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Department of
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Soil
Conservation
Service

Irrigation Training Series

Module 910 - Level Border Irrigation Evaluation

Study Guide

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IRRIGATION TRAINING SERIES

MODULE 910

LEVEL BORDER IRRIGATION EVALUATION

National Employee Development Staff
Soil Conservation Service
United States Department of Agriculture
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PREFACE

This module consists of a study guide, video tape presentation, and field activity. The module is designed as a self-study, facilitator-led package. It may be given as self-study providing that two needs are met:

1. That there is a qualified technical person (resource person) either nearby or available by telephone to answer any questions that may arise.

2. That the trainee receive close supervision and guidance while actually making a field irrigation evaluation within three months following completion of this module.

If a facilitor is used, the trainee will be guided step-by-step through the study guide. Again, an actual field evaluation should be made, with supervision and guidance, within three months following completion of this module.

This Study Guide is designed as a training tool and reference manual for those who perform irrigation system evaluations. It has step-by-step procedures for conducting level border irrigation system evaluations. Included is background material, equipment list, evaluation procedures, example data, and blank worksheets.

Procedures for level border irrigation system evaluations are, in part, from the publication "Farm System Evaluation: A Guide for Management" by John L. Merrian and Jack Keller, published by Agricultural & Irrigation Engineering Department, Utah State University, Logan, Utah. This reference is recommended for anyone involved in level border evaluations.

VIDEO TAPE PRESENTATION

A video presentation is available for use with this module.

The presentation consists of a brief, sixteen (16) minute overview of an evaluation being made in the field. It will give you an idea of what you will be doing during the field portion of the module. At this time, put the video cassette in the player and view it. When you are finished, rewind the tape and continue at this point in your study guide.

ACKNOWLEDGMENT

The design and development of this training program is the result of a concerted effort by practicing engineers in the SCS. The contribution of many technical and procedural reviews has helped to make this program one that can effectively provice basic skills to SCS employees

IRRIGATION TRAINING SERIES

MODULE 910

ENG - LEVEL BORDER IRRIGATION EVALUATION

OBJECTIVES

Upon completion of this module, participants will be able to:

1. Perform an evaluation of level border irrigation using accepted procedures.

2. Determine how well the irrigation system is being managed by calculating the application efficiency.

3. Determine how well the irrigation system is performing by calculating the distribution uniformity.

4. Make recommendations for improvement, if needed, using the results of the evaluation.

This module is designed to bring the trainee to an ASK level 2 (Understanding) upon completion of the self-paced portion, and ASK level 3 (Perform with Supervision) upon completion of the field evaluation.

PREREQUISITES

Module 101, Glossary of Soil and Water Terms used in the Irrigation Training Series, should be used along with this module. Also, it is recommended that in order to more fully understand this module, the participant completes one module each from the 300 and 400 series, all modules in the 600 series, and module 960.

TIME

Approximately 28 hours (self-study portion: 8 hours; Facilitator;s Local example: 4 hours; Field evaluation and report: 16 hours). Credit will be given for 28 hours.

WHO MAY TAKE MODULE

All employees at any level who need training in conducting level border irrigation system evaluations.

METHOD OF COMPLETION

This module consists of two parts: (1) the study guide, although basiclly self-study, should have a state-assigned technical specialist serve as a resource person to answer questions or provide assistance beyond the supervisor's capability. (2) Field activity. A technical facilitar should be assigned to coordinate this portion of the module.

CONTENT

This module provides a participant with enough data to perform, with supervision, a level border irrigation system evaluation. Covered is calculation of application efficiency and distribution uniformity, performance of a field evaluation, and development of an evaluation report complete with recommendations for improvement.

CONTENTS

INTRODUCTION

Irrigation water management is determining and controlling the rate, amount, and timing of irrigation water application in a planned and efficient manner. The effective use of irrigation water helps to manage and control the moisture environment of crops. This, in turn, promotes the desired crop responses, minimizes soil erosion and loss of plant nutrients, controls undesirable water loss, and protects water quality.

The irrigator must have the knowledge and capability to manage and apply water in such a manner that these objectives can be maintained. Irrigation system evaluations can provide some relatively accurate basic information that the irrigator needs in order to manage his system for optimum efficiency.

Evaluations can also provide information useful for improving the system. The data provides the best possible basis for detailed design, since it reflects actual site conditions.

CHARACTERISTICS OF LEVEL BORDER IRRIGATION

Level border irrigation is often called level basin irrigation. It is a gravity method whereby water is supplied to level or nearly level soil surfaces over a short period of time. The basin may be of any shape, surrounded by a control barrier such as a dike. The water is confined until infiltrated into the soil. The maximum slope, or fall, along the length of run may be 0.5 times the depth of application for the border.

Level basins have been used for centuries, especially for rice production. Small contour basins have also been used for many years in orchards. Recently, the procedure has gained increasing importance for irrigation of flat-bed and furrow crops in the water short southwestern part of the United States.

Design of basin size depends on water supply flow rate and soil infiltration characteristics. Level border irrigation can be adapted to most crops, soils, and certain marginal quality water not usable in other methods of irrigation. It is best adapted, however, to low or medium water intake soils.

Level border systems have many characteristics which can result in high irrigation efficiencies as well as offer advantages over other commonly used surface irrigation methods.

METHOD ADVANTAGES

1. If the system is properly designed and managed, deep percolation losses are minimized and high application efficiencies are attained.

2. There is no runoff.

3. Leaching of salts is easier than with other surface methods. The reason is that, since water uniformly covers and remains static

over the entire surface, it has the opportunity to penetrate evenly, reducing residual salts that often remain with sloping types of border irrigation. Also, since rainfall will not run off, it is useful for leaching.

4. The guess work in applying the right amount of water is limited since there is no surface runoff and all water applied to a basin is used within the basin.

5. Relatively light applications of water are possible.

6. Automation can be conveniently applied for the following reasons:

   -The time of set, and thus the amount of water, can be controlled directly with a clock.
   -Only a few outlet structures are needed.
   -No tailwater exists for further handling.

7. Large streams of water can be used, thereby reducing irrigation time and labor.

8. Level basin areas as large as 40 acres can be irrigated when a large stream of water is available and the intake of the soil is low. Fields this large may be easily farmed with large machinery.

