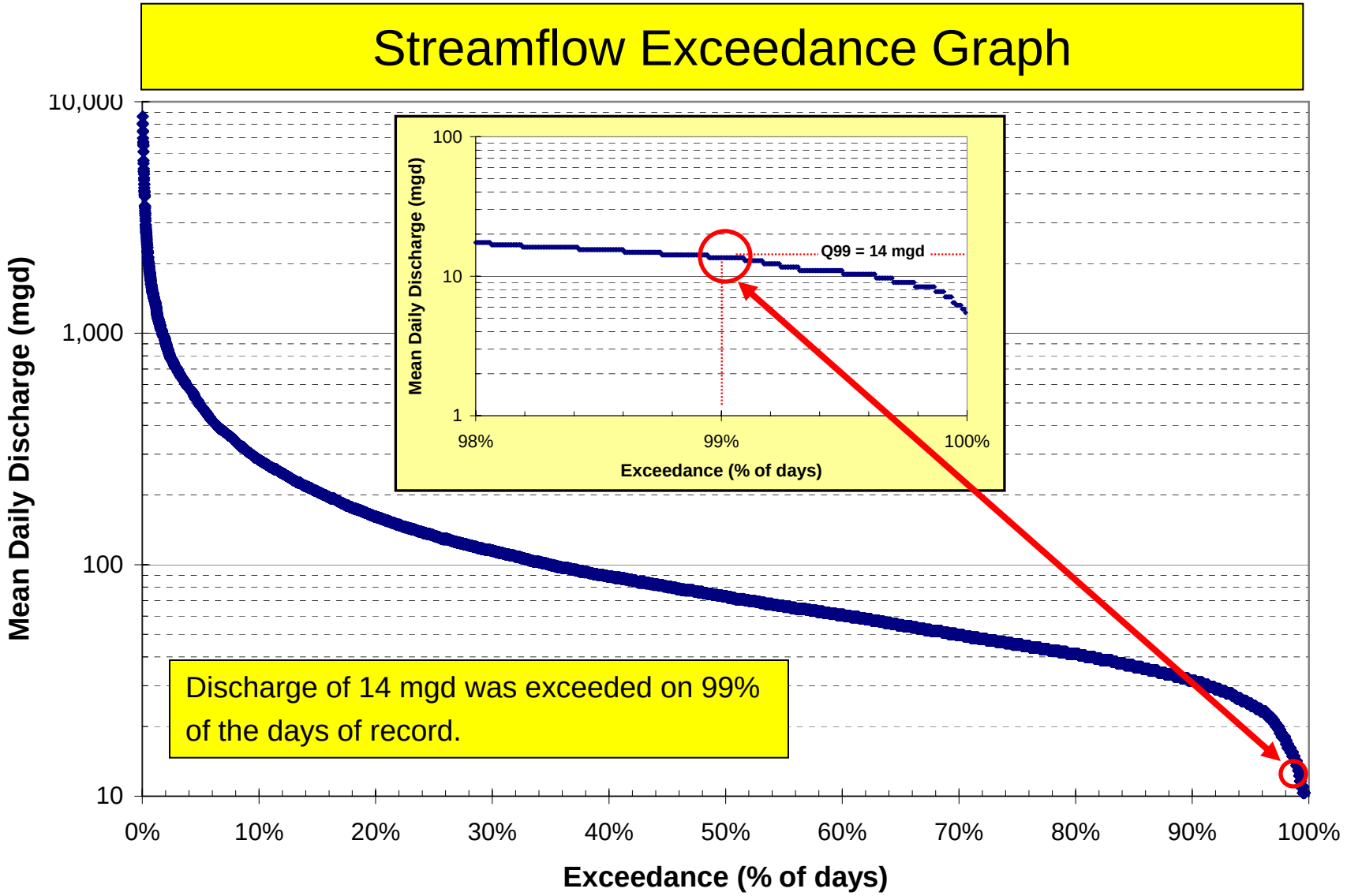
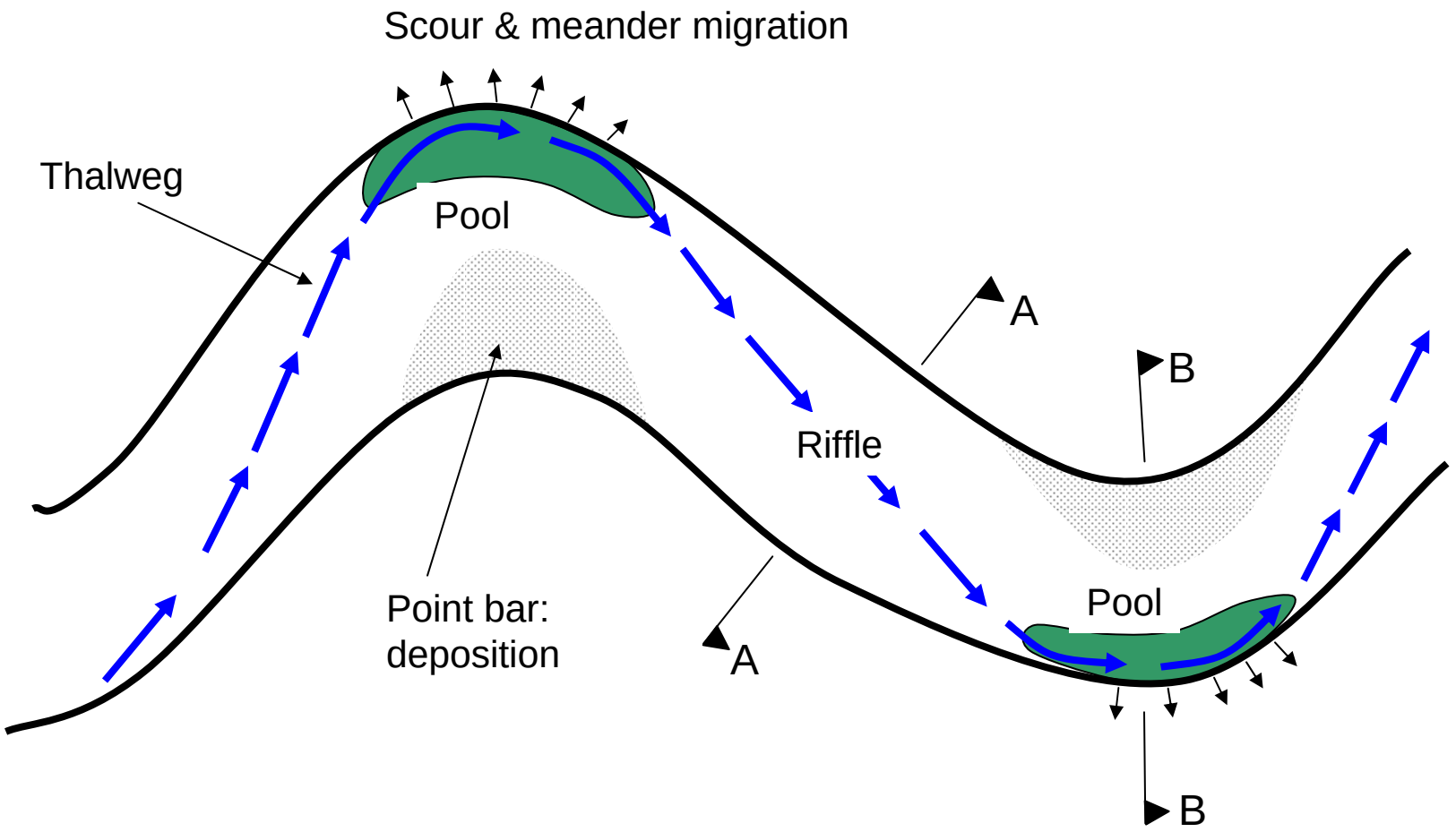
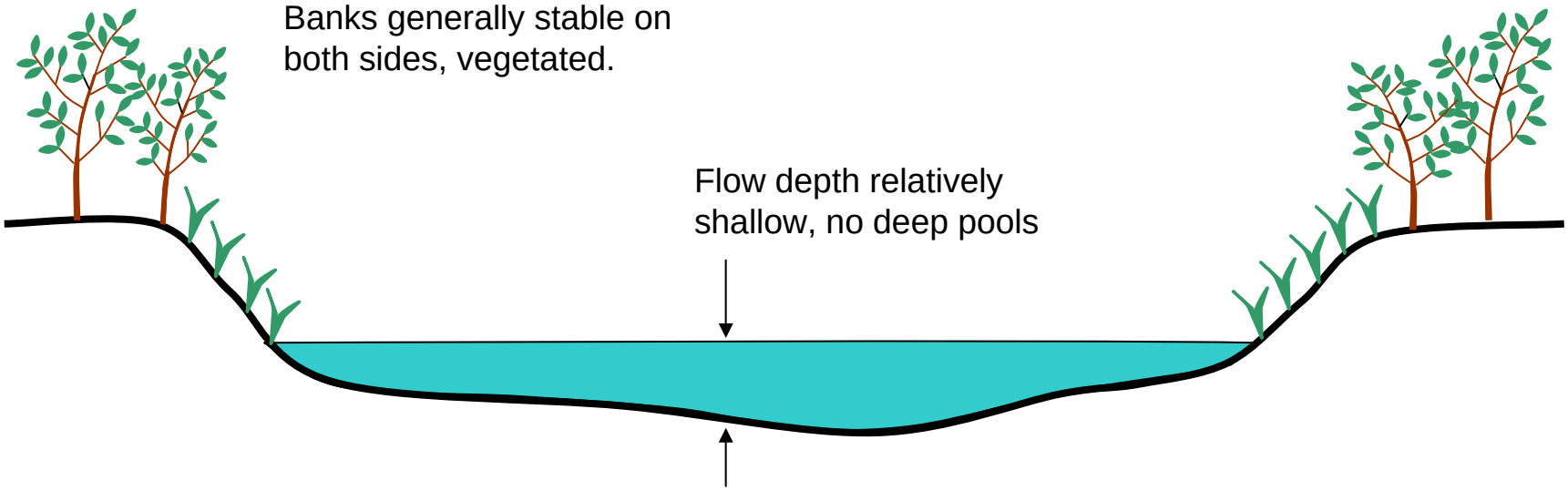


