United States Department of Agriculture
Natural Resources Conservation Service

USDA NRCS

Surface Irrigation
NEH Part 623 Chapter 4

Released September 2012

Replaces Chapter 4 (Border Irrigation)
and Chapter 5 (Furrow Irrigation)

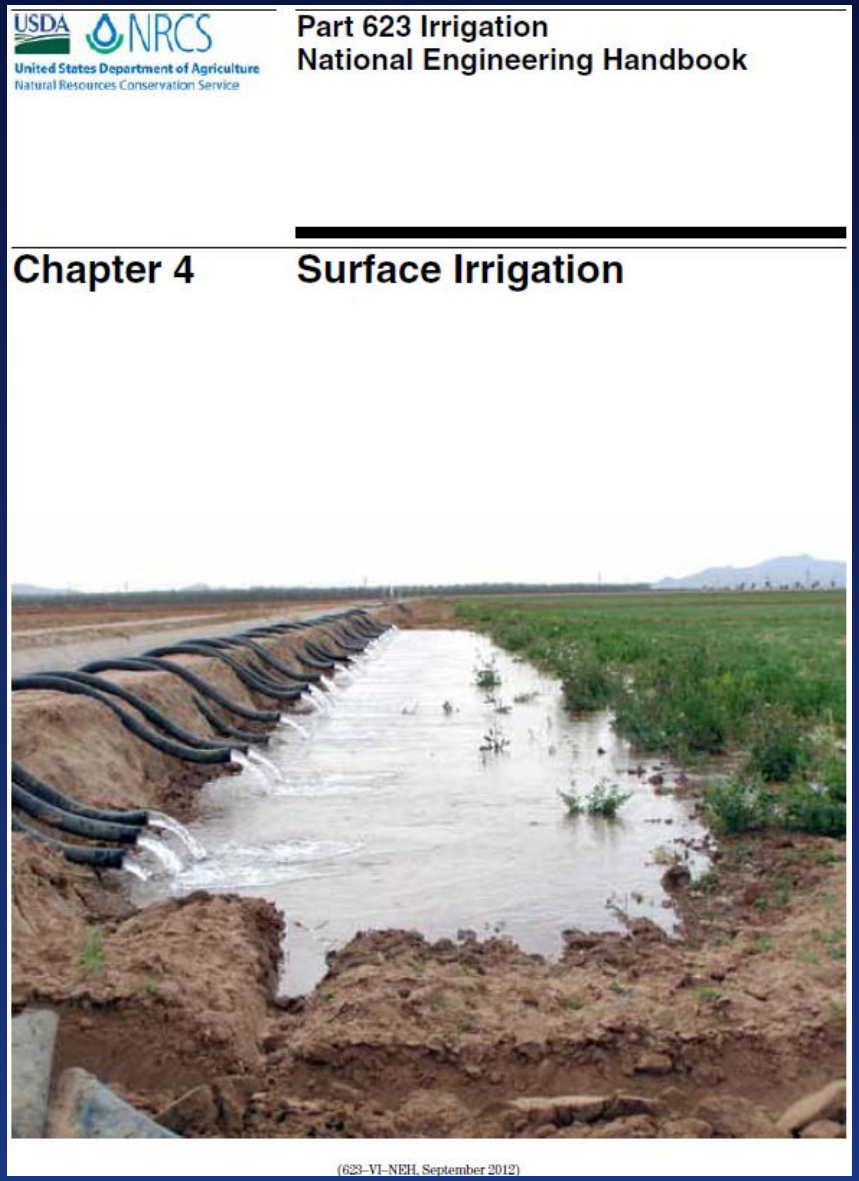
United States Department of Agriculture
Natural Resources Conservation Service

USDA NRCS

Surface Irrigation
NEH Part 623
Chapter 4

First of a short series of webinars on Surface Irrigation

Purpose: To show what is in this recently released irrigation chapter, and make suggestions on what you can use it for.



Chapter 4
Release Party

NEH Part 623 Chapter 4 Surface Irrigation

Most NRCS employees will use Chapter 4 as a user manual for NRCS_Surface.exe.

Sadly, NRCS_Surface.exe is not the main focus of this webinar.

NEH Part 623 Chapter 4 Surface Irrigation

Surface irrigation: aka flood

Surface irrigation has evolved into an extensive array of configurations that can broadly be classified as:

basin irrigation

border irrigation

furrow irrigation

wild flooding

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NEH Part 623 Chapter 4 Surface Irrigation

3 Sections

623.0400 The practice of surface irrigation

623.0401 Surface irrigation principles

623.0402 Design processes

NEH Part 623 Chapter 4 Surface Irrigation

3 Appendices

Appendix 4A: A Note on the Development of the Original NRCS Intake Families and Their Modifications for Furrow Irrigation

Appendix 4B: NRCS Surface Irrigation Simulation, Evaluation, and Design Software

Appendix 4C: Glossary

NEH Part 623 Chapter 4 Surface Irrigation

3 Appendices

Appendix 4A: A Note on the Development of the Original NRCS Intake Families and Their Modifications for Furrow Irrigation

Appendix 4B: NRCS Surface Irrigation Simulation, Evaluation, and Design Software

Appendix 4C: Glossary

Overview of Chapter 4

623.0400
The practice of surface irrigation

19 pages

(a) Introduction
(b) Surface irrigation configurations
(c) Water management in surface irrigation systems