9. Increased yields may result because optimum amounts of water can be applied. Even distribution results in improved germination, improved plant environment, and even growth. Leaching of plant nutrients is controlled.

LIMITATIONS OF METHOD

1. Precision leveling is required for even water distribution.

2. Use of laser controlled leveling equipment is essential if the degree of levelness required is to be obtained.

3. The correct amount of water must be applied. Over application of water may lead to excessive inundation times, leaching of nutrients, and result in crop damage.

4. Earthwork volumes are often greater than for other surface irrigation methods.

5. Variable soils within the basin may create water distribution problems.

6. Large inflows require erosion control measures at outlets.

7. A means of emergency drainage should be provided to protect against irrigator's error (over irrigation) and where rainfall must be diverted off the field.

DESIGN CONSIDERATIONS

Five factors must be considered in system design:

1. Water intake of the soil.
2. Available flow rates.
3. Flow resistance of the crops to be grown.
4. Quantity of water to apply.
5. Topography of the site.

With this information, the length and width (or shape and size) of the basin can be designed to allow acceptable efficiencies.

As a general rule, the basin should be covered by water in not more than 1/2 of the total required opportunity time. For best efficiency, total coverage should take place within not more than 1/4 of required opportunity time. This will minimize the effect of non uniformities of soil intake rate and irregularities in the field surface.

Detailed design information is contained in National Engineering Handbook Section 15, Chapter 4, Border Irrigation. General information is provided in USDA Farmer's Bulletin no. 2261, Level Basin Irrigation. Aids in design include various programable calculator and computer programs.

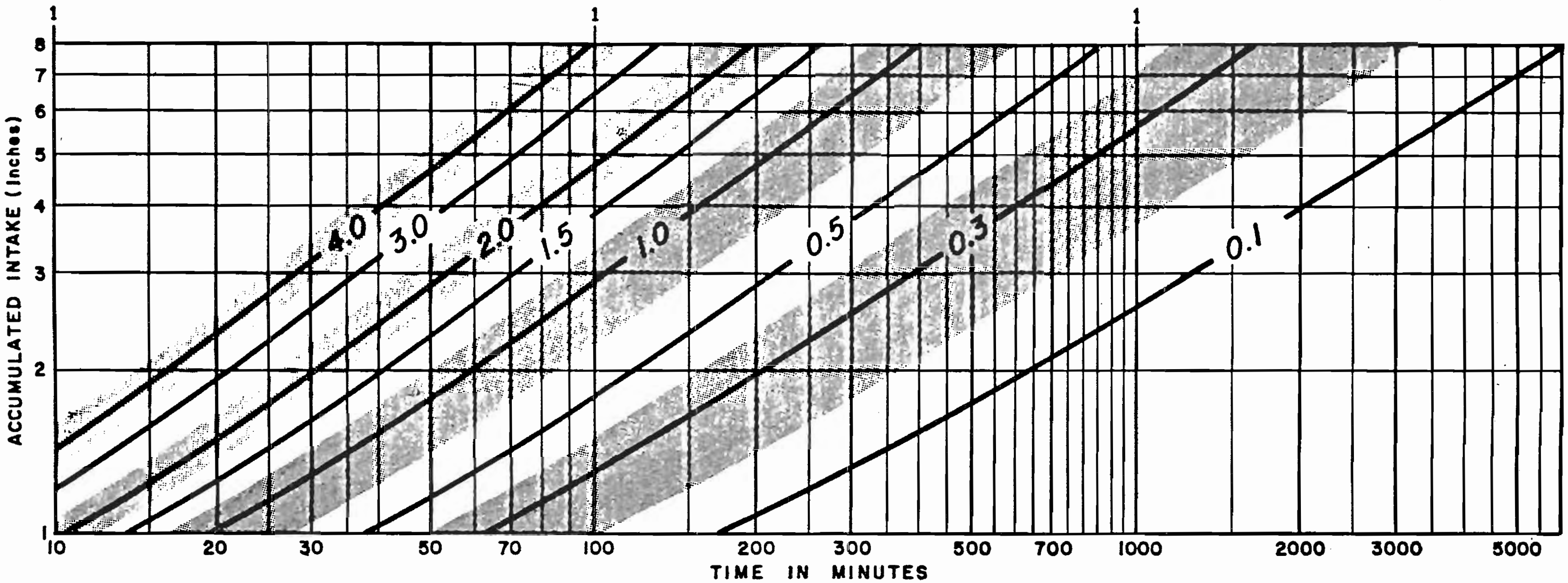
GLOSSARY OF TERMS, DEFINITIONS AND EXPLANATIONS

Appendix B in your Study Guide contains a complete listing of terms, definitions, and explanations used in this module.

CUMULATIVE INTAKE CURVES

Cylinder infiltrometers (Short sections of pipe driven into the ground with water poured into them) are often used to determine the infiltration rate of soil. In the level basin method, the entire basin can be used as if it were one large cylinder infiltrometer.

Cumulative intake curves are plotted based on infiltrometer intake data. A set of standard intake curve families are usually used in design. One objective of the system evaluation is to find where the particular field fits in the intake curve family. Figure 1 shows the standard intake curve families. Figure 2 shows the two point curve determined by the level basin evaluation procedure.



INTAKE GROUPING for SURFACE IRRIGATION DESIGN

INSTRUCTIONS

1. PLOT DATA FROM CYLINDER INTAKE TEST ON MATCHING LOGARITHMIC PAPER USING ACCUMULATED INTAKE (INCHES) AS ORDINATES AND ELAPSED TIME (MINUTES) AS ABSCISSAS. DRAW LINE REPRESENTING TEST RESULTS.

2. PLACE OVERLAY OVER PLOTTED CURVE, MATCHING THE INTERSECTION OF THE LINES FOR 10 MINUTES TIME AND 1.0 INCHES INTAKE. SELECT THE INTAKE FAMILY WHICH BEST REPRESENTS THE PLOTTED CURVE WITHIN THE NORMAL IRRIGATION RANGE.

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Figure 1. -- Intake grouping for surface irrigation design.