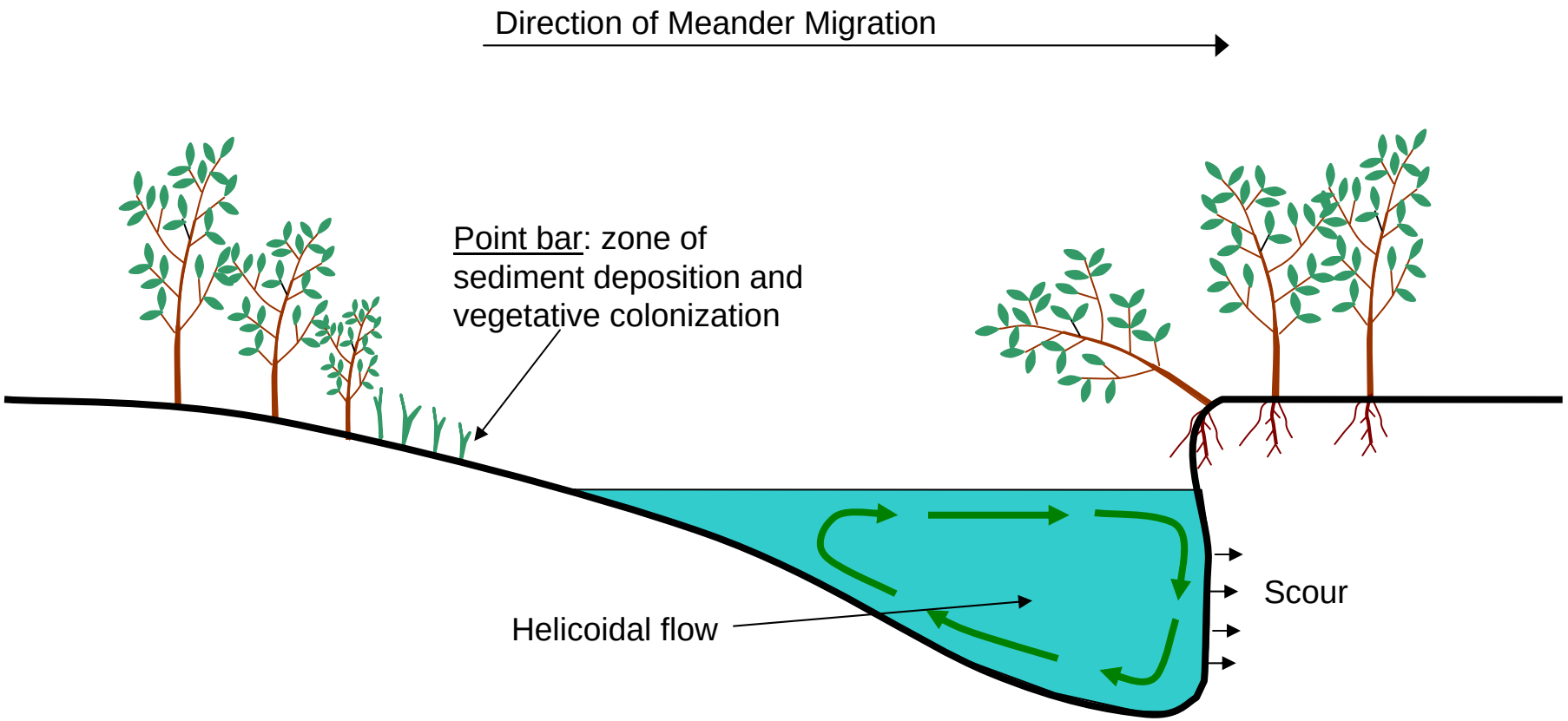
Figure 4: Graph of streamflow exceedance for Río Manatí at Ciales (50035000). The inset graph illustrates the extreme low flow portion of the curve in more detail.

