AERMOD Training

I. Introduction to Understanding the AERMOD System

The TCEQ is intent on streamlining the process of pre-processing the meteorological data. To understand the issues involved in preprocessing, we will examine the data requirements for AERMET.

A. It is critically important to understand the three new surface characteristics that are required by the AERMET preprocessor. The staff of the TCEQ has some ideas that we would like to put forward for comments from you.

B. The goals today are to understand the key surface characteristics used by the AERMET preprocessor.

C. First, it is important to remind some people that Texas is a BIG state! While some states may only have one or two meteorological stations to examine for modeling, Texas has 17 surface stations and 9 upper air stations. We need to have a manageable, reasonable approach to modeling.

D. Texas has a wide variety of climate and surface characteristics. Many times, a smaller state does not have to address such a diversity of climate and surface characteristics.

II. Albedo

A. The definition of albedo is:

"The albedo is the fraction of total incident solar radiation reflected by the surface. Typical values range from 0.1 for thick deciduous forests to 0.90 for fresh snow."

B. Within the modeling domains, there is a wide range of albedo values. There will be bright areas and dark areas. That may involve some white concrete surfaces and some dark asphalt surfaces. There may be some light colored crops and some dark colored trees.

From our modeling point of view, the higher the albedo, the more reflection of incoming solar radiation occurs. The more reflection of incoming solar radiation that occurs, the less energy is available for sensible heat to be lost from our surface. The less sensible heat that is lost from our surface, the less convective turbulence there will be.

C. Remember albedo values by:

"BIG AND BRIGHT" -- A big albedo value is a bright surface.

D. AERMET requires an average noontime albedo. Albedo is not used for nighttime hours.

E. Typically, the modeling domain's surface characteristics are not homogeneous.

Therefore, why "pretend" like an exact value for albedo can be determined?

F. There are known relationships between albedo and general vegetation coverage. If one could use those relationships to determine general albedo values for areas, then one could assign albedo to county-wide areas for modeling purposes.

G. Matthews' (NASA) relationships were used to obtain average noontime albedo values from typical vegetation coverage in Texas. The resulting albedo map of Texas appears to be a reasonable approximation of the characteristic albedo values across the state.

H. Albedo - Just keep it simple!

III. Bowen Ratio

A. The Bowen ratio is the ratio of the sensible heat flux (H) to the latent (evaporative) heat flux (E).

Bowen Ratio = H/E

B. Remember:

"High and Dry" – A high Bowen Ratio is generally a dry surface.

C. AERMET requires an average mid-day Bowen Ratio for calculations related to daytime convective conditions. Bowen Ratio is not used for nighttime hours. As with albedo, if a source's maximum occurs at night, then Bowen Ratio will have no effect on the predicted concentration.

D. Fortunately, in Texas, Bowen Ratios have already been determined based on water models that include rainfall, surface runoff, and other factors. The reference for this study is: "Spatial Water Balance of Texas", Seann M. Reed, et al, Center for Research in Water Resources, University of Texas at Austin.

E. A map of average Bowen Ratio in Texas illustrates the variations in Bowen Ratio.

The darker areas represent the greater Bowen Ratios. One can observe that West Texas has the greatest Bowen Ratios in the State.

F. Bowen Ratio - Just keep it simple!

IV. Roughness Parameter

A. Definition from the AERMET User's Guide:

"The surface roughness length is related to the height of obstacles to the wind flow and is, in principle, the height at which the mean horizontal wind speed is zero. Values range from less than 0.001 meter over a calm water surface to 1 meter or more over a forest or urban area."

B. How can one develop a method to determine roughness that will provide a reasonable representation (model) of the area being modeled? Can the method used provide some consistency in the modeling or will every model run need uniquely pre-processed meteorological data?

C. The concept for choosing a roughness parameter is simplicity, reproducibility, and reasonableness. Remember, ISC3 essentially used only two roughness lengths. The urban and rural roughness lengths.

For "General" modeling, the preferred method will be to choose one of three roughness lengths for modeling. The choice will be based on a review of the modeling domain taking into account the source characteristics. Justification of this choice will need to be documented in the modeling report.

For "Special Case" modeling, the method will be to carefully analyze the surface characteristics. In situations where the surrounding area may have variations in land use, use eight sectors to define the roughness lengths. Examine each sector to a distance of the modeling domain which is dependant upon source characteristics. Choose a roughness length that best fits the land use within each sector.

D. The TCEQ has compiled published roughness parameter data from 20 studies. Over 140 values for roughness length have been tabulated.

E. The published data illustrates the range of roughness values that one must deal with. One must survey the region of the modeling domain. It is important to not think in terms of just a 3 kilometer radius anymore. The modeling domain is dependant upon source characteristics.

After surveying the domain for roughness, what information do you have? It will almost always be a mix of many different roughness values. A general roughness

value for the modeling domain may be chosen from one of three categories of roughness: Low, medium, and high roughness.

F. Next, it is important to stop for a reality check.

How well can one really "calculate", "estimate", or "guess" at the roughness parameter for the modeling domain? How homogeneous is the modeling domain? Can one document it sufficiently for submittal and review to the TCEQ? Is it not true that a 3-category method would work as well?

G. Keep it Simple!

Consider using one of three categories for roughness and document your choice.

Category 1: Flat Areas
0.001 – 0.1 m ----> Use a value of 0.05 m

Category 2: Rural/Suburban Areas
0.1 – 1.0 m ----> Use a value of 0.5 m

Category 3: Urban/Industrial Areas
0.7 – 1.5 m ----> Use a value of 1.0 m

H. Photographic examples of roughness categories may be used to help permit applicants and consultants correctly determine roughness categories for modeling purposes.

V. Summary

The TCEQ's implementation of AERMOD is based on the following:

Reasonable approach
Consistent approach
Equitable/Fair approach
Reviewable approach

One needs a reasonable approach to processing meteorological data in the great state of Texas. It must be consistent, which lead to fair treatment for everyone. And it must be a reviewable approach. A method that the TCEQ can review, audit, and reproduce.