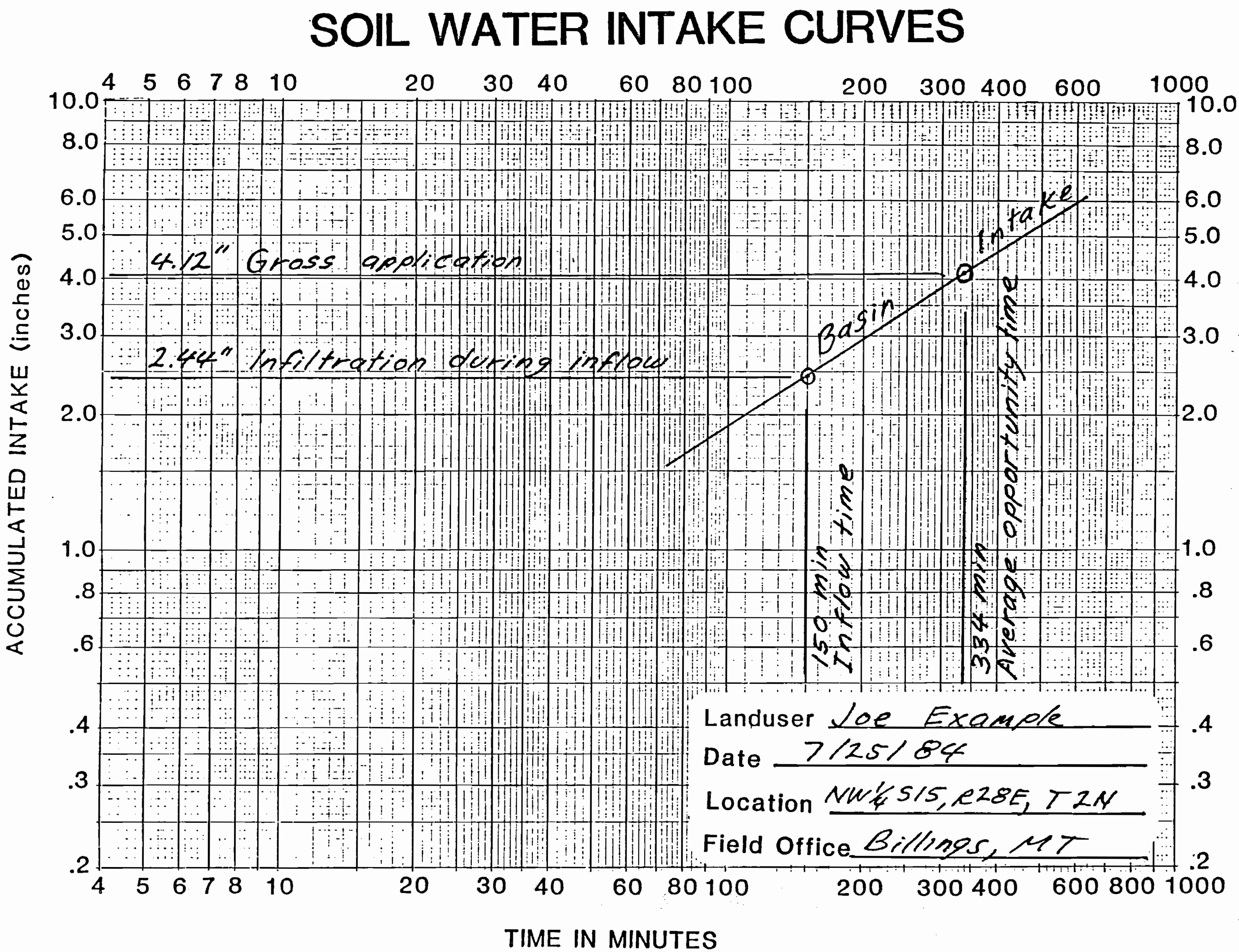


Figure 2. -- Soil water intake curves.

INITIAL EVALUATION

Many important factors concerning how well an irrigation system is operating and how well it is being managed can be determined with very simple observations and evaluation procedures. These same procedures are used whether a simple evaluation or a complete evaluation is performed.

The only equipment needed is a soil auger or, if the soil is rocky, a shovel.

The steps are as follows:

1. Determine basic data about the system and management of the system from the irrigator. Some of the questions which might be asked include:

    a. How does the irrigator determine when to irrigate?
    b. Length of time for each set.
    c. How does the irrigator determine when to turn the water off?
    d. How long does it take the water to reach the end of the field?
    e. What is the rate of flow onto the field or into the system?
    f. What are the problems that the irrigator has experienced with the system?
    g. Are there usually dry spots in the field? Wet spots? Are parts of the field under-irrigated? Over-irrigated?
    h. Crop production: Does production vary throughout the field? If so, what does the irrigator feel are the causes?
    i. How much control does the irrigator have over when and how much irrigation water is available?
    j. What are the irrigator's objectives?
    k. What is the availability of labor?

2. Look around:

    Look around the field in question. Look in the adjacent fields. Look at the supply system. Look at such things as:

    a. Erosion problems.
    b. Leaky ditches, pipes, dikes.
    c. Uneven or discolored crops.
    d. Water-loving plants, weeds.
    e. Saline and/or swampy areas.
    f. Poorly maintained equipment.

3. With the irrigator along, auger some holes at selected locations in the field. Look for such information as:

   a. High water table or indications of fluctuating water table.
   b. Hard pans, compacted layers, mineral layers or other characteristics which can restrict root growth and the movement of water in the soil.
   c. Soil texture at various levels in the soil profile.
   d. Moisture content of the soil layers. (Demonstrate the feel and appearance method).
   e. Root penetration (How deep have roots penetrated? Is this normal for crop stage of growth?).
   f. Tilth and condition of the soil.

4. Discuss the findings and information so far obtained with the irrigator. Make recommendations if there is enough information to do so.

DETAILED EVALUATION PROCEDURES

Choosing an evaluation site

Choose a typical basin in the field to be irrigated. The typical location should be representative of the type of soil that the field is being managed for from an irrigation scheduling standpoint. Basin size and configuration should be typical of those in the field. The evaluation should be run at a time when soil moisture conditions are the same as when irrigation would normally take place.

General accuracy of procedure

The following procedure consists of utilizing the whole basin as if it were one large ring infiltrometer. Inflow volume and volume of water in the basin are measured. Since a small difference in water level in the basin can represent a rather large volume of water, it is very important to measure water level changes accurately.