Table 4-1 General comparison of surface irrigation methods
20 figures (photos, mainly)

Also see: Irrigation ToolBox Video 027 on Surface Irrigation

623.0400
The practice of surface irrigation

(a) Introduction

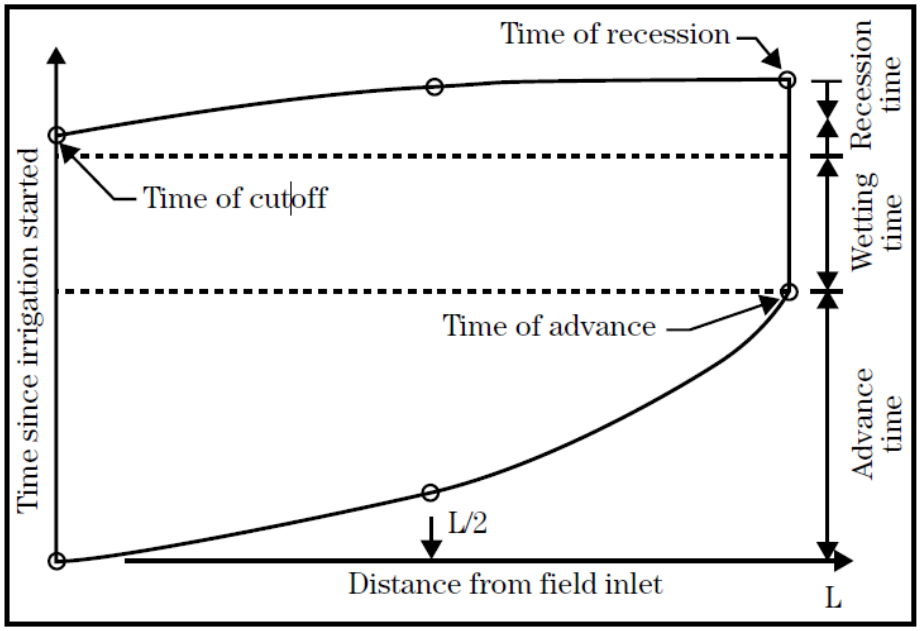
1. Surface irrigation processes

   There are three general phases in a surface irrigation event:

   - advance
   - wetting or ponding
   - recession

623.0400
The practice of surface irrigation

Figure 4–2 Basic phases of a surface irrigation event



623.0400
The practice of surface irrigation

(b) Surface irrigation configurations

1. Basin Irrigation
2. Furrow Irrigation
3. Border Irrigation
4. Summary of Surface Irrigation Methods
   i. Table 4-1 General comparison of surface irrigation methods

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The practice of surface irrigation

(b) Surface irrigation configurations

Figure 4–4 Furrow irrigation using siphon tubes from a field bay

Figure 4–6 Border irrigation in progress

623.0400
The practice of surface irrigation

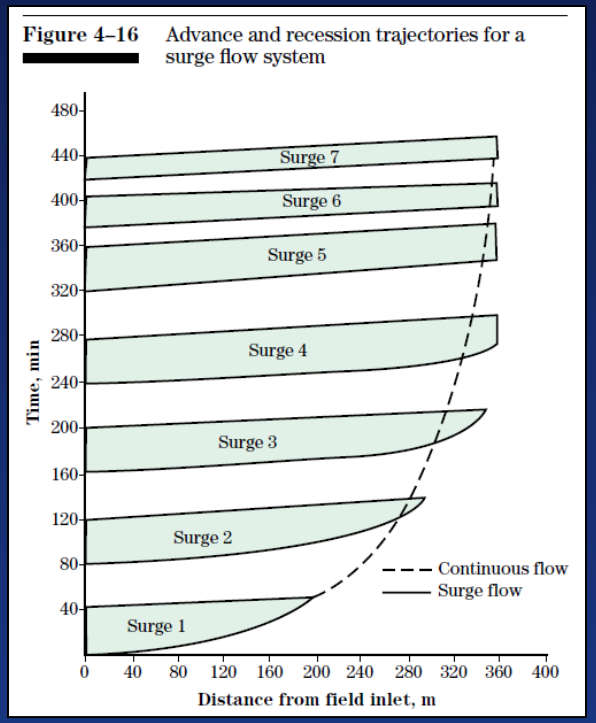
(c) Water management in surface irrigation systems

1. Choosing a surface irrigation system
2. Inflow rate and efficiency
3. Changing the field geometry and topography
4. Tailwater recovery and reuse
5. Automation and equipment
6. Cutback
7. Surge irrigation

623.0400
The practice of surface irrigation

(c) Water management in surface irrigation systems

(7) Surge irrigation



623.0400
The practice of surface irrigation

Use this section as a training resource for people who are new to surface irrigation.

It gives the reader good, basic information that will assist in understanding what is happening out in the field.

Combine it with Video 027 (Surface Irrigation) from the Irrigation ToolBox for a one to 2 hour self directed training session.