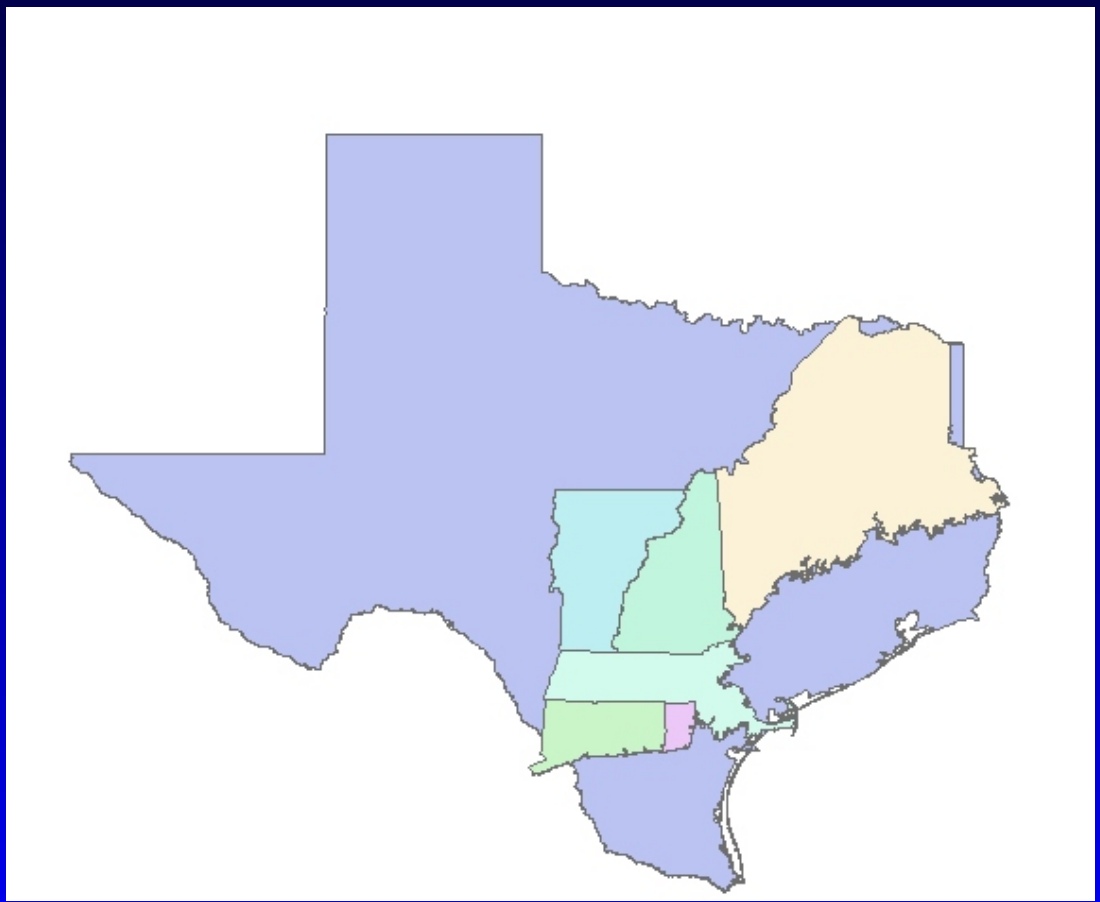
AERMOD TRAINING

Understanding the key surface characteristics used by AERMET

Goals

- **Understand the key surface characteristics used by the AERMET preprocessor:**
  - **Albedo**
  - **Bowen ratio**
  - **Roughness parameter**

Texas is a BIG state!



Albedo

Albedo

Definition

- "The albedo is the fraction of total incident solar radiation reflected by the surface. Typical values range from 0.1 for thick deciduous forests to 0.90 for fresh snow."

Definition from AERMET User's Guide

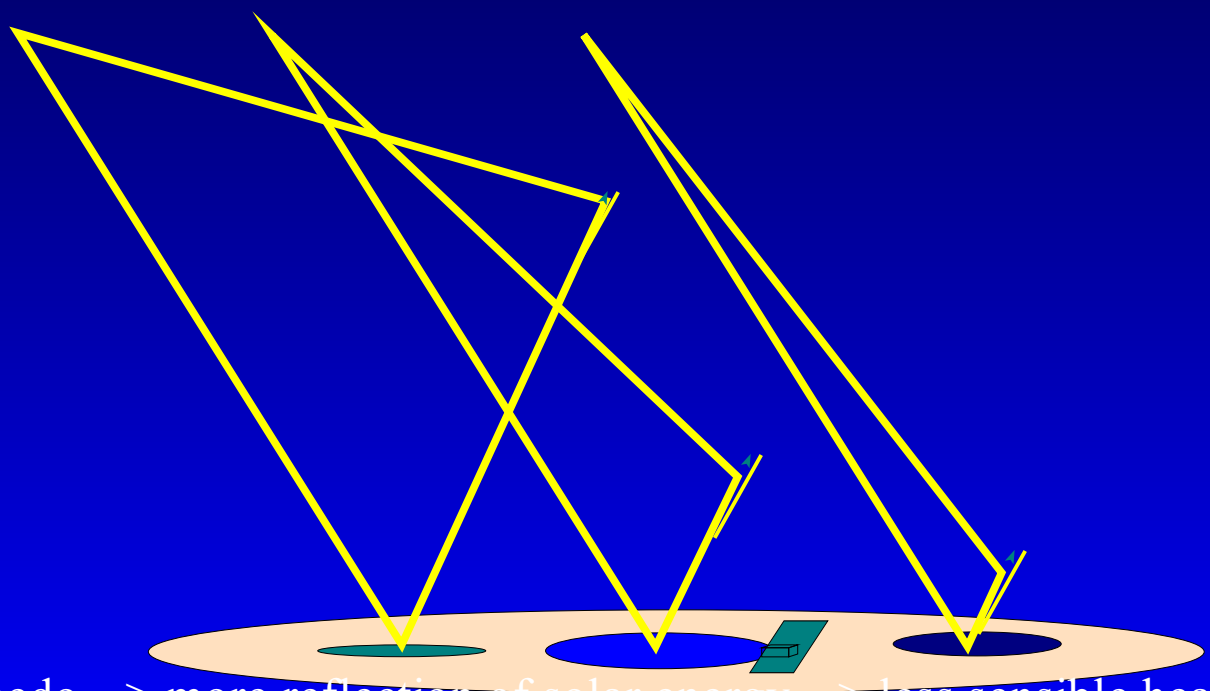
Albedo

Concept

- Reflectivity of the ground within the modeling domain

Albedo

Different albedos within the modeling domain



Higher albedo --> more reflection of solar energy --> less sensible heat radiated --> less turbulence

Albedo

Concept

- Remembering albedo values:

  "BIG AND BRIGHT"

  A big albedo value is a bright surface.

Albedo

Concept

- Related to:
  - vegetation coverage
  - soil type
  - moisture
  - snow cover
- Also related to:
  - sun angle (time of day and latitude)

Albedo

AERMET Requirement

- Average noontime albedo
- Albedo is not used for nighttime hours.