The following procedure will in part yield a two point average intake curve for the basin as a whole. The first point on the curve will be plotted at the time the water is turned off. The second point will be defined by plotting the gross application at the average opportunity time. If a more detailed curve is desired, or if plot points are desired at earlier times, a cylinder infiltrometer test can be run and plotted, and the curve adjusted, all in accordance with the methods described in the procedures for graded border evaluations.

It is impractical to try to determine very exact values of distribution uniformity and application efficiency of the low 1/4, because small variations in soil infiltration rate in various parts of the basin, and low spots, cause appreciable differences in the depth infiltrated. A more refined method of determining distribution uniformity is to stake a grid in the basin and determine advance and recession times (and thus the time of opportunity) at each grid point. The additional points give more measurements to work from.

Our procedure will use a line of stakes down the center of the basin to sample opportunity times. In most cases this will give adequate detail for analysis.

This procedure should work well enough to provide data for making useful recommendations for modifications in management and to the system. When it appears that advance time exceeds 1/2 of the opportunity time required to fill the basin, it is recommended that the graded border procedure for evaluation be used. You may be able to determine these times, roughly, prior to the evaluation by talking to the irrigator. The graded border procedure involves taking cylinder infiltrometer tests and plotting and analyzing advance and recession curves.

Equipment needed

Engineer's level and rod
100 foot chain
Pocket tape marked in inches and tenths/hundredths of feet
Stakes or flags
Marker for stakes or flags
Flume, weir, or other measuring device for measuring inflow
Carpenter's level for setting flume or weir
Gauge for measuring depth of flow in flow measuring device, if needed
Gallon can or larger for stilling well (see text)
Bucket auger
Soil probe
Shovel
Speedy moisture meter/Ely Volumeasure or some other method of determining soil moisture level.
Level border evaluation work sheets
Clip board and pencil
Soils data for field
Watch
Camera
Boots

Before start of irrigation

Before start of irrigation:

1. Get basic information about the existing irrigation system procedures and problems from the irrigator.

2. Set stakes or flags at 50 to 100 foot stations down the border and mark stations.

3. Take level rod readings on the average ground level at each station. Readings should be taken to the nearest 0.05 foot or to 0.01 foot. Take care to take readings at average elevations at each measurement point.

4. As soon as the water is shut off into the basin, an accurate measurement of water surface elevation in the basin must be determined. This should be done with a level rod reading to the nearest 0.01 foot. If there is wind or other disturbance in the basin, a stilling well should be set up in the basin. This will allow taking the water surface elevation in a sheltered environment. The well can be constructed from a gallon or larger can with the bottom cut out and small holes punched in the sides below water level. This will buffer wave action. Make sure the buffer location is far enough away from the turnout so that it is not affected by flow from the turnout.

5. Set the measuring devices to measure inflow.

6. Check the soil water deficit (SWD) at several points in the basin. Use the feel and appearance, Ely Volumeasure/Speedy Moisture Meter, push tube/oven or some other method. For the location chosen as the controlling typical soil, record the SWD data on the evaluation worksheet.

7. At the same time, make note of soil profile conditions such as:

   a. Depth to water table
   b. Apparent root depth
   c. Compacted layers
   d. Mineral layers
   e. Hard pans and bedrock
   f. Soil texture changes

8. Record information about type of delivery system, type and size of turnouts, width and length of border.

Field observations

Make visual observations of the field including crop uniformity, weeds, erosion problems, crop condition or color changes, salinity problems, etc.

During the irrigation

Irrigate with the flow rate normally used by the irrigator and record the start time.

Check and record the flow rate several times during inflow. Record the turn off time.

Observe the advance of the water front across the basin. Record the time water reaches each station. Record the time, in 24 hour clock readings, to the nearest minute.

Immediately after water turn-off, use the level and rod to determine the elevation of the water surface in the basin. Take this reading as accurately as possible. A small error can make a large difference in water volume. Record this reading on the work sheet.

Observe the recession of the water in the basin. Record the time when water has receded at each of the stations where advance was recorded. Recession should be determined as that time when not more than 10% of the water in the vicinity of the station point is still visible on the surface. It is likely that there will be some low spots in the basin. It is recommended that a sketch be made of the basin showing an outline of areas still containing surface water at the time that 10 percent of the basin still has water on it. This will give an indication of uniformity of leveling in the basin.

Immediately after recession, use a probe or auger to check depth of penetration at several locations in the field. A check at this time will indicate whether water has already percolated too deeply. The water will continue to move downward through the soil until field capacity is reached.

If possible, check the adequacy and uniformity of irrigation at a time when the soil profile has reached the field capacity moisture level. Sandy soils can be checked in about 24 hours after irrigation. Clayey soils should be checked about 48 hours after irrigation so that gravitational water has drained.

If it is necessary to establish field capacity, determine the soil water content when checking for adequacy and uniformity of irrigation.

IRRIGATION WATER MANAGEMENT

LEVEL BORDER IRRIGATION SYSTEM EVALUATION

ACTIVITY 1 (WITH STEP-BY-STEP PROCEDURE)

LEVEL BORDER IRRIGATION SYSTEM EVALUATION
Procedure for Completion of Module

1. If self-study, you will carefully proceed through the step-by-step evaluation procedure. Be sure you do not move to the next step until you fully understand where all the information came from and where and how it is to be recorded. Data from the field example is usually recorded on the even numbered page facing a worksheet. Solutions to each item are included, but try not to look at them until you have exhausted every effort to do the work on your own. You should fill out each blank on the various worksheets as though you were actually doing the evaluation. If you have trouble with any item, you should look at the solution. If you still do not understand, call or talk to your resource person.

2. If facilitator-led, you will be led through this activity step-by-step. You will fill out blanks on the various worksheets as though you were actually doing the evaluation.

3. As an aid to you when you return to your headquarters and perform your own evaluations, we have included a step-by-step procedure to guide you through the worksheets and computations. At first it may seem complicated, but, if you follow the procedure you should be able to perform a complete evaluation with no additional assistance.