Overview of Chapter 4

623.0401
Surface irrigation principles

21 pages

(a) Introduction

(b) Important surface irrigation concepts

(c) Field evaluations

623.0401
Surface irrigation principles

(b) Important surface irrigation concepts

1. Soil Moisture
2. Infiltration
3. Revised NRCS Intake Families
4. Irrigation efficiency and uniformity
5. Water Measurement and Control

623.0401
Surface irrigation principles

(b) Important surface irrigation concepts

1. Soil Moisture
    a) Equations for porosity, saturation, moisture content
    b) 2 example calculations
        i. Calculate bulk density
        ii. Calculate volume of irrigation water given soil sample data

623.0401
Surface irrigation principles

(b) Important surface irrigation concepts

2. Infiltration: controls the amount of water entering the soil and impacts the duration of advance and recession

Kostiakov equation for furrows and basin/borders

$$Z=Kt^{a}$$

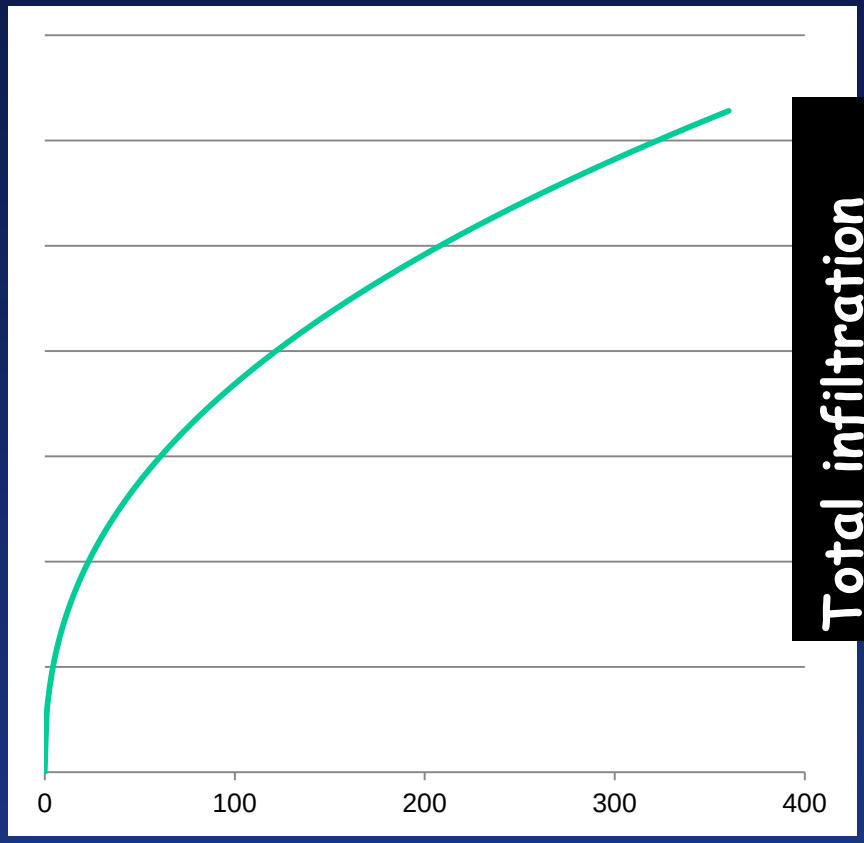
Kostiakov-Lewis equation:

$$Z=Kt^{a}+F_{o}t$$

Kostiakov (graph on left) underestimates total infiltration for long irrigation sets