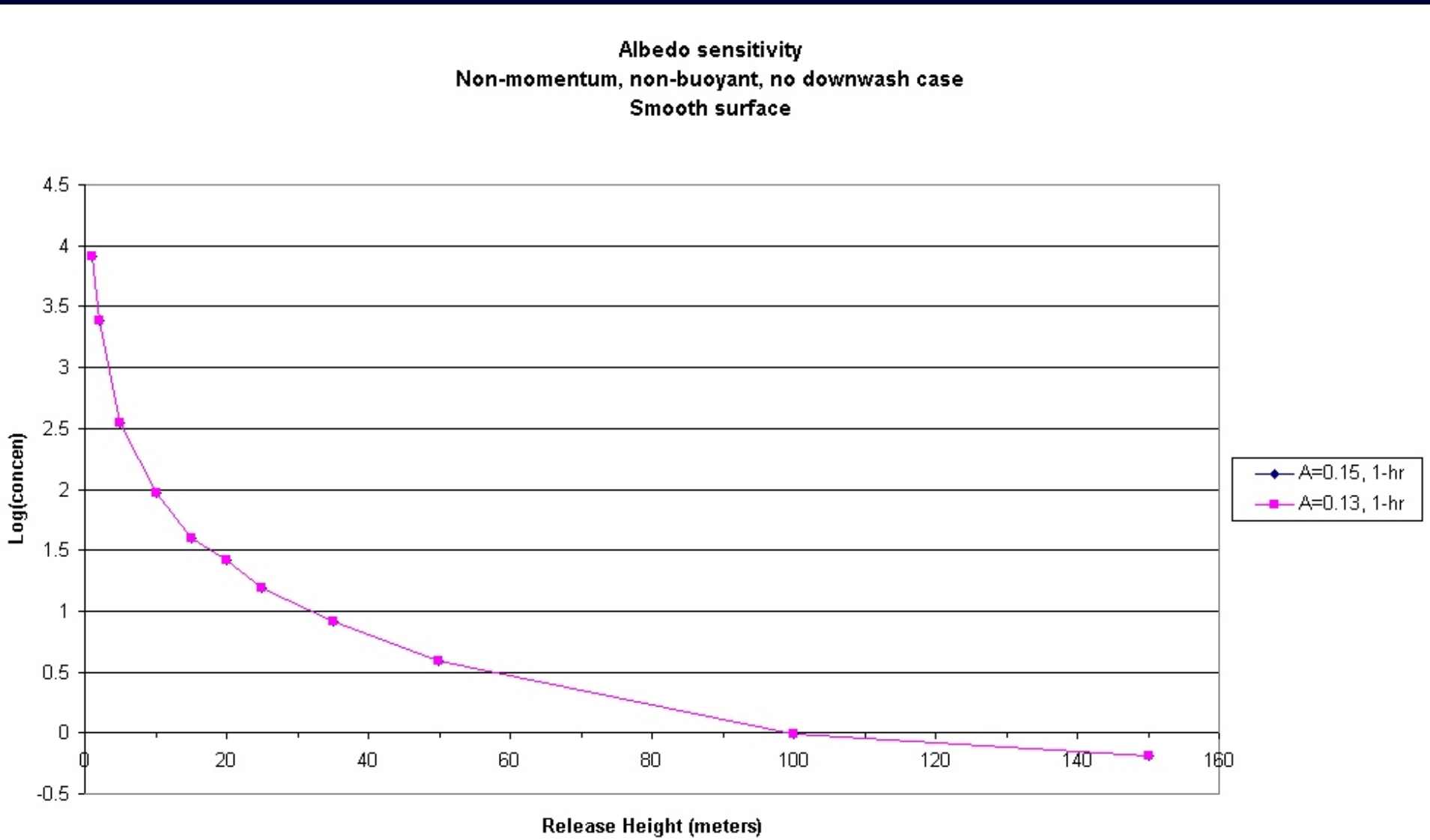
Albedo

The Effects of Albedo

- In general, model is not sensitive to small variations in albedo

  Nighttime dispersion is totally unaffected by albedo

  Small changes in the convective boundary layer


Albedo sensitivity
Non-momentum, non-buoyant, no downwash case
Smooth surface
Log(concen)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
0
20
40
60
80
100
120
140
160
Release Height (meters)
A=0.15, 1-hr
A=0.13, 1-hr

Albedo

Concepts

- Surface characteristics not homogeneous
- Therefore, why “pretend” like an exact value for albedo can be determined?

Albedo

Concepts

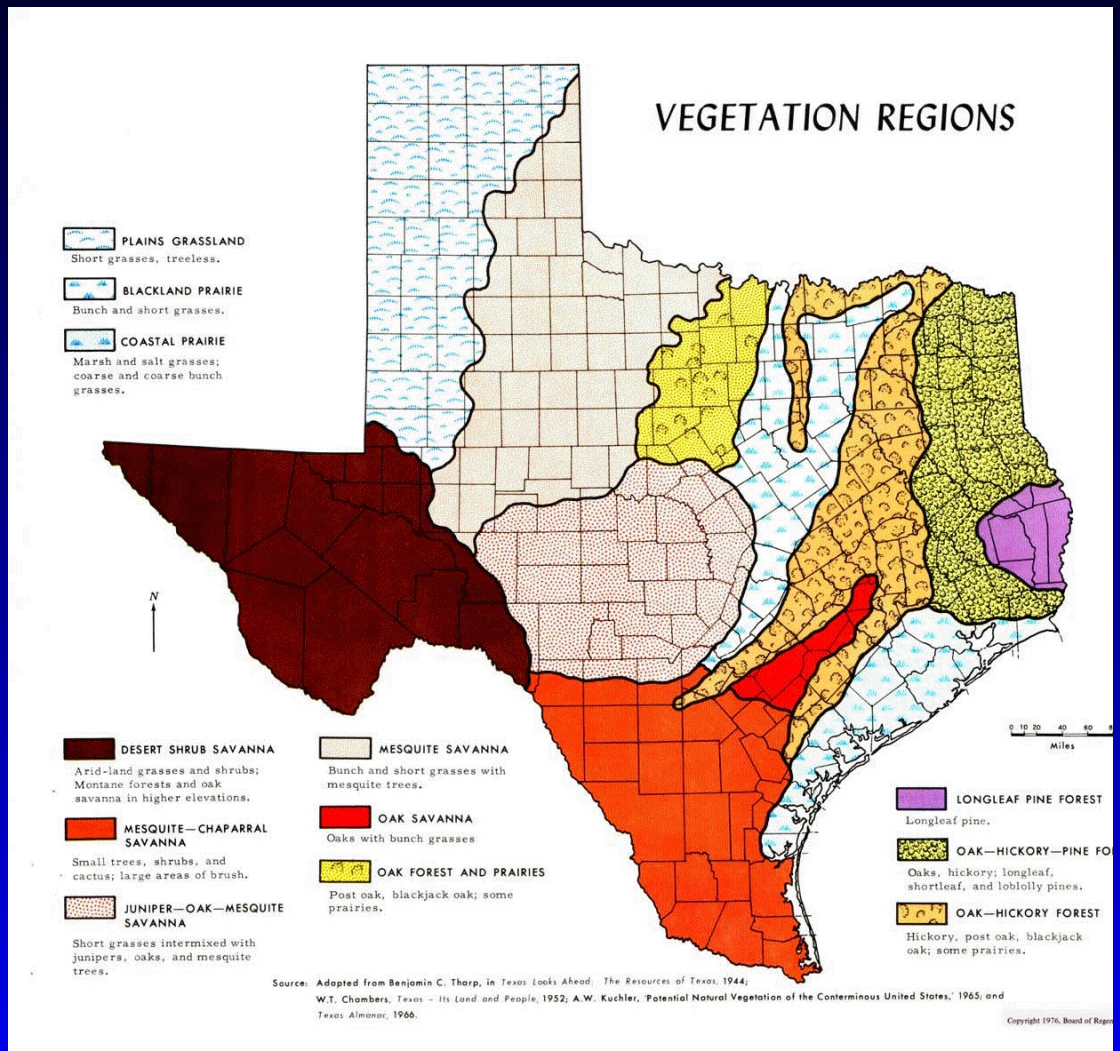
- Known relationships between albedo and vegetation coverage
- Use those relationships to determine general albedo values for areas

Albedo

Concepts

- Matthews' relationships were used to obtain average noontime albedo values from typical vegetation coverage in Texas.