GRADED BORDER IRRIGATION SYSTEM EVALUATION

ACTIVITY 1

The data recorded below was taken from the landuser's conservation plan (plan map, soils map, irrigation plan), State Irrigation Guide, and on-site observations and measurements. This information contains brief explanations to help complete the worksheets. Transfer this data to the Level Border Evaluation Worksheet A.

Field Data Inventory

1. Landuser's name - Joe Example. Use current date. Use your field office.
2. Field name/number (from conservation plan) - West 40
3. Field area (from conservation plan) - 40 acres
4. Border location (on-site determination) - - 3rd border from west side of field.
5. Crop (on-site determination) - Alfalfa
6. Root zone depth (conservation plan soils map, Irrigation Guide, field observation) - 5 feet
7. Stage of crop (on-site observations) - one week after cutting
8. Soil-water data for controlling soil (conservation plan soils map, Irrigation Guide, on-site observations and measurements):
    a. Soil name (conservation plan soils map) - Lohmiller silty clay, gravelly varient
    b. Location of sample (on-site selection. Usually any location representative of the basin would be okay) 2+00 center of border
    c. Method used to determine soil moisture content (Ely Volumeasure/Speedy Moisture meter, Volume Sampler/Oven-dry, or feel and appearance methods). Ely/Speedy was used.
    d. Data for chart:

Depth	Texture	AWC (in) 1/	SWD (%) 2/	SWD (in) 3/
0-1'	silty clay	1.6	60	.96
1-2'	silty clay	1.6	50	.80
2-3'	loam	2.0	40	.80
3-4'	clay loam	1.6	40	.64
4-5'	gravelly sand	0.5	20	.10

1/ Depth, Texture and Available Water Capacity (AWC) from site specific information or, if not available, from the Irrigation Guide.

2/ Soil Water Deficit (SWD). This is the actual percent of available water remaining in the soil at given increments. Measured by use of "Feel and Appearance", Ely/Speedy, or Volume Sampler/Oven-dry methods.

3/ SWD (in) computed by multiplying AWC (in) by SWD (%).

e. MAD (%) Management Allowed Deficit (from landuser, Irrigation Guide, NEH-15). Irrigate when approximately 50% of the available water in the root zone depth is depleted.

f. $\text{MAD (in)} = \frac{\text{MAD (\%)}}{100} \times \text{total AWC (in)}$

9. Comments about soils: There is a dense, compact layer between 9 and 12 inches. Surface cracks are evident throughout the field.

10. Typical irrigation duration (from landuser or irrigator) - 2-1/2 hr.

11. Typical irrigation frequency - (from landuser or irrigator) 12 days maximum.

12. Typical number of irrigations per year (from landuser or irrigator) - 10 +/-

13. Annual net irrigation requirement (from Irrigation Guide, use rate for crops) - 22.14 inches for alfalfa

14. Type of delivery system (on-site observation and measurements, if necessary) - Earth ditch from main ditch. Maximum allowed diversion flow rate = 10 cfs.

15. Type and size of turn outs (on-site observation) - 24" cmp pipe with slide gate attached to headwall.

16. Size of basin (on-site measurement) - 250' wide by 800 ft long rectangular basin

Field Observations

Crop uniformity - The crop is uniform in height and appearance throughout the basin

SURFACE SYSTEM EVALUATION WORKSHEET A

LEVEL BORDERS
CROP AND SOIL DATA

Landuser ______________ Date _______ Field office ______________________
Observer ________________ Field name/number _________________________

FIELD DATA INVENTORY

Field area __________ acres
Border location: ____
Crop ______________________ Root zone depth _____ ft MAD ______% 1/
Stage of crop ____

Soil-water data for controlling soil:
Soil name ____
Location of sample ______________________________________
Moisture determination method ___________________________

Depth	Texture	AWC (in) 2/	SWD (%) 3/	SWD (in)
	Totals			

$$\text{MAD (in)} = \frac{\text{MAD (\%)}}{100} \times \text{total AWC (in)} = \frac{\quad \times \quad}{100} = \underline{\qquad\qquad} \text{ in}$$

Comments about soils ____
____
____

Typical irrigation duration ______ hr, Irrigation frequency __________ days
Annual net irrigation requirements _______ inches for ____________ (crop)
Typical number of irrigations per year ____________

Type of delivery system (Earth ditch, concrete ditch, pipeline) ____________
____

Type and size of turnouts (automated turnout, manual screw gate, alfalfa valve etc.)
____

Size of basin: Width ________ ft, Length _________ ft

FIELD OBSERVATIONS

Crop uniformity ____
____
Salinity problems ____
____
Other observations ____
____
____

1/ MAD = Management allowed deficit 2/ AWC = Available water capacity
3/ SWD = Soil water deficit

SURFACE SYSTEM EVALUATION WORKSHEET A

LEVEL BORDERS
CROP AND SOIL DATA

Landuser *Joe Example* Date *7/25/86* Field office *Billings, MT*
Observer *Ed Evaluate* Field name/number *West 40*

FIELD DATA INVENTORY

Field area *40* acres
Border location: *3rd border from west side of field*
Crop *Alfalfa* Root zone depth *5* ft MAD *50* % 1/
Stage of crop *2nd cutting - one week after*

Soil-water data for controlling soil:
Soil name *Lohmiller silty clay, gravelly variant*
Location of sample *NW¼, S15, R 18E T2N*
Moisture determination method *Speedy & Ely*

Depth	Texture	AWC (in) 2/	SWD (%) 3/	SWD (in)
0-1'	*silty clay*	*1.6*	*60*	*.96*
1-2'	*silty clay*	*1.6*	*50*	*.80*
2-3'	*loam*	*2.0*	*40*	*.80*
3-4'	*clay loam*	*1.6*	*40*	*.64*
4-5'	*gravelly sand*	*0.5*	*20*	*.10*
	Totals	*7.3*		*3.30*

$$\text{MAD (in)} = \frac{\text{MAD (\%)}}{100} \times \text{total AWC (in)} = \frac{50 \times 7.3}{100} = 3.65 \text{ in}$$

Comments about soils *Dense, compact layer 9 to 12 inches. Surface cracks evident throughout field.*

Typical irrigation duration *2½* hr, Irrigation frequency *12* (max) days
Annual net irrigation requirements *22.14* inches for *Alfalfa* (crop)
Typical number of irrigations per year *10*

Type of delivery system (Earth ditch, concrete ditch, pipeline) *Earth ditch from main ditch. Max allowed diversion 10 cfs.*

Type and size of turnouts (automated turnout, manual screw gate, alfalfa valve etc.)
24" CMP pipe with slide gate on headwall

Size of basin: Width *250* ft, Length *800* ft

FIELD OBSERVATIONS

Crop uniformity *Crop uniform throughout basin*

Salinity problems

Other observations

1/ MAD = Management allowed deficit 2/ AWC = Available water capacity
3/ SWD = Soil water deficit

Evaluation Computations - Surface System Evaluation Worksheet B, Inflow Data

1. Enter the type of flow measuring device being used. In the example - 36 inch sharp crested trapezoidal weir in supply ditch.