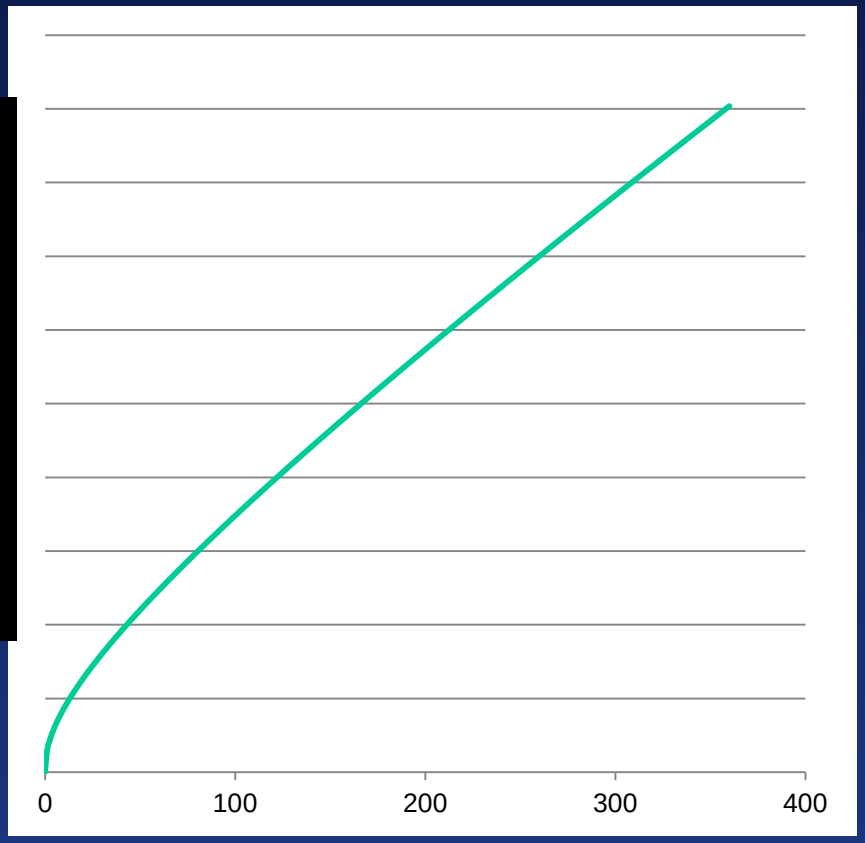
$Z=Kt^a$

Kostiakov



$Z=Kt^a+F_ot$

Kostiakov - Lewis



623.0401
Surface irrigation principles

(b) Important surface irrigation concepts

3. Revised NRCS Intake Families

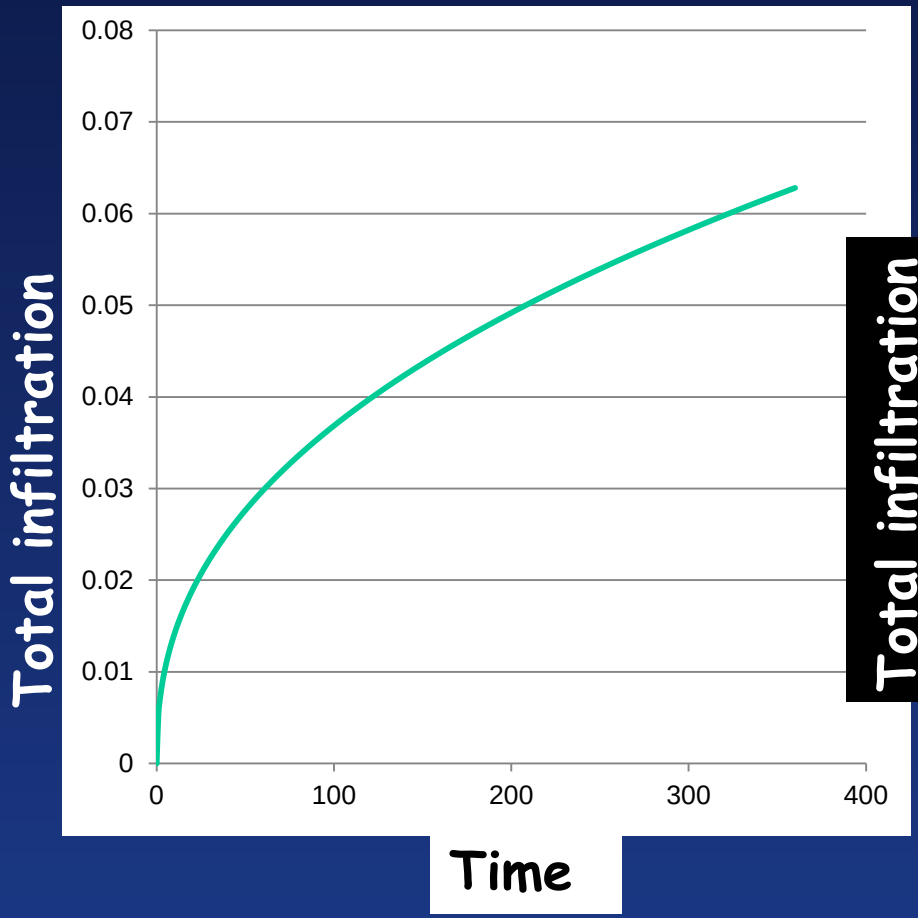
The original SCS intake families are based on

$$Z = Kt^a + c$$

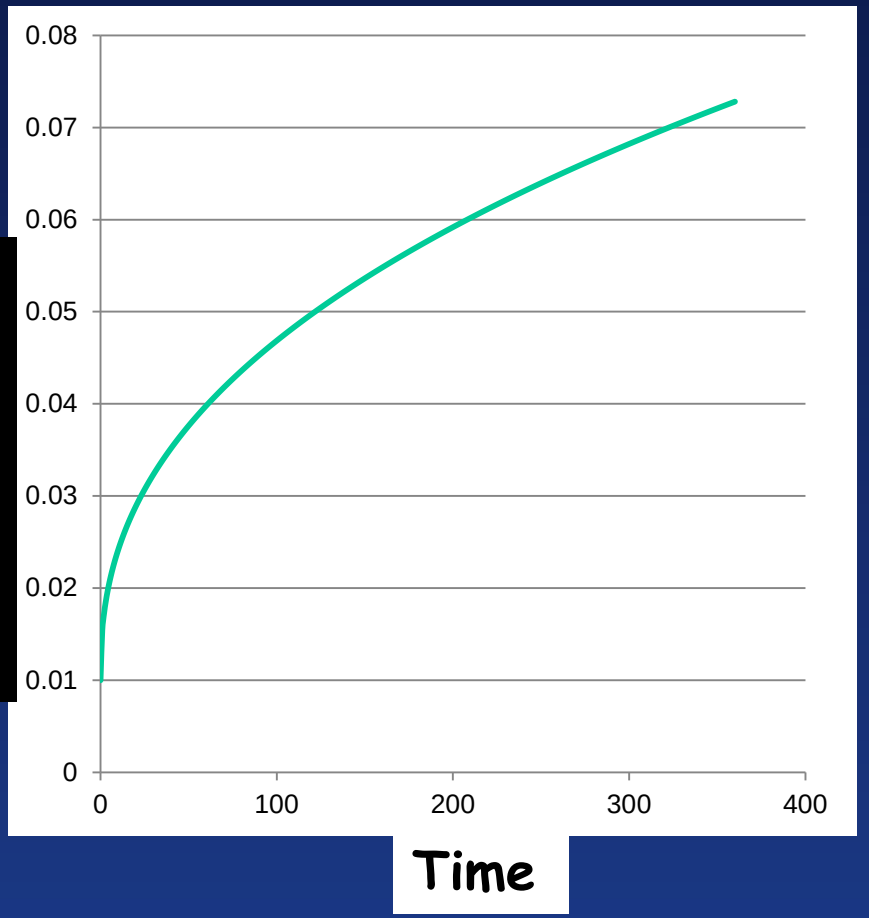
These family intake curves are revised here to correspond to $Z = Kt^a + F_o t$