Matthews, Elaine., 1983. "Vegetation, Land Use and Seasonal Albedo Data Sets: Documentation of Archived Data Tape." NASA Technical Memorandum #86107

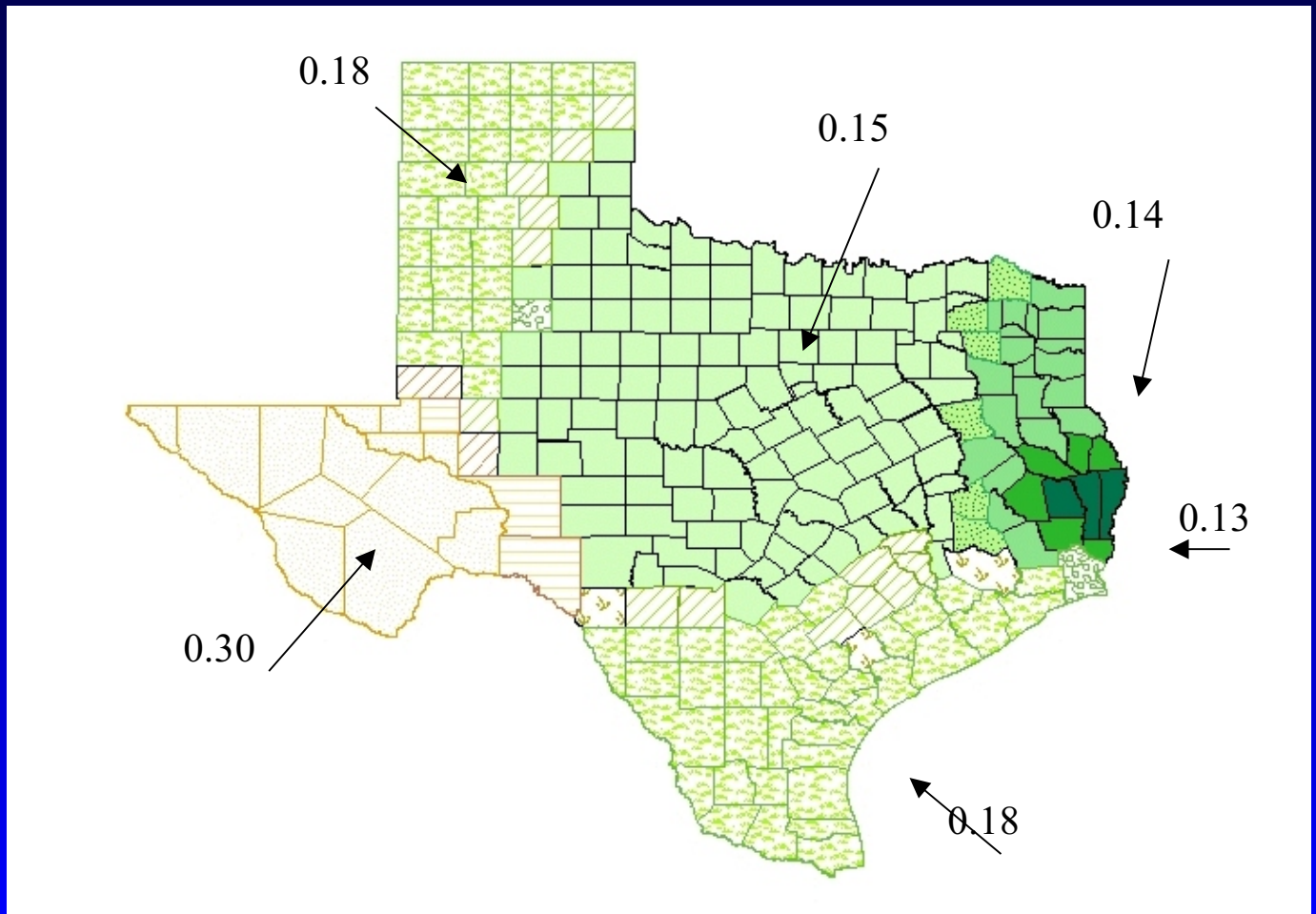

VEGETATION REGIONS
PLAINS GRASSLAND
Short grasses, treeless.
BLACKLAND PRAIRIE
Bunch and short grasses.
COASTAL PRAIRIE
Marsh and salt grasses; coarse and coarse bunch grasses.
N
DESERT SHRUB SAVANNA
Arid-land grasses and shrubs; Montane forests and oak savanna in higher elevations.
MESQUITE—CHAPARRAL SAVANNA
Small trees, shrubs, and cactus; large areas of brush.
JUNIPER—OAK—MESQUITE SAVANNA
Short grasses intermixed with junipers, oaks, and mesquite trees.
MESQUITE SAVANNA
Bunch and short grasses with mesquite trees.
OAK SAVANNA
Oaks with bunch grasses
OAK FOREST AND PRAIRIES
Post oak, blackjack oak; some prairies.
0 10 20 40 60
Miles
LONGLEAF PINE FOREST
Longleaf pine.
OAK—HICKORY—PINE FO
Oaks, hickory; longleaf, shortleaf, and loblolly pines.
OAK—HICKORY FOREST
Hickory, post oak, blackjack oak; some prairies.
Source: Adapted from Benjamin C. Tharp, in Texas Looks Ahead. The Resources of Texas, 1944; W.T. Chambers, Texas – Its Land and People, 1952; A.W. Kuchler, 'Potential Natural Vegetation of the Conterminous United States,' 1965; and Texas Almanac, 1966.
Copyright 1976, Board of Regen

Albedo

Methodology

- Assign albedo values to vegetation types typical to regions in Texas.