2. The exact use of the inflow data worksheet depends on the type of inflow measuring device used. Usually some type of flume or weir will be used. In that case, the gauge column heading should be changed to indicate the units of measurement. In the example, we are using a 36 inch trapezoidal weir and the units are delta H, in feet. Our flume chart reads out in cubic feet per second, so we enter cfs in the Flow Rate column headings.

3. The first measurement is taken as soon as the water is turned on. It is best to use 24 hour clock time in the Clock time column. This makes computations easier. In this example the water is turned on at 7:05 am. The gauge reading is 0.78 feet.

4. Initially, the inflow readings are taken at frequent intervals. Reading intervals are taken less frequently when the flow rate has become relatively constant. Enough readings should be taken to accurately determine the total volume of water which enters the border. The example information has been recorded for you.

5. A final reading is taken at 9:35 am, when the water is turned off.

6. Calculate the elapsed time to each reading in minutes. This is the difference from "Turn on" to time of reading. In our example, the elapsed time at 7:10 is 5 minutes (7:10 - 7:05). The next elapsed time is 13 minutes (7:18 - 7:05).

7. Calculate the difference in time, in minutes, between each reading (delta time). The difference in time from "turn on" to 7:10 is 5 minutes (7:10 - 7:05). The difference in time between 7:18 and 7:10 is 8 minutes. (7:18 - 7:10).

8. From the flow rate chart for the trapezoidal weir, determine the flow rate, in cfs, for each reading time. (See Table 1). The flow rate, in cfs, for a head of 0.78 ft. and a 36" weir is 6.97 cfs.

9. Compute the average flow rate between adjacent reading times.

10. Using one of the factors shown at the bottom of the worksheet, compute flow rate over time, to volume in acre inches. For example:
6.97 cfs x 5 min x 0.01653 = 0.5761 ac-in

11. Compute the Cumulative Volume (ac-in) column, including the total irrigation volume. This later is the total volume of water that entered the border during the irrigation.

12. Compute the average inflow rate:

$$\text{Inflow} = \frac{\text{Total irrigation volume (ac-in) x 60.5}}{\text{Total inflow time}}$$