SCS Intake formula adds a constant to account for instantaneous infiltration (e.g cracks in clay)

$Z=Kt^a$
Kostiakov



$Z=Kt^a+C$
SCS Intake Formula



623.0401
Surface irrigation principles

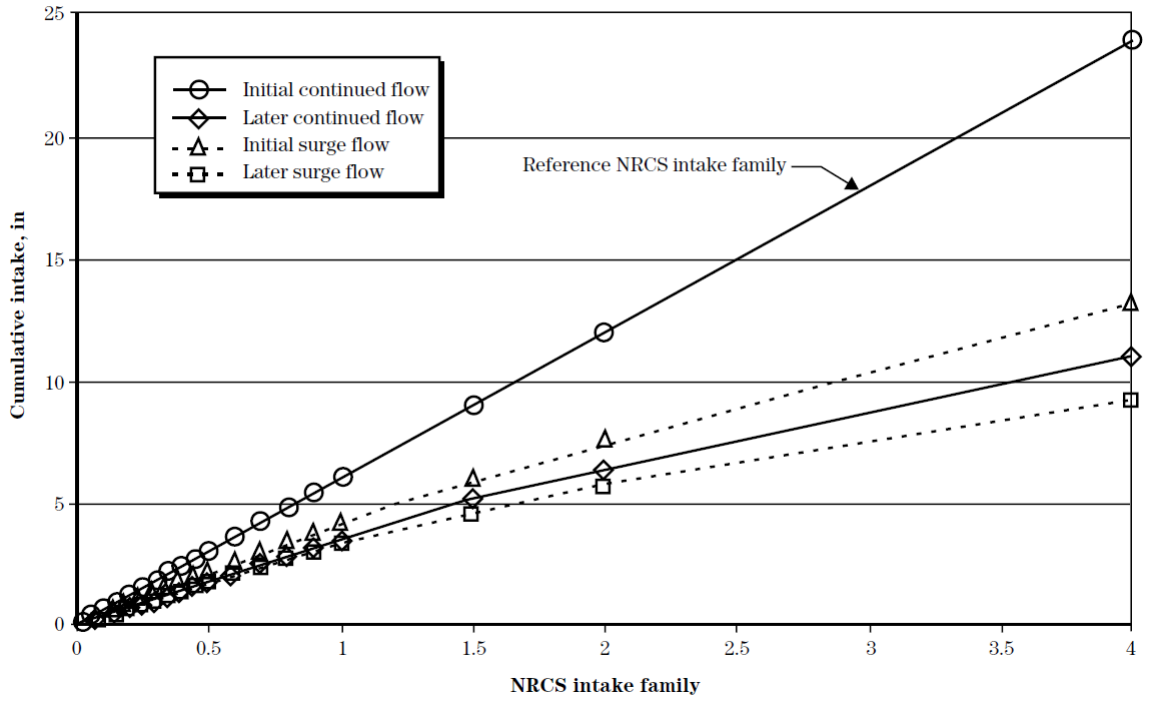
(b) Important surface irrigation concepts

3. Revised NRCS Intake Families

- Reference family structure is formulated for furrow irrigation and modified for borders and basins.
- Intake families should encompass both initial and later irrigations

623.0401
Surface irrigation principles

Figure 4–24 Average 6-hour intake rate for the revised NRCS furrow intake families



623.0401
Surface irrigation principles

(b) Important surface irrigation concepts

3. Revised NRCS Intake Families

- The intake families are denoted with numbers from 0.02 to 4 inches per hour. This is the average irrigation rate over 6 hours.
- The exponent "a" in $Z = Kt^a + F_o t$ is the same for a soil whether it's furrow or border/basin.

623.0401
Surface irrigation principles

As an example, the NRCS curve number for this sandy clay (0.25), means that over a 6 hour period, the average infiltration rate will be 0.25 inches per hour, or 1.50 inches total.

Table 4–3 Average 6-hour intake

NRCS curve no.	Soil type
0.02	Heavy clay
0.05	Clay
0.10	Clay
0.15	Silty clay
0.20	Sand/silt clay
0.25	Sandy clay
0.30	Sandy clay
0.35	Silty clay loam
0.40	Silty clay loam
0.45	Clay loam
0.50	Clay loam
0.60	Sandy clay loam
0.70	Sandy clay loam
0.80	Silt loam
0.90	Silt

623.0401
Surface irrigation principles

Table 4–4 / Table 4-5 Continuous flow furrow intake families—initial / later irrigations

Table 4–6 / Table 4–7 Surge flow furrow intake families—initial / later irrigations

Table 4–8 / Table 4–9 Continuous flow border/basin intake families—initial / later irrigations

$$Z = Kt^a + F_o t$$

All the parameters for all the intake families are given:

K, a and F_o

For furrows, the flow rate into the furrow and the wetted perimeter for the furrow is also defined.