Albedo by Vegetation



Albedo by EPA

Concept

TABLE 4-1

ALBEDO OF GROUND COVERS BY LAND-USE AND SEASON

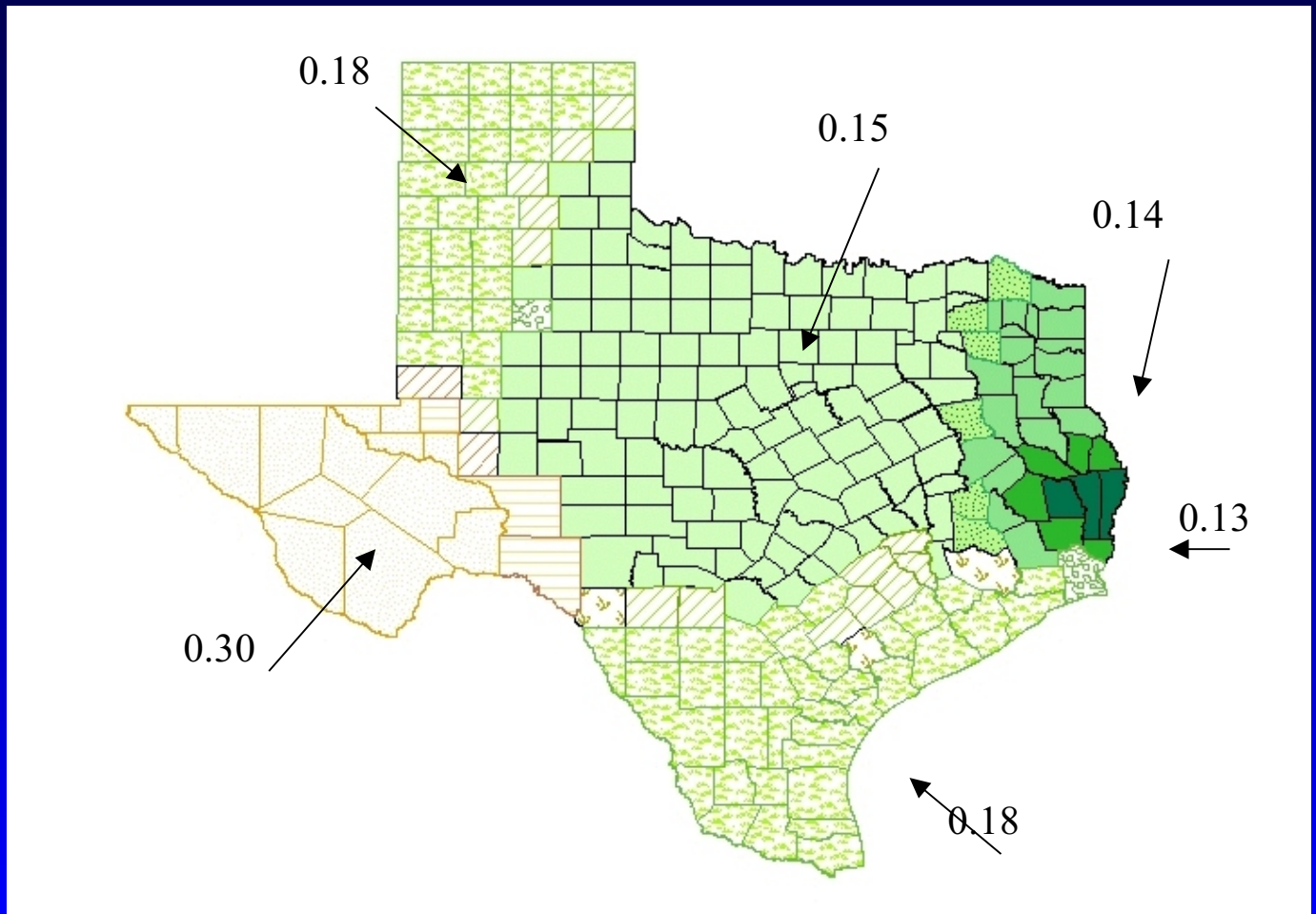
Land-Use	Spring	Summer	Autumn	Winter
Water (fresh and sea)	0.12	0.10	0.14	0.20
Deciduous Forest	0.12	0.12	0.12	0.50
Coniferous Forest	0.12	0.12	0.12	0.35
Swamp	0.12	0.14	0.16	0.30
Cultivated Land	0.14	0.20	0.18	0.60
Grassland	0.18	0.18	0.20	0.60
Urban	0.14	0.16	0.18	0.35
Desert Shrubland	0.30	0.28	0.28	0.45

Albedo

Reality Check

- Are you really better off trying to fit your area's characteristics for albedo to EPA's broad category approach?
- How would the TCEQ audit the values that you chose based on this approach?

Albedo - Keep it Simple



Bowen Ratio

Bowen Ratio

Definition

- The ratio of the sensible heat flux to the latent heat flux.

$$B = \frac{H}{E}$$

Bowen Ratio

Concept

- Think of the Bowen Ratio as a measure of how dry a surface is.
  - A large Bowen Ratio is indicative of a dry surface.
  - A small Bowen Ratio is indicative of a moist surface.

$$B = \frac{H}{E}$$

Bowen Ratio

Concept

- Remember:

  "High and Dry"

  A high Bowen Ratio is generally a dry surface.

Bowen Ratio

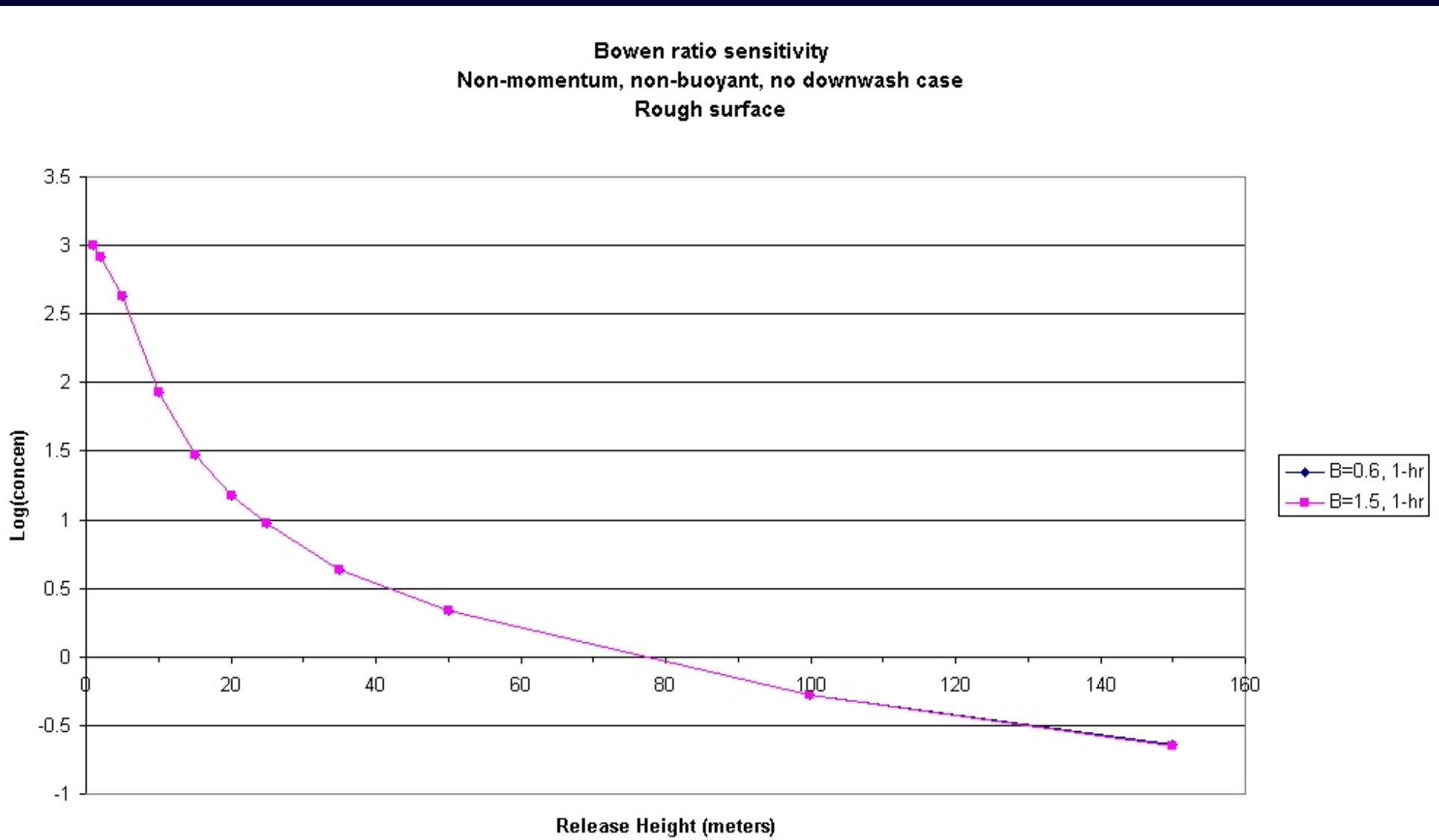
Concept

- Desert surface = dry surface = high Bowen
  - West Texas has greater Bowen Ratios than East Texas

Bowen Ratio

AERMET Requirement

- Average noonday Bowen ratio
- Not used for nighttime hours
- Model is not very sensitive to small changes in Bowen Ratio in many cases.