Illustration of Aquatic Riverbed Habitat Area



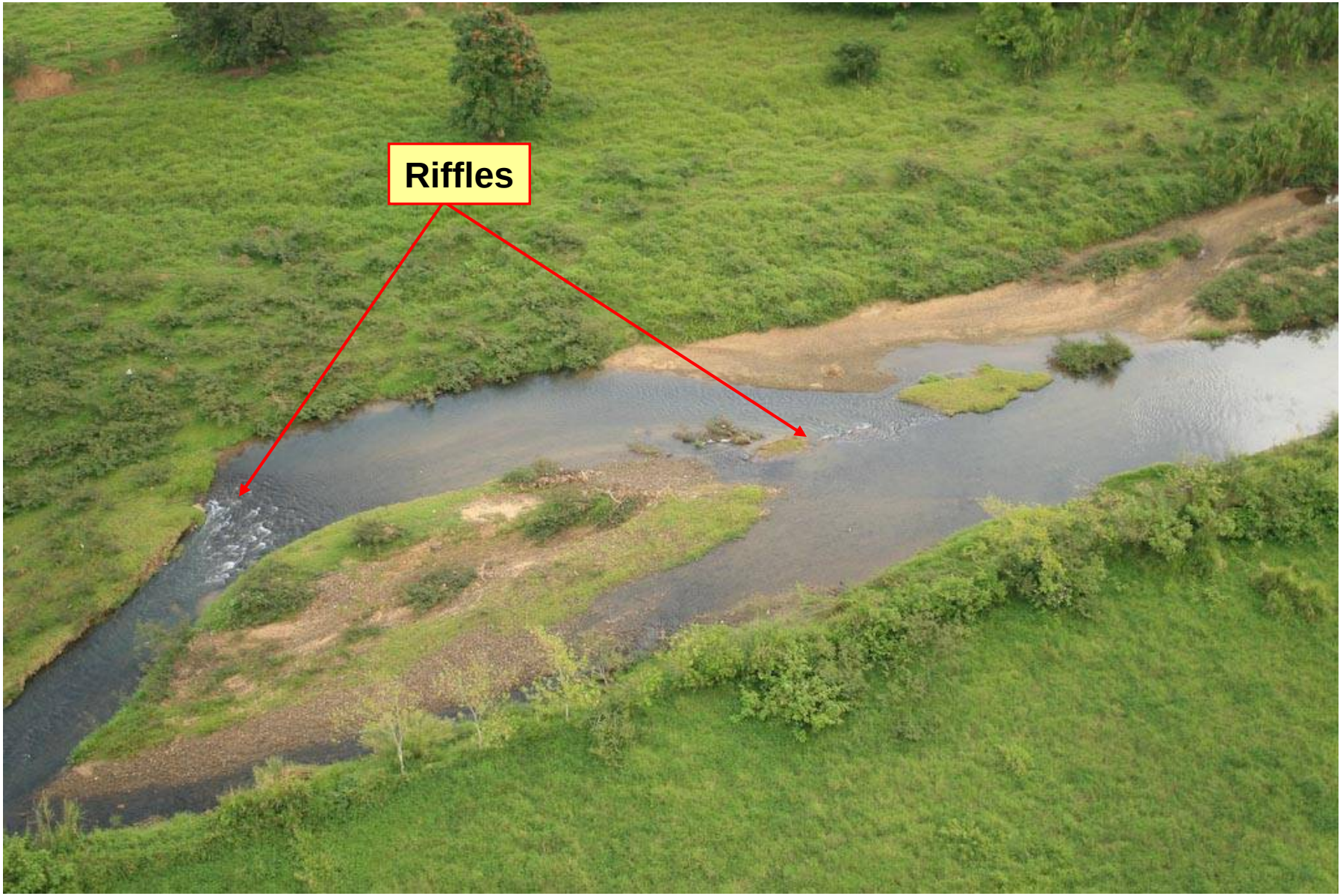


Section A-A
CROSSING



Section B-B
MEANDER BEND

Illustration of Aquatic Riverbed Habitat Area (Rio Gurabo)



Conceptual relationship between discharge and aquatic habitat
Low flows are particularly important to sustain aquatic ecosystems.

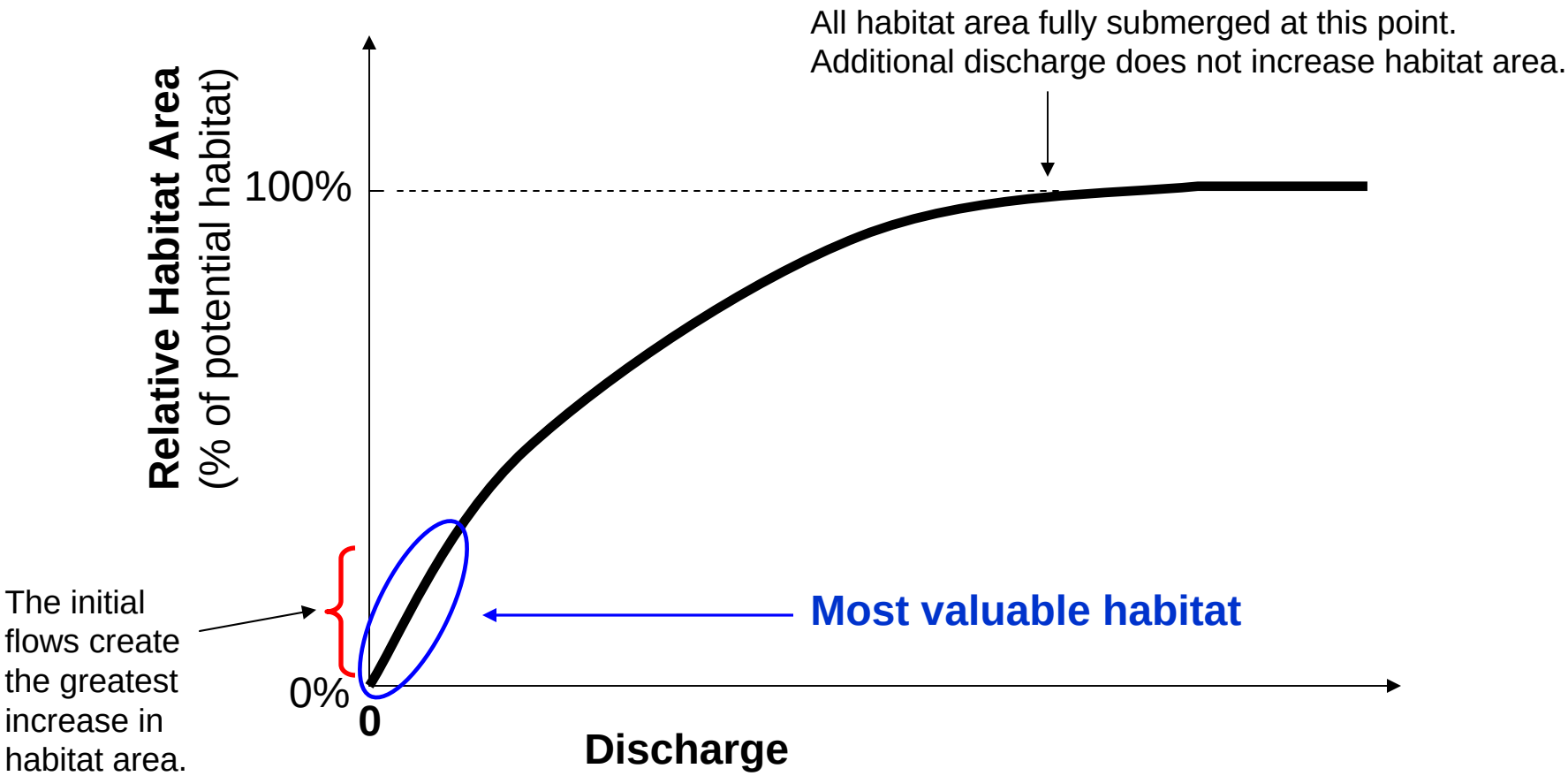


Figure 5: Conceptual relationship between discharge and area of aquatic habitat.

Table 1: Summary of Possible Operating Rules for River Intakes.

Rule		Priority Use	Instream Flow Guarantee	Description
#0	No rule, unregulated withdrawals	Extraction	No	There is no requirement to maintain instream flow. The stream can be dewatered.
#1	Fixed exceedance	Instream	Yes	Extraction not allowed when streamflow falls below a certain exceedance interval (e.g. Q99).
#2	Specify minimum instream flow	Instream	Yes	Extraction not allowed when streamflow falls below a fixed minimum value.
#3	Specify maximum extraction rate	Extraction	No	Extraction allowed at all time, but the extraction rate is limited and may be reduced during periods of low streamflow.

Rule #0 – Unregulated Withdrawals

- In the absence of a rule for apportioning water between withdrawals and instream use, the stream may be totally dewatered.