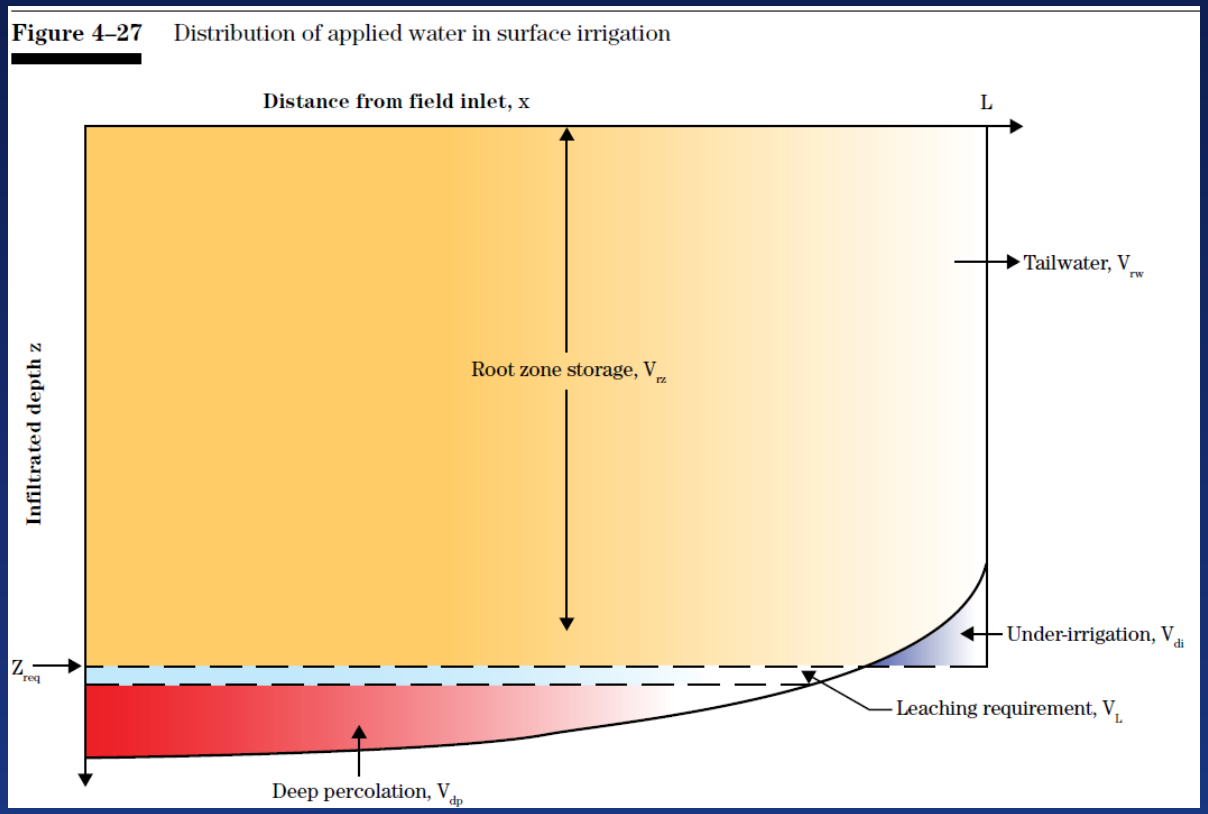
623.0401
Surface irrigation principles

Table 4–4 Continuous flow furrow intake families—initial irrigations

Continuous Flow Intake Curve Parameters for Initial Irrigations

ID	Soil Name	a	K (ft^3/ft/mn^a)	Fo (ft^3/ft/mn)	Qr (gpm)	Wpr (ft)
.02	Heavy Clay	0.192	0.002620	0.0001461	7.411	0.365
.05	Clay	0.247	0.004756	0.0002340	8.255	0.399
.10	Clay	0.303	0.006783	0.0003475	9.648	0.452
.15	Silty Clay	0.348	0.008500	0.0004621	11.023	0.500
.20	Sil/Sand Clay	0.385	0.010086	0.0005797	12.381	0.544
.25	Sandy Clay	0.416	0.011517	0.0006961	13.721	0.586
.30	Sandy Clay	0.442	0.012870	0.0008130	15.042	0.626
.35	Silty Clay Lo	0.464	0.014166	0.0009285	16.347	0.663
.40	Silty Clay Lo	0.483	0.015383	0.0010425	17.633	0.699
.45	Clay Loam	0.499	0.016541	0.0011534	18.901	0.733
.50	Clay Loam	0.514	0.017660	0.0012628	20.152	0.767
.60	Sandy Clay Lo	0.537	0.019750	0.0014715	22.599	0.830
.70	Sandy Clay Lo	0.556	0.021701	0.0016687	24.976	0.889
.80	Silt Loam	0.572	0.023512	0.0018535	27.281	0.945
.90	Silt	0.585	0.025224	0.0020268	29.514	0.999
1.00	Loam	0.597	0.026836	0.0021894	31.677	1.050
1.50	Sandy Loam	0.638	0.033830	0.0028582	41.420	1.282
2.00	Loamy Sand	0.666	0.039706	0.0033515	49.381	1.483
4.00	Sand	0.751	0.059331	0.0044455	63.401	2.131

623.0401
Surface irrigation principles



623.0401
Surface irrigation principles

(b) Important surface irrigation concepts

4. Irrigation efficiency and uniformity
    1. Definitions is the form of equations for:
        a) Irrigation efficiency
        b) Application efficiency
        c) Storage or requirement efficiency
        d) Distribution uniformity
        e) Deep percolation ratio
        f) Tailwater ratio