Bowen ratio sensitivity
Non-momentum, non-buoyant, no downwash case
Rough surface
Log(concen)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
0
20
40
60
80
100
120
140
160
Release Height (meters)
B=0.6, 1-hr
B=1.5, 1-hr

Bowen Ratio

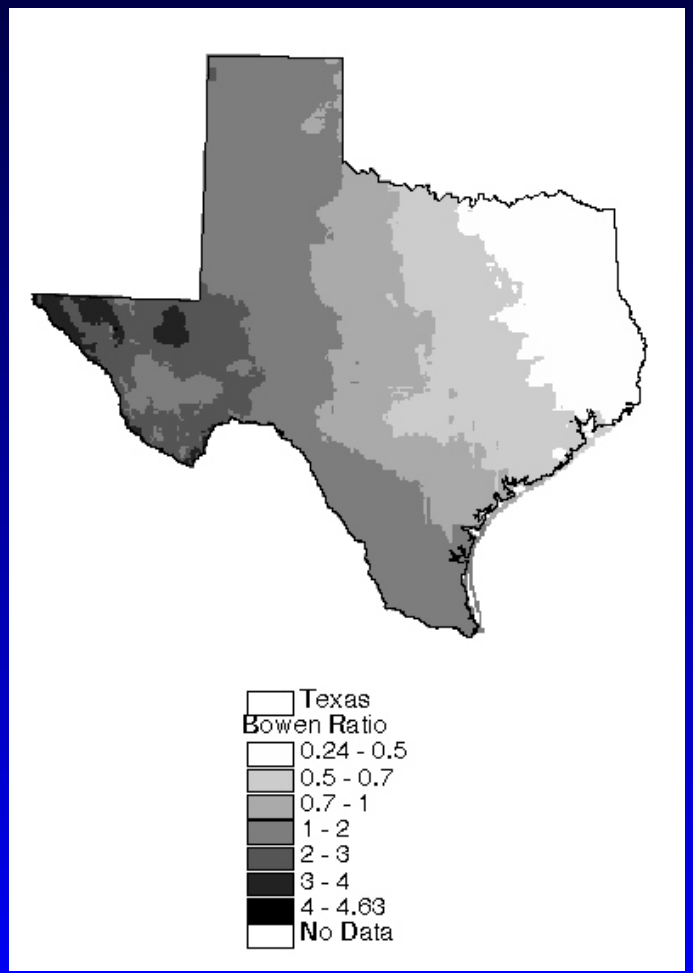
How to determine it

- Texas Bowen Ratios have already been determined

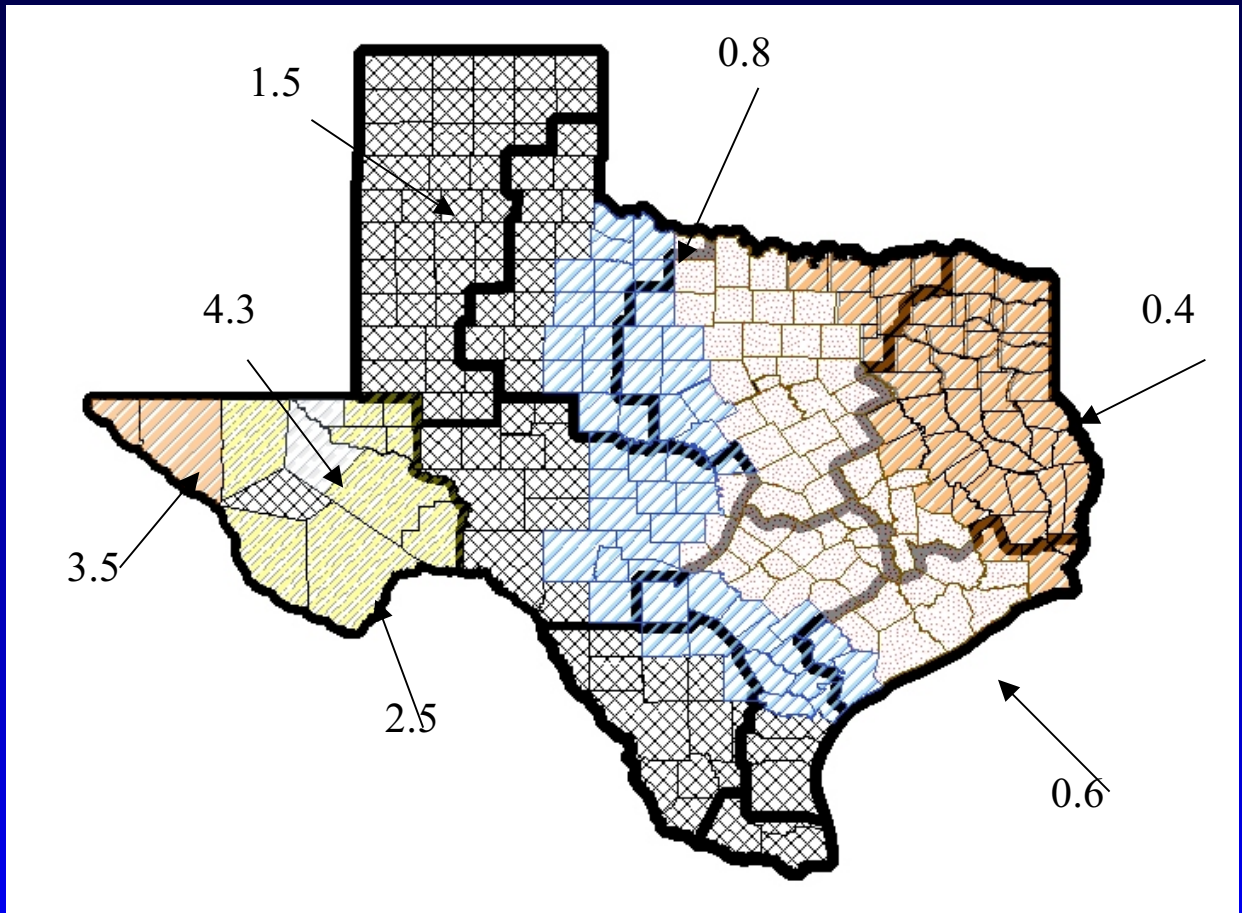
Reference: "Spatial Water Balance of Texas", Seann M. Reed, et al, Center for Research in Water Resources,

University of Texas at Austin

Bowen Ratio



Bowen Ratio



Bowen Ratio

EPA Guidance

TABLE 4-2b

DAYTIME BOWEN RATIO BY LAND-USE AND SEASON
AVERAGE MOISTURE CONDITIONS

Land-Use	Spring	Summer	Autumn	Winter
Water (fresh and sea)	0.1	0.1	0.1	1.5
Deciduous Forest	0.7	0.3	1.0	1.5
Coniferous Forest	0.7	0.3	0.8	1.5
Swamp	0.1	0.1	0.1	1.5
Cultivated Land	0.3	0.5	0.7	1.5
Grassland	0.4	0.8	1.0	1.5
Urban	1.0	2.0	2.0	1.5
Desert Shrubland	3.0	4.0	6.0	6.0

Bowen Ratio

Reality Check

- Are you really better off trying to fit your area's characteristics for Bowen Ratio to EPA's broad category approach?
- How would the TCEQ audit the values that you chose based on this approach?