Rule #0: No instream flow requirement

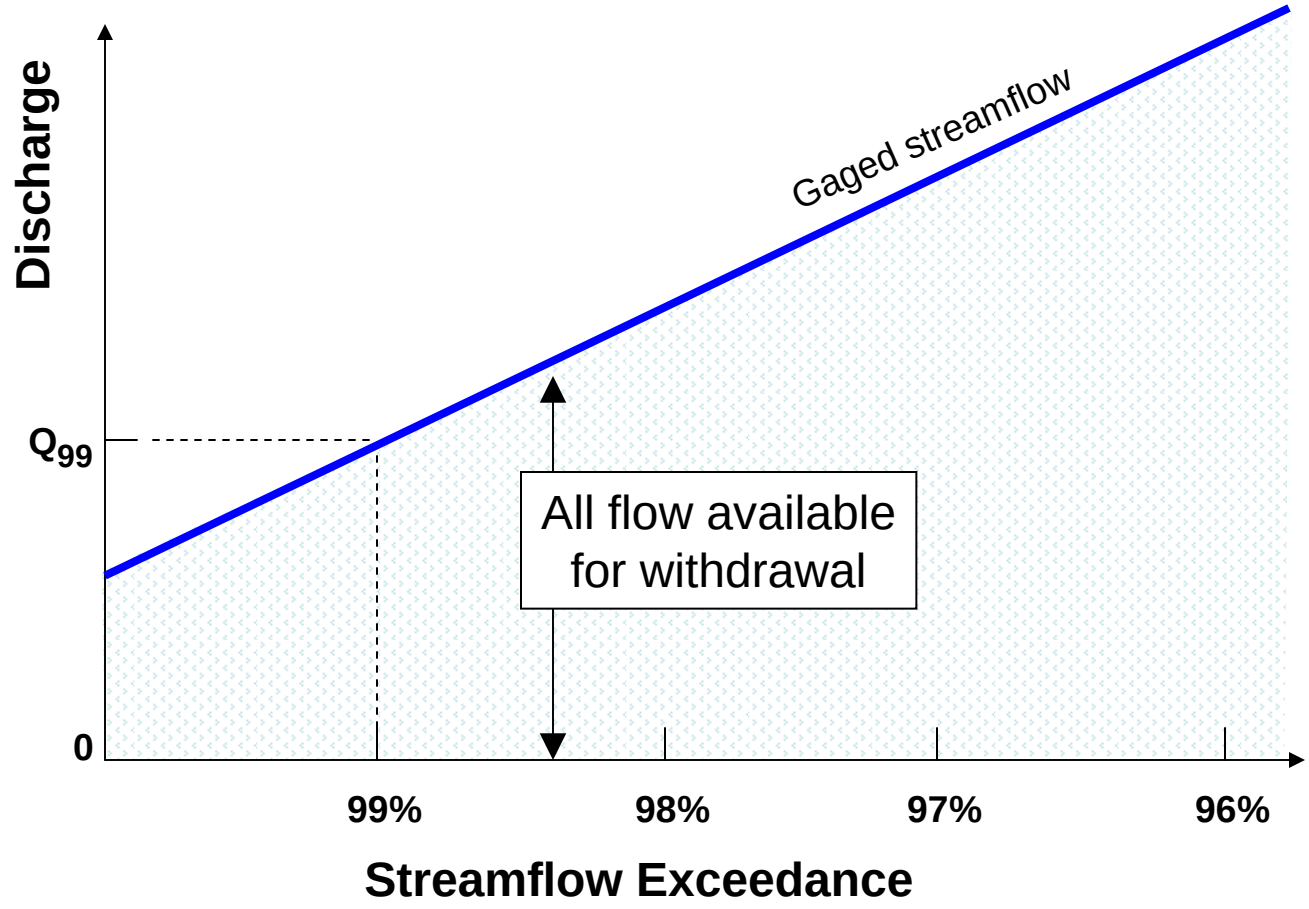


Figure 6: In the absence of any type of regulation, the entire low flow is available to be withdrawn from the stream .

Rule #1 – Fixed Exceedance

- If the required minimum instream flow is established as equal to a fixed flow exceedance (Q99 for example), the flow available for withdrawal will be limited to the flow in excess of the stated exceedance value,
- A rule based on exceedance values will always produce days when zero flow will be available for extraction, regardless of the size of the river, even if applied to the Mississippi.
- Applicable to reservoirs. Problematic for run-of-river intakes.

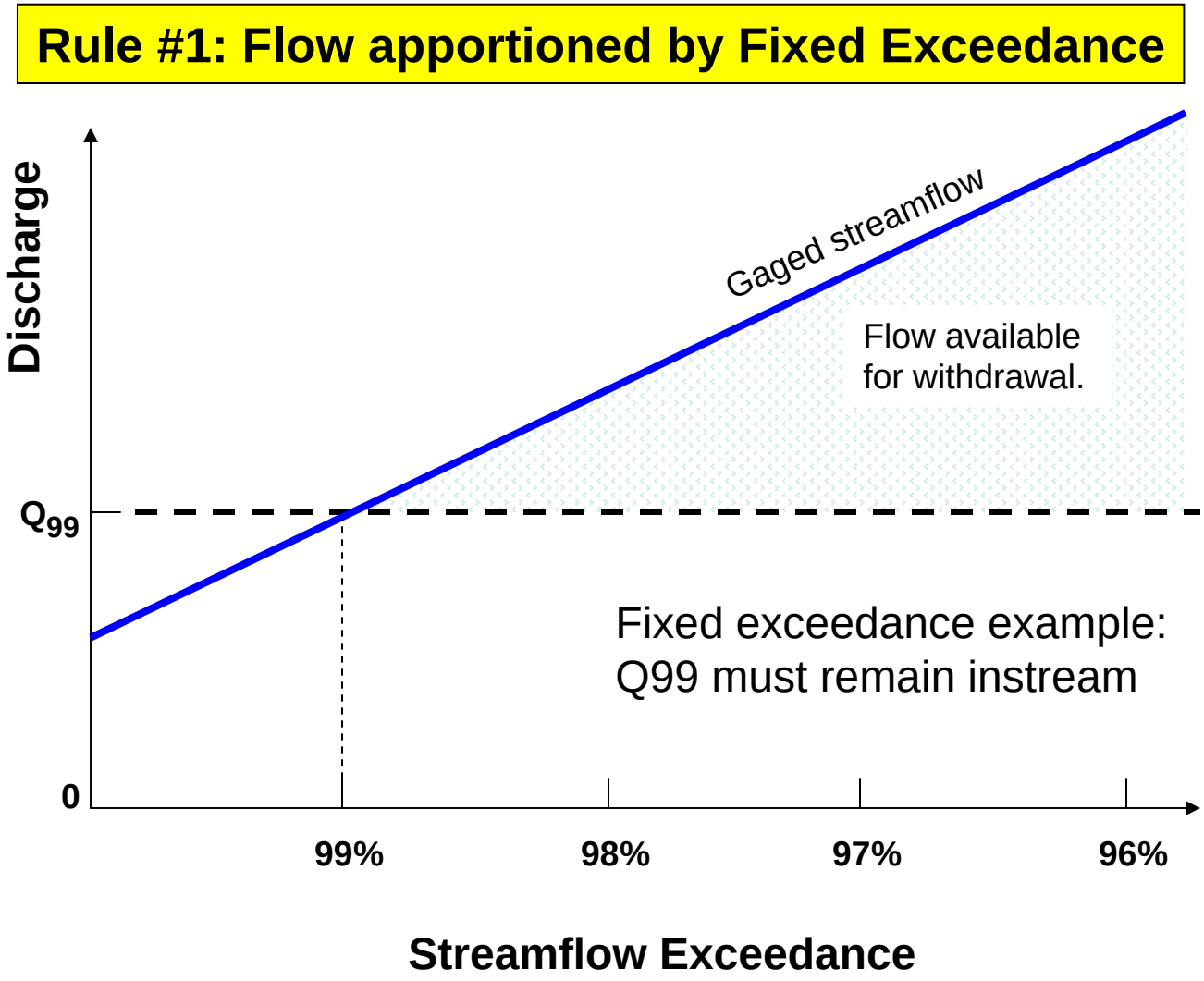
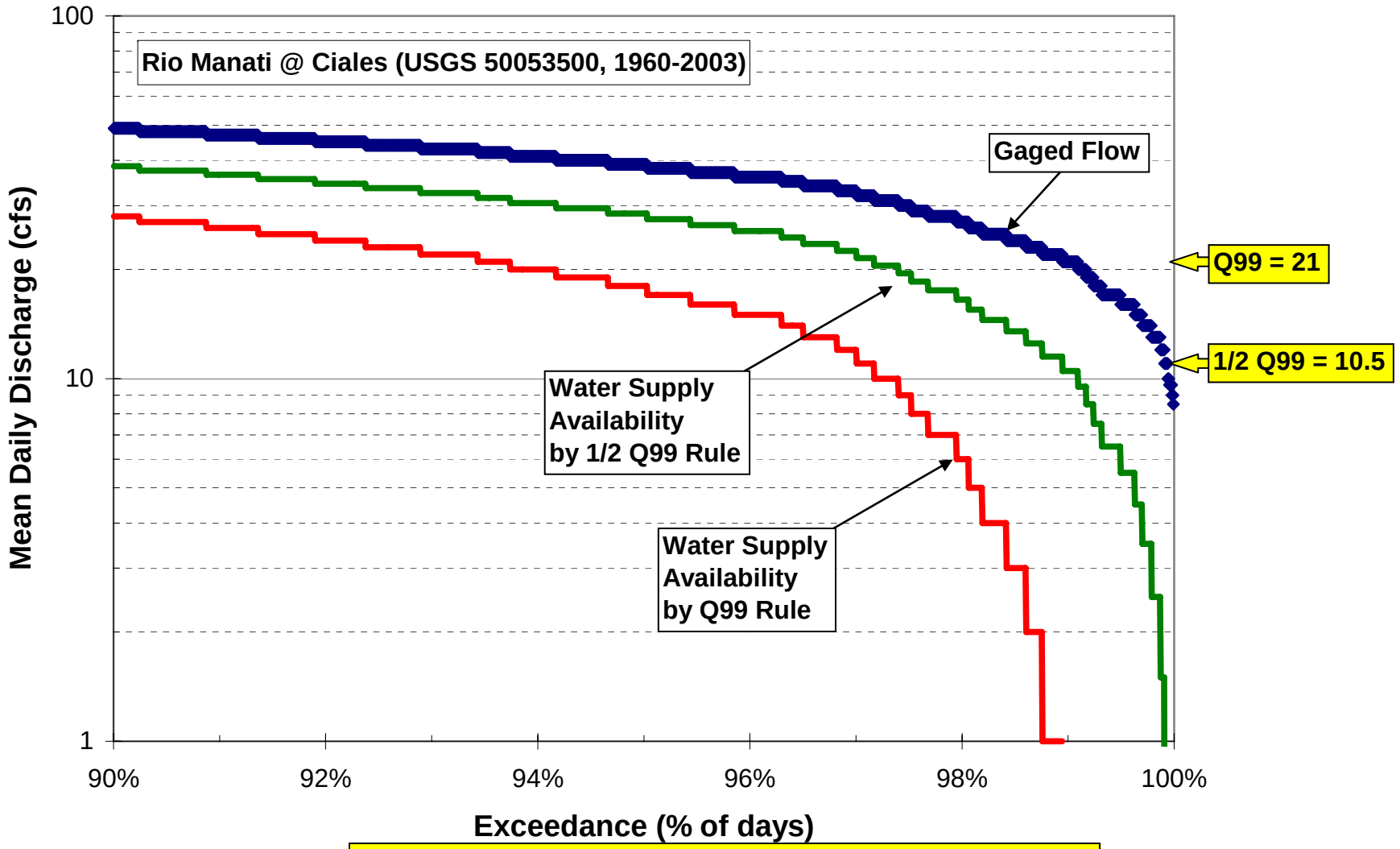