Head, H[1]		Discharge, *Q*, for crest length, *L*, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Feet	*Inches*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*	*Second-feet*
0. 65	7 13/16	1. 84	2. 68	3. 53	5. 24	6. 95	10. 6	14. 1	17. 6
. 66	7 15/16	1. 89	2. 75	3. 61	5. 36	7. 11	10. 8	14. 4	18. 1
. 67	8 1/16	1. 93	2. 81	3. 70	5. 48	7. 28	11. 1	14. 8	18. 5
. 68	8 3/16	1. 98	2. 87	3. 79	5. 61	7. 44	11. 3	15. 1	18. 9
. 69	8 1/4	2. 02	2. 94	3. 87	5. 73	7. 61	11. 6	15. 4	19. 3
. 70	8 3/8	2. 07	3. 01	3. 95	5. 86	7. 77	11. 8	15. 8	19. 7
. 71	8 1/2	2. 12	3. 07	4. 04	5. 99	7. 94	12. 1	16. 1	20. 1
. 72	8 5/8	2. 16	3. 14	4. 13	6. 12	8. 11	12. 3	16. 5	20. 6
. 73	8 3/4	2. 21	3. 21	4. 22	6. 24	8. 28	12. 6	16. 8	21. 0
. 74	8 7/8	2. 26	3. 28	4. 31	6. 38	8. 45	12. 9	17. 1	21. 4
. 75	9	2. 31	3. 35	4. 40	6. 51	8. 62	13. 1	17. 5	21. 9
. 76	9 1/8	2. 36	3. 42	4. 49	6. 64	8. 80	13. 4	17. 8	22. 3
. 77	9 1/4	2. 41	3. 49	4. 58	6. 77	8. 97	13. 6	18. 2	22. 7
. 78	9 3/8	2. 46	3. 56	4. 67	6. 90	9. 15	13. 9	18. 6	23. 2
. 79	9 1/2	2. 51	3. 63	4. 76	7. 04	9. 33	14. 2	18. 9	23. 6
. 80	9 5/8	2. 56	3. 70	4. 85	7. 18	9. 51	14. 5	19. 3	24. 1
. 81	9 3/4	2. 61	3. 77	4. 95	7. 31	9. 69	14. 7	19. 6	24. 5
. 82	9 13/16	2. 66	3. 84	5. 04	7. 45	9. 87	15. 0	20. 0	25. 0
. 83	9 15/16	2. 71	3. 92	5. 14	7. 59	10. 0	15. 3	20. 4	25. 5
. 84	10 1/16	2. 77	3. 99	5. 23	7. 73	10. 2	15. 6	20. 7	25. 9
. 85	10 3/16	2. 82	4. 07	5. 33	7. 87	10. 4	15. 8	21. 1	26. 4
. 86	10 5/16	2. 87	4. 14	5. 43	8. 01	10. 6	16. 1	21. 5	26. 9
. 87	10 7/16	2. 93	4. 22	5. 52	8. 15	10. 8	16. 4	21. 9	27. 3
. 88	10 9/16	2. 98	4. 29	5. 62	8. 30	11. 0	16. 7	22. 2	27. 8
. 89	10 11/16	3. 04	4. 37	5. 72	8. 44	11. 2	17. 0	22. 6	28. 3
. 90	10 13/16	3. 09	4. 45	5. 82	8. 59	11. 4	17. 2	23. 0	28. 7
. 91	10 15/16	3. 15	4. 53	5. 92	8. 73	11. 6	17. 5	23. 4	29. 2
. 92	11 1/16	3. 20	4. 60	6. 02	8. 88	11. 7	17. 8	23. 8	29. 7
. 93	11 3/16	3. 26	4. 68	6. 13	9. 03	11. 9	18. 1	24. 2	30. 2
. 94	11 1/4	3. 32	4. 76	6. 23	9. 17	12. 1	18. 4	24. 5	30. 7
. 95	11 3/8	3. 37	4. 84	6. 33	9. 32	12. 3	18. 7	24. 9	31. 2
. 96	11 1/2	3. 43	4. 92	6. 44	9. 48	12. 5	19. 0	25. 3	31. 7
. 97	11 5/8	3. 49	5. 00	6. 55	9. 62	12. 7	19. 3	25. 7	32. 2
. 98	11 3/4	3. 55	5. 09	6. 64	9. 78	12. 9	19. 6	26. 1	32. 7
. 99	11 7/8	3. 61	5. 17	6. 75	9. 93	13. 1	19. 9	26. 5	33. 2
1. 00	12	3. 67	5. 25	6. 86	10. 1	13. 3	20. 2	26. 9	33. 7
1. 01	12 1/8	------	5. 33	6. 96	10. 2	13. 5	20. 5	27. 3	34. 2
1. 02	12 1/4	------	5. 42	7. 07	10. 4	13. 7	20. 8	27. 7	34. 7
1. 03	12 3/8	------	5. 50	7. 18	10. 6	13. 9	21. 1	28. 2	35. 2
1. 04	12 1/2	------	5. 59	7. 29	10. 7	14. 2	21. 4	28. 6	35. 7
1. 05	12 5/8	------	5. 67	7. 40	10. 9	14. 4	21. 7	29. 0	36. 2
1. 06	12 3/4	------	5. 76	7. 51	11. 0	14. 6	22. 0	29. 4	36. 7
1. 07	12 13/16	------	5. 84	7. 62	11. 2	14. 8	22. 4	29. 8	37. 3
1. 08	12 15/16	------	5. 93	7. 73	11. 4	15. 0	22. 7	30. 2	37. 8
1. 09	13 1/16	------	6. 02	7. 84	11. 5	15. 2	23. 0	30. 6	38. 3
1. 10	13 3/16	------	6. 11	7. 96	11. 7	15. 4	23. 3	31. 1	38. 8
1. 11	13 5/16	------	6. 20	8. 07	11. 8	15. 6	23. 6	31. 5	39. 4
1. 12	13 7/16	------	6. 29	8. 18	12. 0	15. 8	23. 9	31. 9	39. 9
1. 13	13 9/16	------	6. 38	8. 29	12. 2	16. 0	24. 3	32. 4	40. 4
1. 14	13 11/16	------	6. 47	8. 41	12. 3	16. 3	24. 6	32. 8	41. 0
1. 15	13 13/16	------	6. 56	8. 53	12. 5	16. 5	24. 9	33. 2	41. 5
1. 16	13 15/16	------	6. 65	8. 65	12. 7	16. 7	25. 2	33. 6	42. 1
1. 17	14 1/16	------	6. 74	8. 76	12. 8	16. 9	25. 6	34. 1	42. 6
1. 18	14 3/16	------	6. 83	8. 88	13. 0	17. 2	25. 9	34. 5	43. 2
1. 19	14 1/4	------	6. 93	9. 00	13. 2	17. 4	26. 2	35. 0	43. 7

Table 1. -- Discharge values for trapezoidal weirs with complete contractions.

NOTE: Table from NEH 15, Ch 9, pg 39.

$$\text{Inflow} = \frac{18.907 \text{ ac-in} \times 60.5}{150 \text{ min}} = 7.63 \text{ cfs}$$

13. Compute unit flow per foot of border width:

$$qu = \frac{\text{Average flow rate (cfs)}}{\text{Border spacing (ft)}} = \frac{7.63 \text{ cfs}}{250 \text{ ft}} = 0.03 \text{ cfs/ft}$$

SURFACE SYSTEM EVALUATION WORKSHEET B

LEVEL BORDERS
INFLOW DATA

Landuser *Joe Example* Date *7/25/84* Field Office *Billings, MT*

Type of Measuring device *36" sharp-crested trapezoidal weir in supply ditch*

Clock 1/ Time (hr:min)	Elapsed Time (min)	ΔT (min)	ΔH (*Ft*)	Flow Rate ( )	Avg. Flow: Rate ( )	2/ Volume (ac-in)	Cum. Volume (ac-in)
Turn on		///////			///////	///////	///////
(*07:05*)	/////////		*.78*				
07:10			*.79*				
07:18			*.80*				
07:36			*.84*				
08:05			*.85*				
08:35			*.84*				
09:06			*.83*				
Turn off							
(*09:35*)		///////					

Total Volume (ac-in) ______

Average flow rate =

$$\frac{\text{Total irrigation volume (ac-in)} \times 60.5}{\text{Inflow time (min)}} = \_\_\_\_\_\_ = \_\_\_\_\_\_ \text{ cfs}$$

Unit flow:

$$qu = \frac{\text{Average flow rate (cfs)}}{\text{Border spacing (ft)}} = \_\_\_\_\_\_ = \_\_\_\_\_\_ \text{ cfs/ft}$$

1/ Use a 24-hour clock reading; i.e., 1:30 p.m. should be recorded as 1330

2/ Flow rate to volume factors:

To find volume using cfs:
volume (ac-in) = .01653 x time (min) x flow (cfs)
To find volume using gpm:
volume (ac-in) = .00003683 x time (min) x flow (gpm)