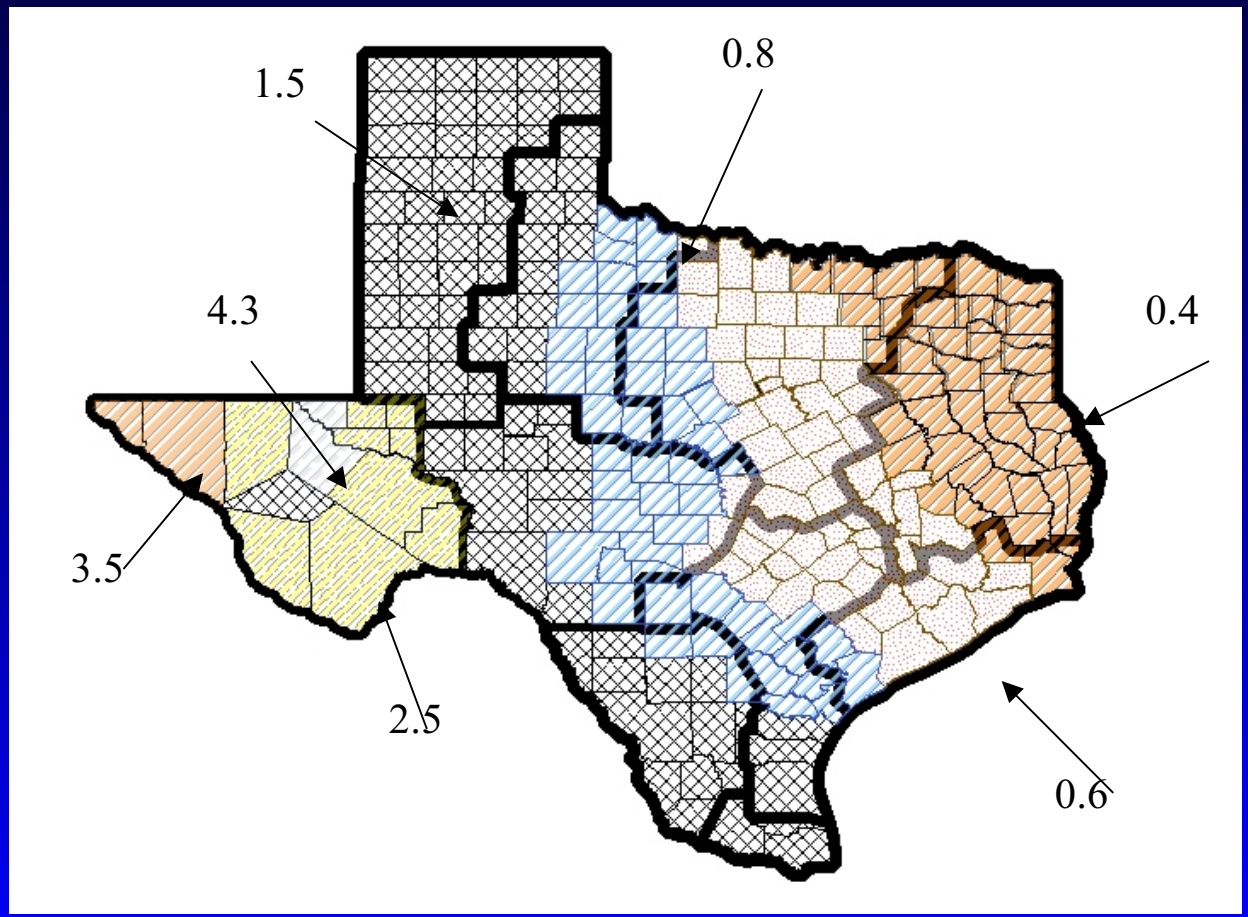
Bowen Ratio

Comparison: EPA & TCEQ

- TCEQ values
  Range from 0.4 in East Texas to 4.3 in West Texas

- EPA values
  Range from 0.9 (deciduous forests) to 4.8 (for desert shrub land).

Bowen Ratio - Keep it Simple



Roughness Parameter

Roughness Parameter

Definition

- "The surface roughness length is related to the height of obstacles to the wind flow and is, in principle, the height at which the mean horizontal wind speed is zero."

"Values range: less than 0.001 meter over a calm water surface to 1 meter or more over a forest or urban area" (AERMET User's Guide)

Roughness Parameter

Goals

- Develop reasonable roughness values that will provide a reasonable representation (model) of the areas we are analyzing
- Provide consistency in the modeling

Roughness Parameter

Concept

- General modeling (Preferred method)

  Choose one of three roughness lengths for modeling.

  Base the choice on a review of the modeling domain taking into account the source characteristics. The justification of the choice of roughness length will need to be documented in the modeling report.

Roughness Parameter

- Special case modeling

  In situations where the surrounding area may have extreme variations in land use, use sectors to define the roughness lengths.

  Examine each sector (different directions) to the appropriate modeling domain distance taking into account source characteristics.

  Choose roughness length that best fits the land use within each sector.

  Document approach and have method pre-approved by TCEQ

Roughness Parameter

AERMET Requirement

- Single value may be used to describe the modeling domain
- Multiple values may be used based on sectors around the compass
- Multiple values may be used based on seasons

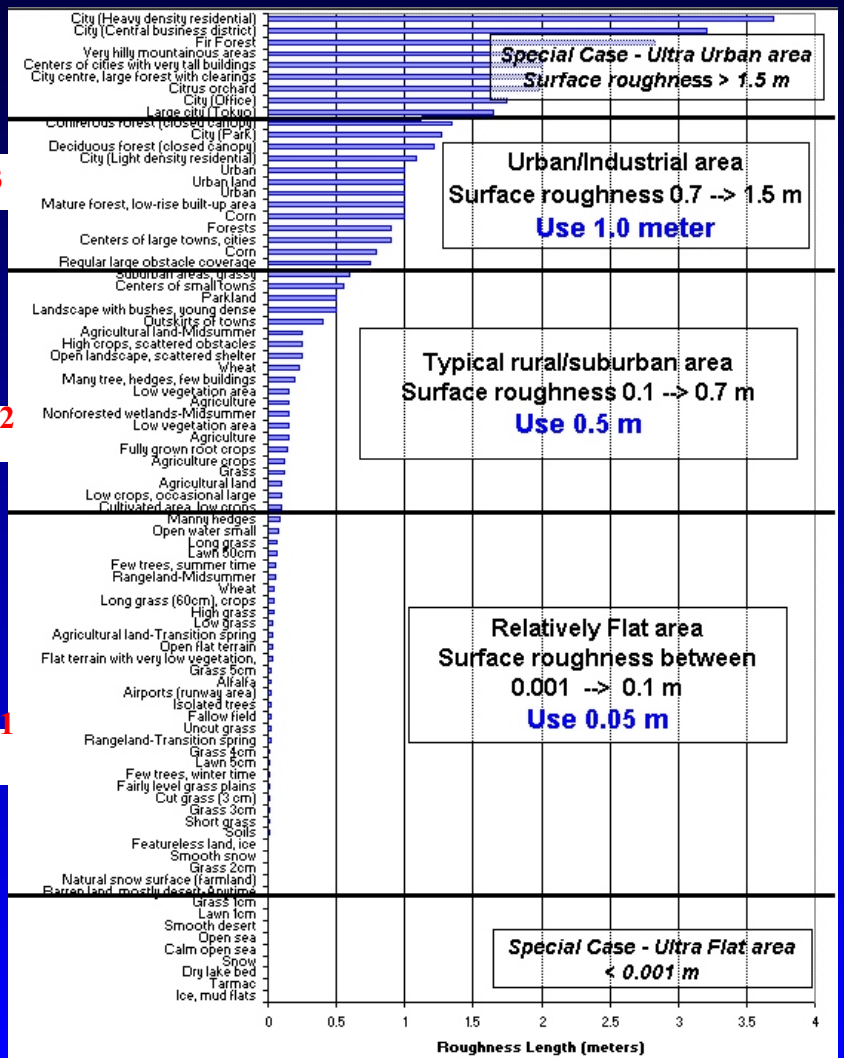
Roughness Parameter

Data

- TCEQ has compiled Published Roughness Parameter Data from 20 Studies

  Over 140 values for roughness have been tabulated.