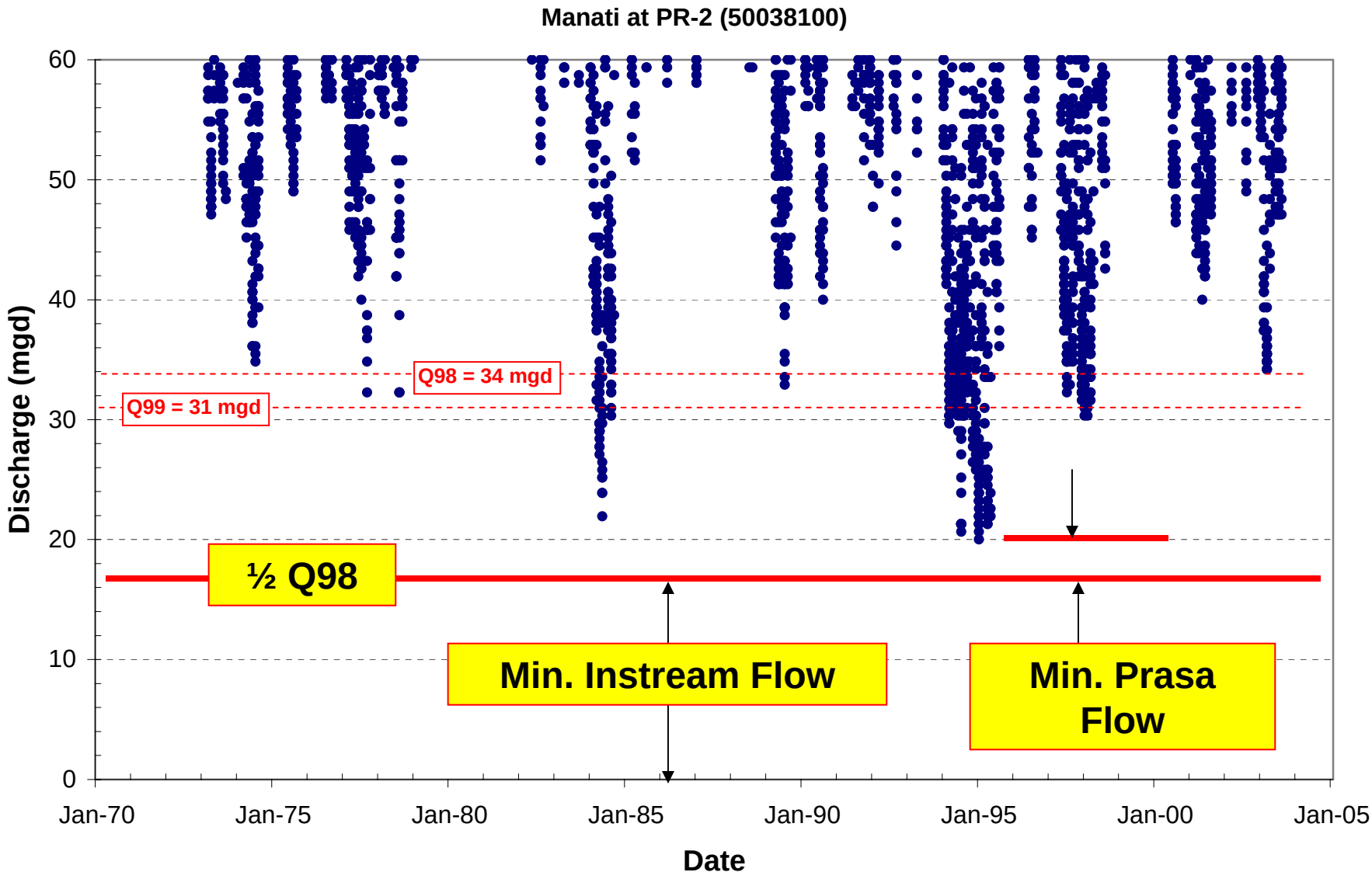
Figure 7: Rule #1requires that a fixed exceedance percentage remain instreamm in this case Q99. The flow available for withdrawal diminishes to zero as streamfloe declines to the Q99 discharge. A similar pattern occurs for any other exceedance selected, such as Q98.



Availability for water supply is always **zero** for some percentage of the days.

Rule #2 – Fixed Min. Flow

- Specified minimum flow must always remain in the river. Whether it always guarantees water for extraction depends on the specified minimum flow rate.
- This rule may be implemented in a stepped manner, such that during low flow periods the required instream flow value may be decreases, thereby of withdrawal will be decreased (rationing), while at the same time the instream flow is also lower, yet still guaranteed.
- A ½ Q98 instream flow is this type of a rule because it establishes a fixed flow rate, not an exceedance.


Manati at PR-2 (50038100)
Discharge (mgd)
60
50
40
30
20
10
0
Q98 = 34 mgd
Q99 = 31 mgd
½ Q98
Min. Instream Flow
Min. Prasa Flow
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Jan-00
Jan-05
Date