623.0401
Surface irrigation principles

(b) Important surface irrigation concepts

4. Irrigation efficiency and uniformity

Example—A furrow-irrigated set consists of 27 furrows spaced 30 inches apart with a furrow length of 1,320 feet. At the time that the irrigation event was begun, the soil moisture deficit was 4.3 inches. The estimated leaching requirement was 0.4 inches. Each furrow had an inflow of 13 gallons per minute for 24 hours. The distribution of infiltrated water depth along the furrow length was as follows:

Furrow length, l/L	.05	.15	.25	.35	.45	.55	.65	.75	.85	.95
Infiltrated depth (in)	6.2	6.0	5.8	5. 6	5.4	5.1	4.8	4.3	3.7	3.0

What are the values of the various efficiencies and uniformities for this irrigation event?

623.0401
Surface irrigation principles

(b) Important surface irrigation concepts

5. Water Measurement and Control

$$QT = DA$$

623.0401
Surface irrigation principles

(c) Field Evaluations (6 pages)

The objective of a field evaluation is to establish a water balance for the field so that the efficiencies and uniformities can be determined.

Use this section (Field Evaluations) as a take home final for a graduate level course on Surface Irrigation

623.0401
Surface irrigation principles

Main Use: Contains technical information for the use of NRCS_Surface.exe, particularly the revised NRCS intake families.

Explains the switch from SCS intake formula to Kostiakov Lewis

Also contains several moderately difficult examples with solutions for understanding basic irrigation efficiency concepts.

623.0402
Design processes

27 pages

(a) The objective and scope of surface irrigation design

(b) Basic design process

(c) Basic design computations

(d) Distribution system

(e) Headland facilities

(f) Drainage facilities

623.0402
Design processes

Important section when preparing to use NRCS_Surface.exe

It won't tell you how to run the software, but it gives some important background that will help you understand NRCS_Surface.exe.

623.0402
Design processes

a) The objective and scope of surface irrigation design

Actually, redesign.

Design is a trial and error procedure.

A selection of lengths, slopes, field inflow rates, and cutoff times can be made that maximize efficiency and uniformity for a particular configuration.

623.0402
Design processes

a) The objective and scope of surface irrigation design

Minimize differences in intake opportunity times.

$$Z = Kt^a + F_o t + C$$

623.0402
Design processes

(b) Basic design process

1. Preliminary design
2. Detailed design

Fundamental information included here.

Important section when preparing to use NRCS_Surface.exe

623.0402
Design processes

(c) Basic design computations

Good section that details:

- Field characteristics
- Field layout
- Blocked end systems
- Cutback systems
- Tailwater reuse systems
- Surge flow systems

623.0402
Design processes

(c) Basic design computations

One example of the information:

Under field layout:

"It is always good practice to evaluate the extreme conditions such as the maximum and minimum run lengths to anticipate the management problems the irrigator will face"

623.0402
Design processes

(d) Distribution system

Brief description of farm ditches, pipelines, etc

(e) Headland facilities

Lots of cool tables

623.0402
Design processes

(e) Headland facilities

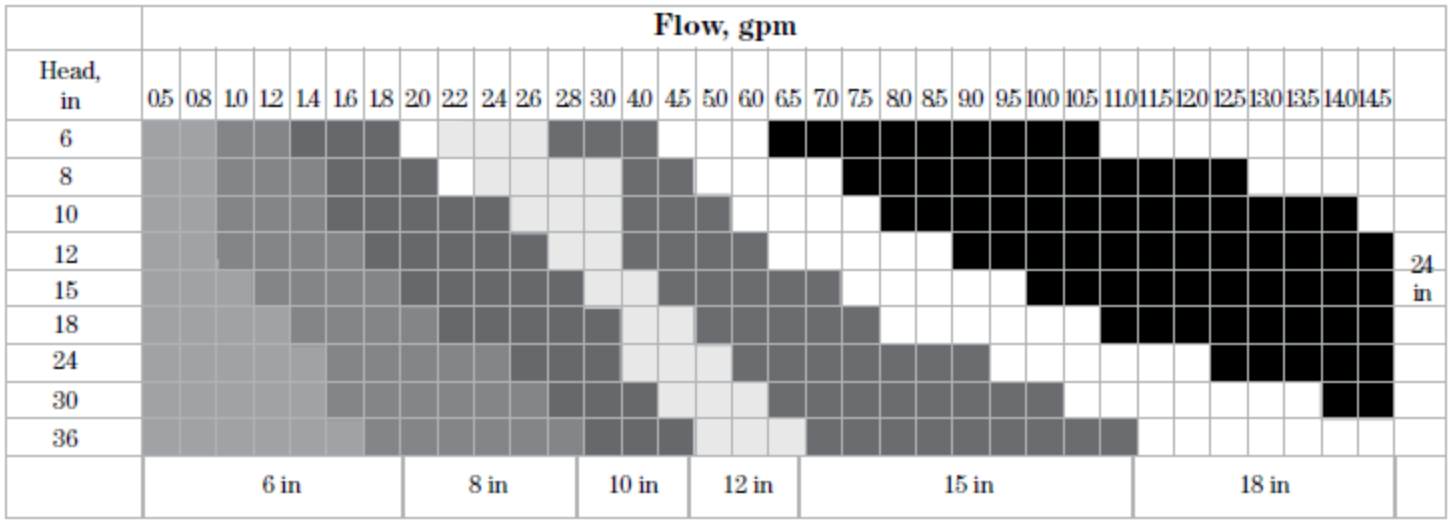
1. Head Ditch design
   i. Three criteria
2. Sizing siphon tubes and spiles
3. Sizing small ditch gates
4. Sizing check outlets and large ditch gates
5. Gated pipe design
6. Comparing Alternatives