Roughness Parameter



Category 3

Category 2

Category 1

High

Medium

Low

Roughness Parameter

EPA Guidance

TABLE 4-3

SURFACE ROUGHNESS LENGTH, IN METERS, BY LAND-USE AND SEASON

Land-Use	Spring	Summer	Autumn	Winter
Water (fresh and sea)	0.0001	0.0001	0.0001	0.0001
Deciduous Forest	1.00	1.30	0.80	0.50
Coniferous Forest	1.30	1.30	1.30	1.30
Swamp	0.20	0.20	0.20	0.05
Cultivated Land	0.03	0.20	0.05	0.01
Grassland	0.05	0.10	0.01	0.001
Urban	1.00	1.00	1.00	1.00
Desert Shrubland	0.30	0.30	0.30	0.15

An additional source of information for surface roughness length can be found in Stull (1988).

Roughness Parameter

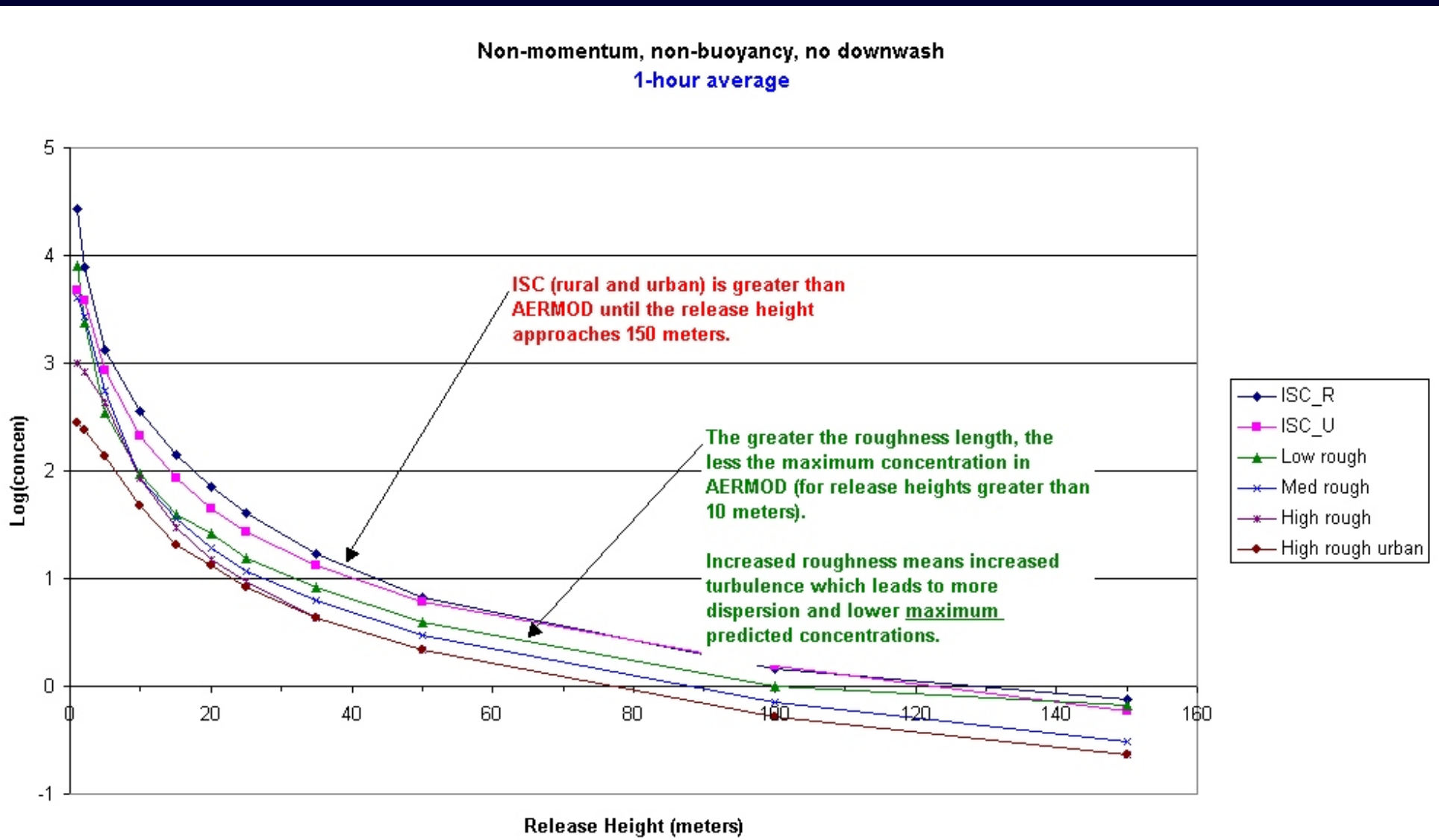
Reality Check

- How well can you really “calculate”, “estimate”, or “guess” at the roughness parameter for your modeling domain?
- How homogeneous is your area, really?
- Can you document it sufficiently for submittal and review to the TCEQ?
- Would a 3-category method work as well?

Roughness Parameter

Keep it Simple, Use Three Categories

- Category 1: Flat Areas
  0.001 – 0.1 m ----> Use a value of 0.05 m
- Category 2: Rural/Suburban Areas
  0.1 – 1.0 m ----> Use a value of 0.5 m
- Category 3: Urban/Industrial Areas
  0.7 – 1.5 m ----> Use a value of 1.0 m


Non-momentum, non-buoyancy, no downwash
1-hour average
Log(concen)
Release Height (meters)
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
160
ISC (rural and urban) is greater than AERMOD until the release height approaches 150 meters.
The greater the roughness length, the less the maximum concentration in AERMOD (for release heights greater than 10 meters).
Increased roughness means increased turbulence which leads to more dispersion and lower maximum predicted concentrations.
ISC_R
ISC_U
Low rough
Med rough
High rough
High rough urban

Roughness Parameter

Examples

- Category 1: Flat Areas

Roughness Parameter

Examples

- Category 2: Rural/Suburban

Roughness Parameter

Examples

- Category 3: Urban/Industrial Areas

Roughness Parameter

Keep it Simple

- Choose one of three values
  - Category 1: Flat Areas (0.05 m)
  - Category 2: Rural/Suburban Areas (0.5 m)
  - Category 3: Urban/Industrial Areas (1.0 m)

Summary for AERMOD Refined Screening

Keep it Simple
Keep it Simple
Keep it Simple
Keep it Simple

- Reasonable approach
- Consistent approach
- Equitable/Fair approach
- Reviewable approach

Summary for AERMOD