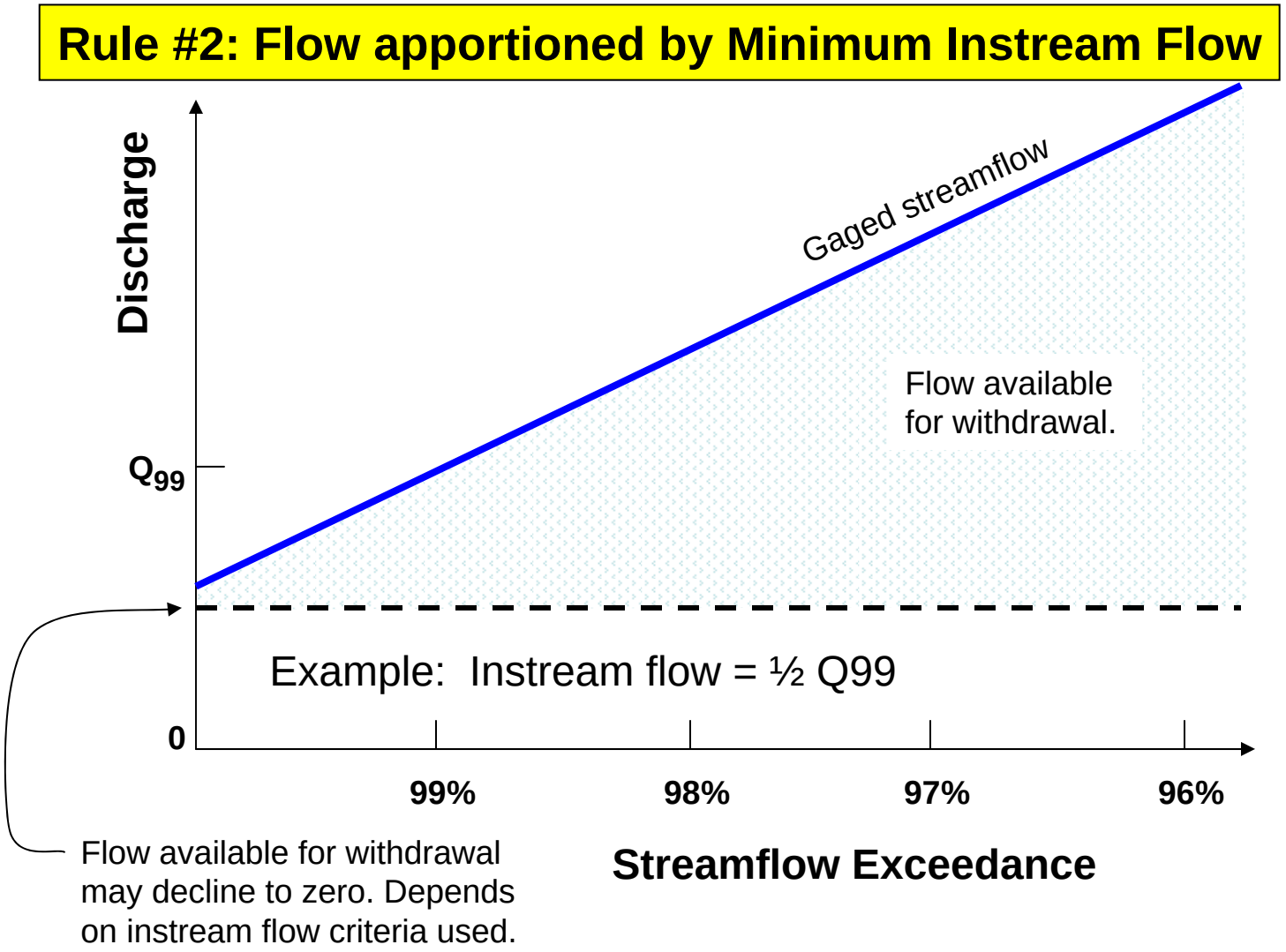


Figure 8: Rule #2 requires that a fixed flow rate remain instream, in this case ½ Q99. The flow available for withdrawal depends on the variability of streamflow. In streams where the minimum daily flow is less than ½ Q99, there would be zero water available for withdrawal on those days.

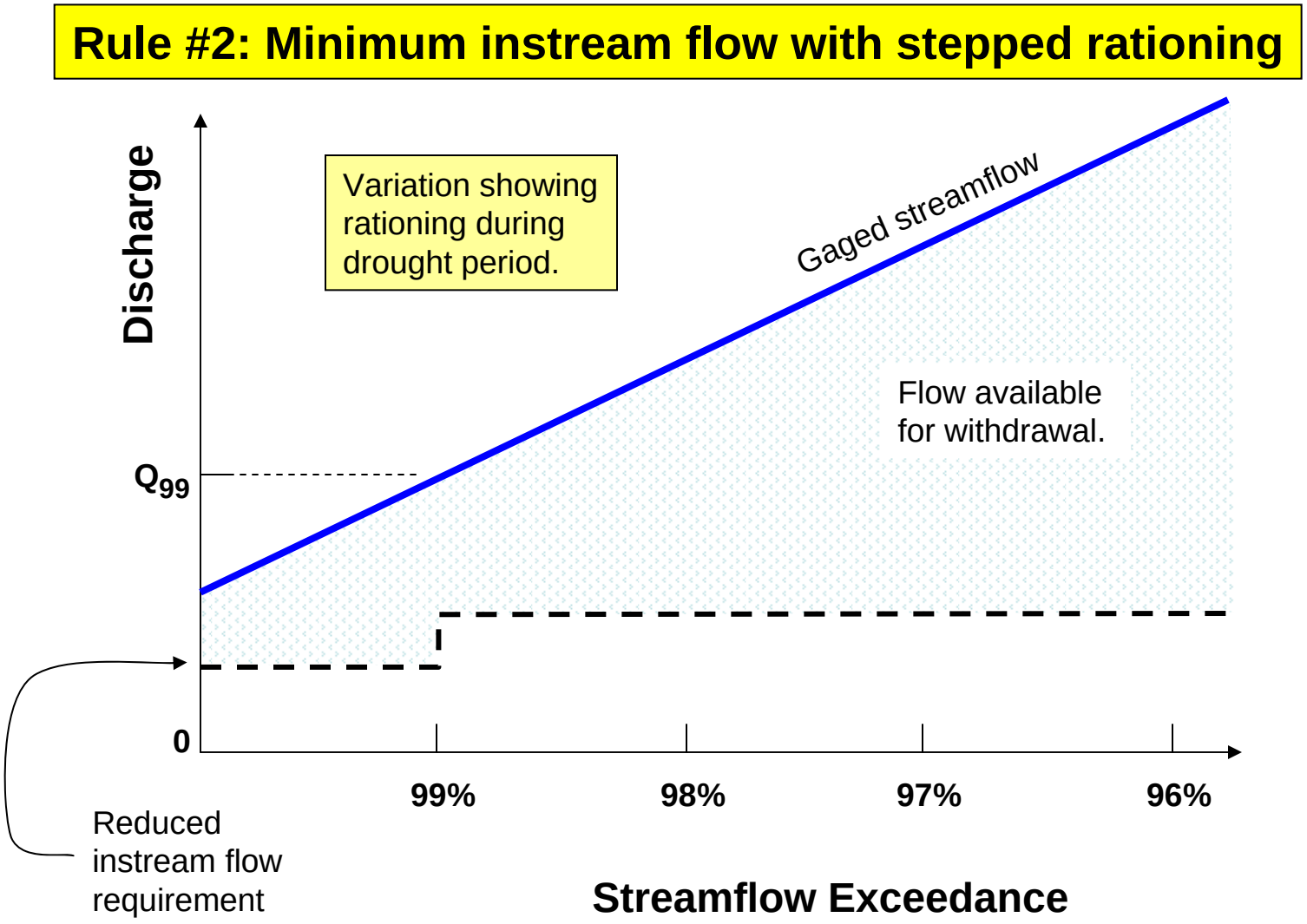


Figure 9: Rule #2 with reducedn instream flow during low flow period.

Rule #3 – Fixed Max. Extraction

- Limits extraction to a specified maximum rate.
- DNER water franchises typically specify a maximum withdrawal rate. Whether or not this guarantees any instream flow depends on the size of the authorized withdrawal.
- If the authorized rate of extraction exceeds the minimum streamflow, there will be zero instream flow,