623.0402
Design processes

(e) Headland facilities

Sizing small ditch gates (round entrances)

Table 4–14 Recommended ditch gate sizes for surface irrigation systems



623.0402
Design processes

(e) Headland facilities

5. Gated pipe design

Example gated pipe design

Given a field that is 1,180 feet long and 2,362 feet wide. The field design for initial irrigations called for 18 sets to be organized by subdividing the length into two parts and the width into nine parts. The cross slope was 0.0001. The design furrow flow is 22.5 gallons per minute, and the total flow is 2,362 gallons per minute.

623.0402
Design processes

Main Use: Contains background information that will be helpful in understanding the options available in NRCS_Surface.exe.

If you intend to use NRCS_Surface.exe, eventually reading this section will be worthwhile.

This section is my favorite of the three. (Engineering vs. Research)

Appendix 4A
A Note on the Development of the Original NRCS Intake Families and Their Modifications for Furrow Irrigation

6 pages

Offers technical explanation on the shift to the new NRCS Intake Families.

Table 4A–2 Comparison of original and revised furrow intake family values

Original curve no.	Revised curve equivalent	Original a-value	Original k-value, in/min	Assumed P, ft	Equivalent revised a-value	Equivalent revised k-value, ft³/ft/min	Equivalent revised f_o-value, ft³/ft/min	Equivalent revised curve reference flow, gpm	Equivalent revised curve reference perimeter, ft
0.05	0.09	0.618	0.0210	1.27	0.294	0.00645	0.000285	9.47	0.44
0.10	0.12	0.661	0.0244	1.30	0.320	0.00729	0.000354	10.15	0.46
0.15	0.14	0.683	0.0276	1.33	0.341	0.00805	0.000416	10.77	0.49
0.20	0.16	0.699	0.0306	1.36	0.360	0.00878	0.000477	11.38	0.51
0.25	0.19	0.711	0.0336	1.38	0.378	0.00953	0.000540	12.02	0.53
0.30	0.21	0.720	0.0364	1.41	0.394	0.01026	0.000602	12.66	0.55
1.00	0.61	0.785	0.0703	1.66	0.539	0.02010	0.001503	22.92	0.84
1.50	0.90	0.799	0.0899	1.77	0.585	0.02535	0.002019	29.61	1.01
2.00	1.20	0.808	0.1084	1.85	0.616	0.02987	0.002468	35.88	1.16
4.00	1.75	0.850	0.1876	1.98	0.656	0.03684	0.003132	45.72	1.39

.60 Sandy Clay Lo	0.537	0.019750	0.0014715	22.599	0.830
.70 Sandy Clay Lo	0.556	0.021701	0.0016687	24.976	0.889
.80 Silt Loam	0.572	0.023512	0.0018535	27.281	0.945
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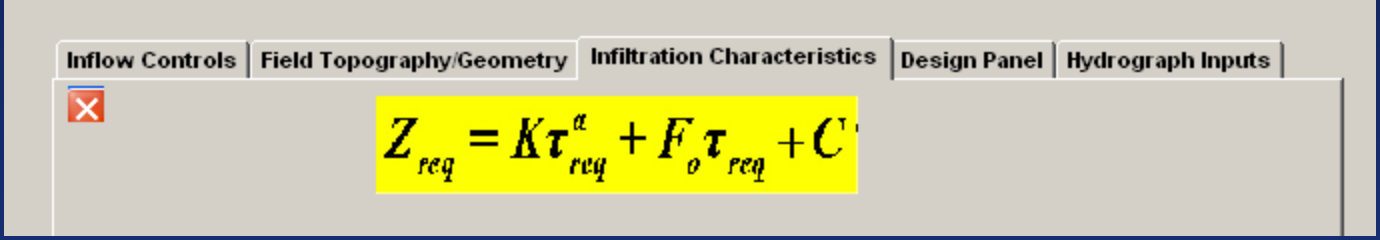
1.50 Sandy Loam	0.638	0.033830	0.0028582	41.420	1.282

Overview of Chapter 4
Appendix 4B
NRCS Surface Irrigation Simulation, Evaluation, and Design Software

42 pages

User manual for NRCS_Surface.exe



Overview of Chapter 4
Appendix 4C
Glossary

7 pages

Irrigation efficiency (Ie)	At the field level, irrigation efficiency is the ratio of the average depth or volume of irrigation water stored in the root zone plus the depth or volume of deep percolation that is needed for leaching to the average depth or volume of irrigation water applied. Inefficiencies are caused by tailwater and deep percolation losses above the leaching requirement.
Irrigation interval	The interval between irrigation events. Usual units are days.
Irrigation requirement	Quantity of water, exclusive of effective precipitation, that is required for crop demands including evapotranspiration and leaching, as well as special needs such as seed bed preparation, germination, cooling

Overview of Chapter 4 NEH Part 623 Surface Irrigation

Questions?