Rule #3: Flow apportioned by Maximum Withdrawal Rate

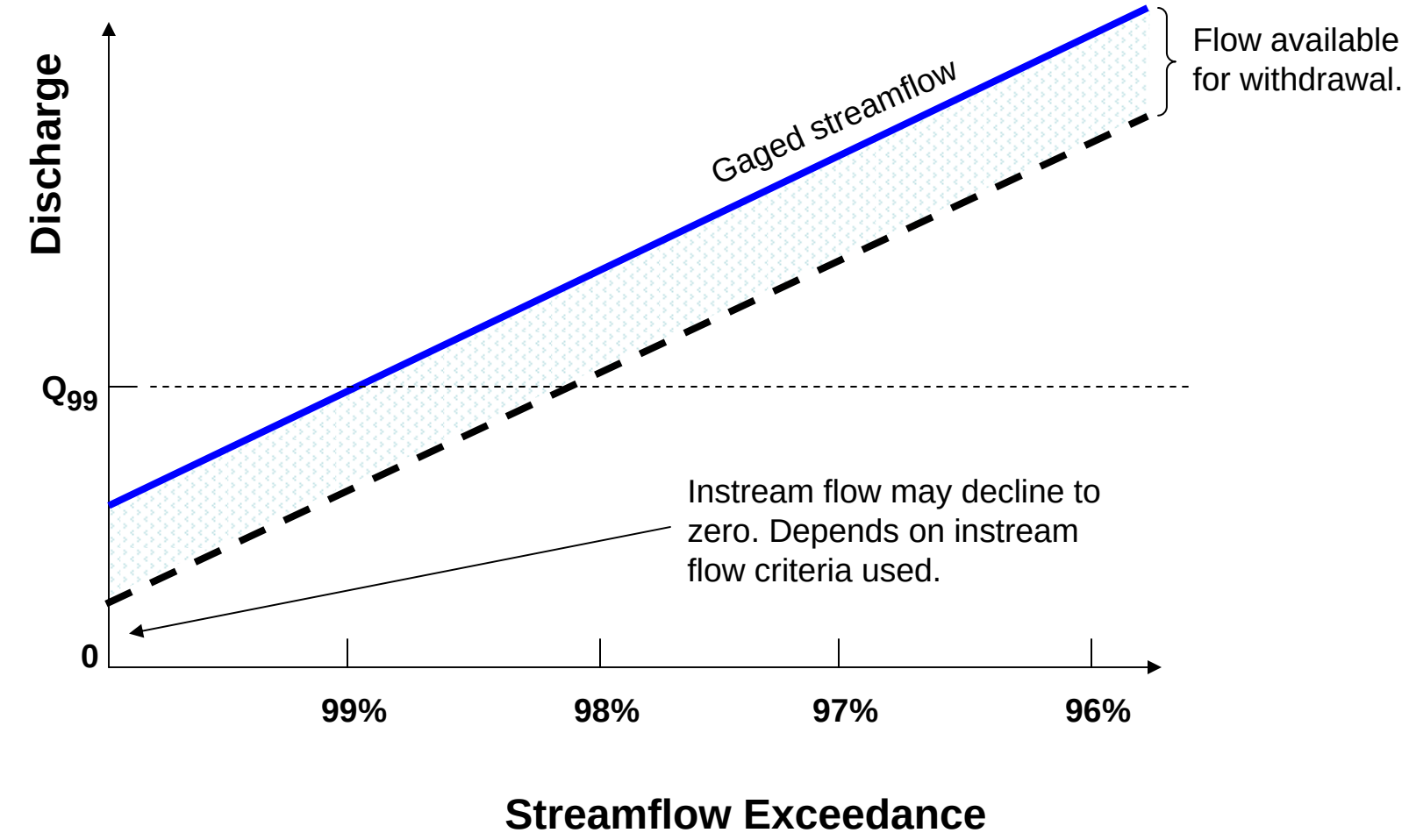


Figure 10: Rule #3 with reducedn instream flow during low flow period.

Rule #3: Normal withdrawal rate exceeds minimum streamflow

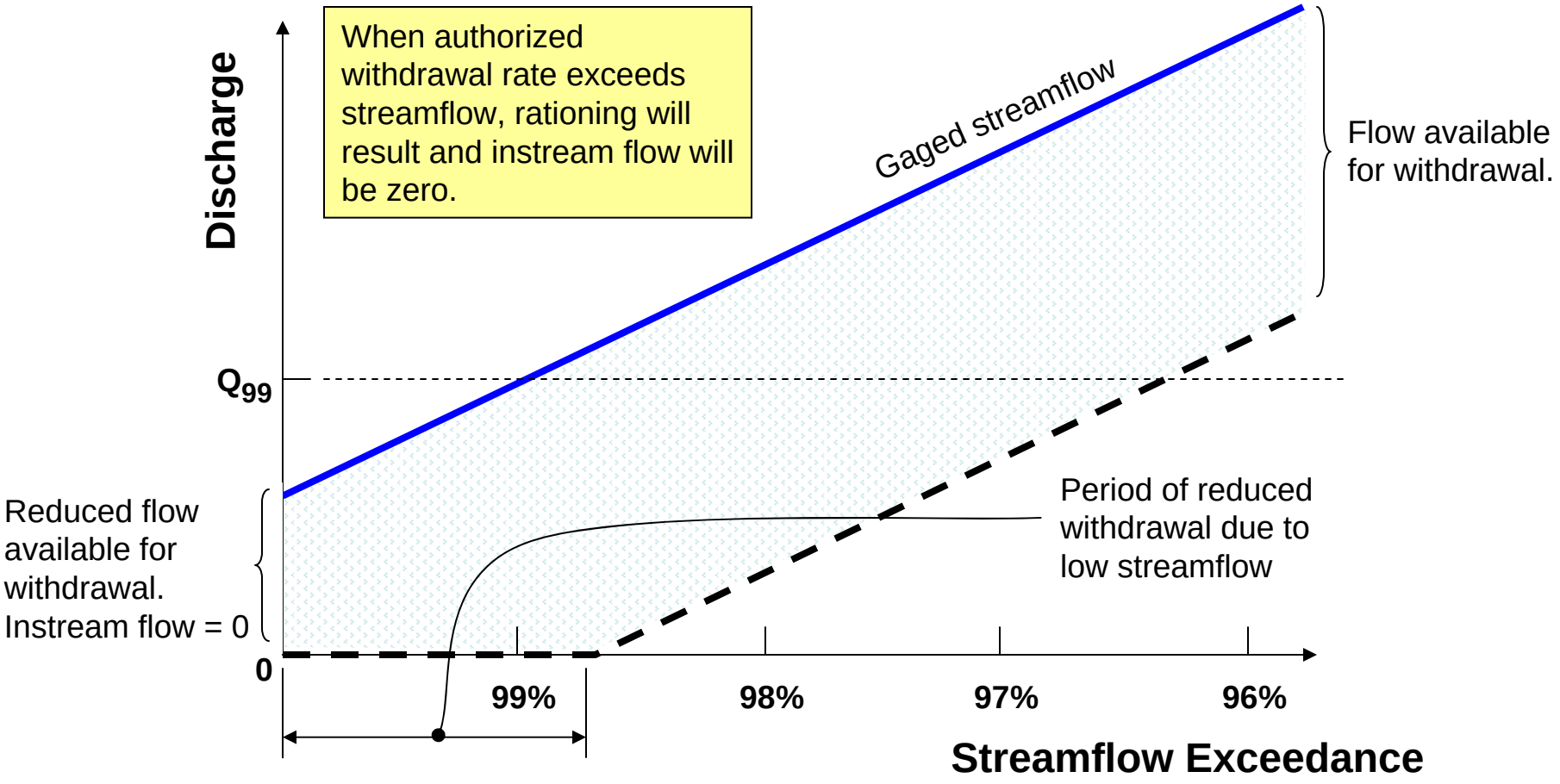


Figure 11: Rule #3 with normal rate of withdrawal exceeding minimum streamflow, resulting in zero instream flow and a reduced rate of extraction. This condition has occurred at a number of the water supply intakes in Puerto Rico.

Rule #3: Maximum withdrawal rate with rationing period

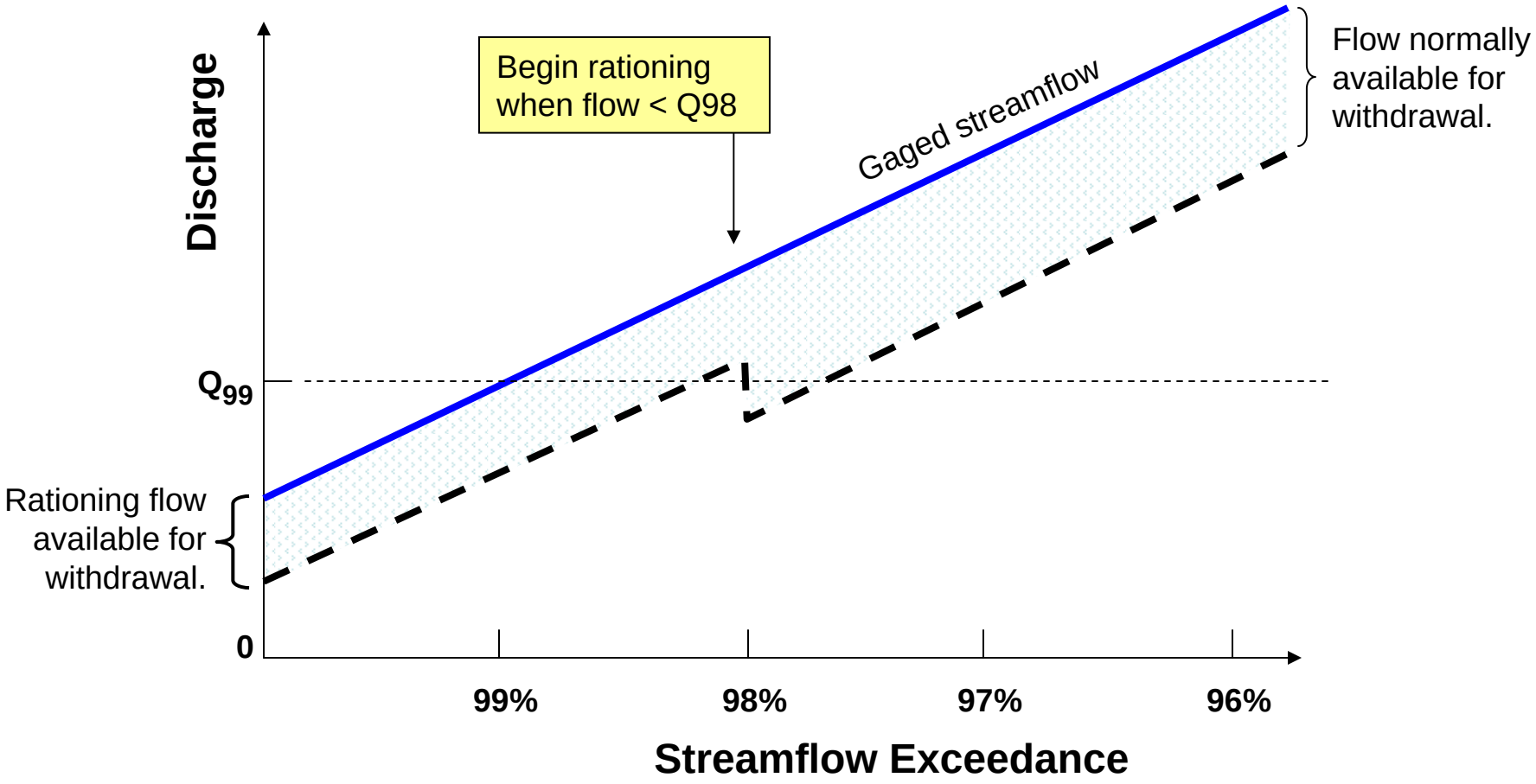


Figure 12: Rule #3 with a rationing rule requiring a reduction in withdrawals (rationing) when streamflow is reduced to Q98.

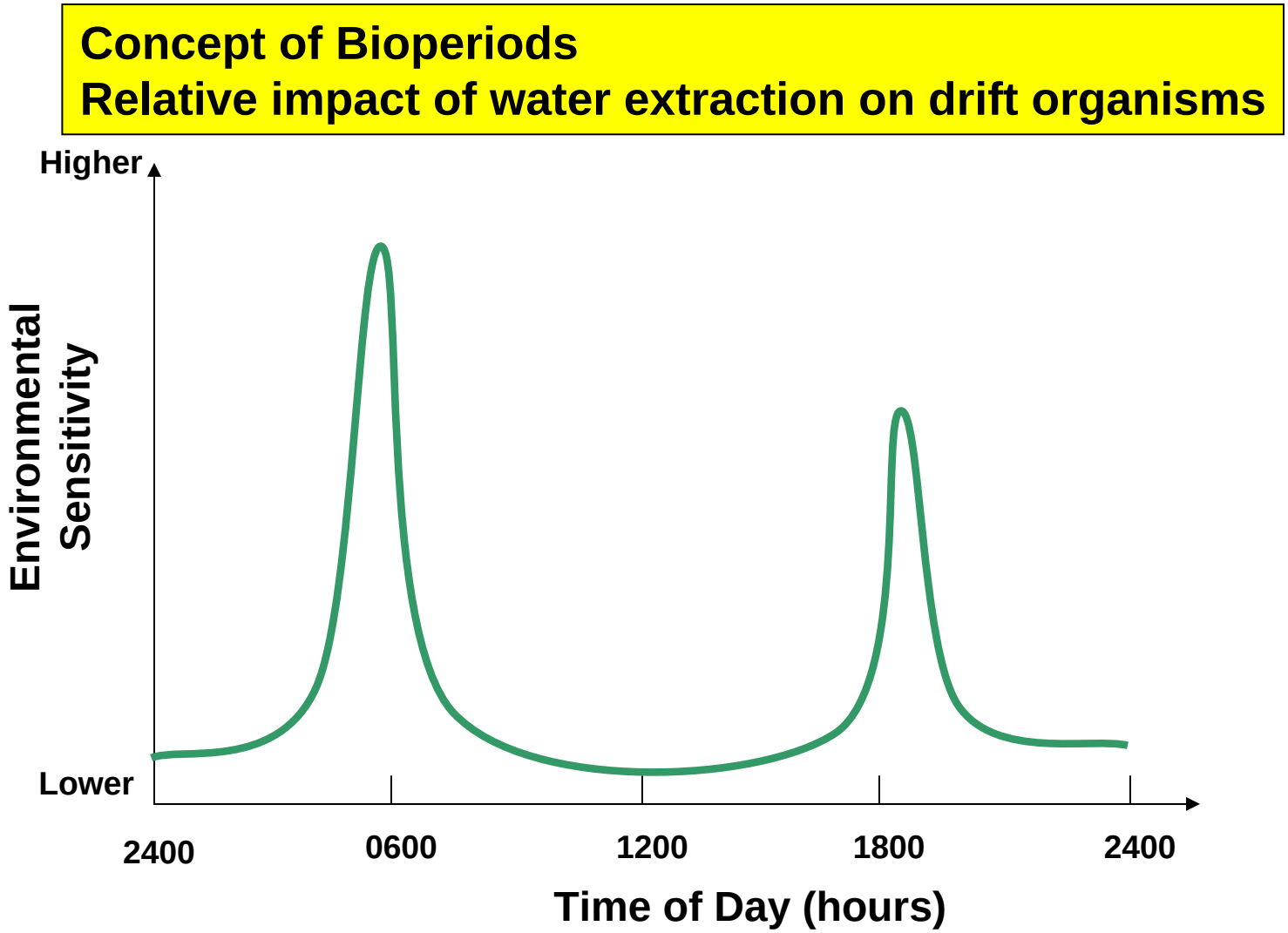


Figure 13: Conceptual bioperiod for drift organisms. Most of the almost microscopic larval aquatic organisms “drift” migrate downstream around dawn and dusk, making these two periods of the day particularly important for maintaining reproductive cycles. This increases the importance of reducing or eliminating water withdrawals during these hours of the day.

Bioperiod Mitigation Alternative

- Intakes operation can suction aquatic organisms into the water supply system.
- The smallest larval organisms are most vulnerable because they are weak swimmers.
- Bioperiods of maximum larval migration in Puerto Rico are around dusk and dawn.
- Turning off intakes about 3 hours per day may reduce larval mortality by about two-thirds.

Potential PRASA Strategies to Sustain Instream Flows

- Interconnected intakes to allow reduced withdrawals from one river to be compensated by withdrawal from another
- Rely more on reservoirs than on rivers on most severe drought days.
- Rely on storage in tanks during daily periods when intakes are shut off.

Final Comments

- PRASA rationing events should be closely tied to instream flows at each intake.
- Whatever method is used to establish minimum flow in the permit must be enforcable and fit the hydraulic condition of the intake and its pumping units (if any).
- Public consciousness is crucial.
- Compliance will not occur without enforcement.
- Rules should be knowledge-based and not arbitrary.

Thank You

Gregory Morris

gregmorris@attglobal.net

www.gmaeng.com

Gage station data are not always without question