SURFACE SYSTEM EVALUATION WORKSHEET B

LEVEL BORDERS
INFLOW DATA

Landuser *Joe Example* Date *7/25/84* Field Office *Billings, MT*

Type of Measuring device *36" sharp-crested trapezoidal weir in supply ditch*

Clock 1/ Time (hr:min)	Elapsed Time (min)	ΔT (min)	ΔH (*Ft*)	Flow Rate (*cfs*)	Avg. Flow: Rate (*cfs*)	2/ Volume (ac-in)	Cum. Volume (ac-in)
Turn on (*07:05*)	/////////	///////	*.78*	*6.90*	//////////	//////////	//////////
		5			*6.97*	*.5761*	*.5761*
07:10	*5*		*.79*	*7.04*			
		8			*7.11*	*.9402*	*1.5163*
07:18	*13*		*.80*	*7.18*			
		18			*7.46*	*2.2196*	*3.7359*
07:36	*31*		*.84*	*7.73*			
		29			*7.80*	*3.7391*	*7.4750*
08:05	*60*		*.85*	*7.87*			
		30			*7.80*	*3.8680*	*11.343*
08:35	*90*		*.84*	*7.73*			
		31			*7.66*	*3.9252*	*15.2682*
09:06	*121*		*.83*	*7.59*			
		29			*7.59*	*3.6384*	*18.967*
Turn off							
(*09:35*)		///////	*.83*	*7.59*			

Total Volume (ac-in) *18.907*

Average flow rate =

$$\frac{\text{Total irrigation volume (ac-in)} \times 60.5}{\text{Inflow time (min)}} = \frac{18.907 \times 60.5}{150} = 7.63 \text{ cfs}$$

Unit flow:

$$qu = \frac{\text{Average flow rate (cfs)}}{\text{Border spacing (ft)}} = \frac{7.63}{250} = 0.03 \text{ cfs/ft}$$

1/ Use a 24-hour clock reading; i.e., 1:30 p.m. should be recorded as 1330

2/ Flow rate to volume factors:

To find volume using cfs:
volume (ac-in) = .01653 x time (min) x flow (cfs)
To find volume using gpm:
volume (ac-in) = .00003683 x time (min) x flow (gpm)

Evaluation Computations - Surface System Evaluation Worksheet C, Advance Recession Data

1. Stakes were set at 100 foot intervals down the basin. Elevations are taken with a level rod to hundredths of a foot. Because levelness is so critical in a level basin, measuring to the nearest tenth is not usually accurate enough. This data is recorded in the first two columns of the data sheet. The example information has been recorded for you.

2. As the advancing water front hits each station point during inflow, the time is recorded in the Advance Time column. Use 24 hour clock time. The example information has been recorded for you.

3. Using a stilling well, or picking a calm site, use the level and rod to determine the water surface elevation in the basin immediately after the water into the basin is turned off. Record this on the worksheet. For our example, this information has been recorded for you.

4. When the irrigation is complete and all surface water has disappeared from each station point, record the time in the Recession Time column. The example information has been recorded for you.

5. Compute the opportunity time at each station point. This is the difference, in minutes, between Advance Time and Recession Time at each point. In our example, for station 0+00, the opportunity time is 370 minutes (13:15 - 7:05 = 6 hrs 10 min).

6. Total the Elevations column and the Opportunity Time columns.

7. Calculate the average field elevation:

$$\text{Average field elevation} = \frac{\text{Elevation total}}{\text{Number of elevation points}}$$

$$= \frac{444.86}{9} = 49.43 \text{ ft}$$

8. Calculate the depth infiltrated after water turnoff:

d after = (Water elev. at turnoff - Average field elev.) x 12

= (49.57 - 49.43) x 12 = 1.68 in

9. Calculate average opportunity time:

$$\text{To av} = \frac{\text{Total opportunity time}}{\text{Number of sample location points}}$$

$$= \frac{3005}{9} = 334 \text{ minutes}$$

10. Now leave this worksheet for a while and plot an intake curve.

SURFACE SYSTEM EVALUATION WORKSHEET C

LEVEL BORDERS
ADVANCE-RECESSION DATA

Landuser *Joe Example* Date ______ Field Office ______

Sta.	Elev. (ft)	Advance Time 1/ (hr:min)	Recession Time 1/ (hr:min)	Opportunity Time "To" (min)	2/ Intake (in)	Minimum/ Maximum Intake (in)
0+00	*49.51*	*07:05*	*13:15*			
1+00	*49.44*	*07:09*	*13:11*			
2+00	*49.46*	*07:14*	*13:07*			
3+00	*49.45*	*07:19*	*13:04*			
4+00	*49.43*	*07:26*	*13:00*			
5+00	*49.38*	*07:32*	*12:55*			
6+00	*49.42*	*07:39*	*12:52*			
7+00	*49.39*	*07:47*	*12:49*			
8+00	*49.38*	*07:56*	*12:45*			
Totals	______			______		

Water surface elevation at water turnoff *49.57* ft 3/

Average field elevation = $\frac{\text{Elevation total}}{\text{No. of elevations}}$ = ______ = ______ ft

Depth infiltrated after water turnoff
= (Water surface at turnoff - Average field elev) x 12

= (______ - ______) x 12 = ______ in

Average opportunity time = $\frac{\text{Total opportunity time}}{\text{No. of sample locations}}$ = ______ = ______ min

1/ Use 24 hour clock time. As a minimum, record times at upper end, mid point

2/ Obtain intake from plotted intake curve.

3/ Water surface elevation must be read to nearest 0.01 ft.

SURFACE SYSTEM EVALUATION WORKSHEET C

LEVEL BORDERS
ADVANCE-RECESSION DATA

Landuser *Joe Example* Date *7/25/84* Field Office *Billings, MT*

Sta.	Elev. (ft)	Advance Time 1/ (hr:min)	Recession Time 1/ (hr:min)	Opportunity Time "To" (min)	2/ Intake (in)	Minimum/ Maximum Intake (in)
0+00	49.51	07:05	13:15	370		
1+00	49.44	07:09	13:11	362		
2+00	49.46	07:14	13:07	353		
3+00	49.45	07:19	13:04	345		
4+00	49.43	07:26	13:00	334		
5+00	49.38	07:32	12:55	323		
6+00	49.42	07:39	12:52	313		
7+00	49.39	07:47	12:49	302		
8+00	49.38	07:56	12:45	289		
Totals	444.86			3005		

Water surface elevation at water turnoff *49.57* ft 3/

Average field elevation = $\frac{\text{Elevation total}}{\text{No. of elevations}} = \frac{444.86}{9} =$ *49.43* ft

Depth infiltrated after water turnoff
= (Water surface at turnoff - Average field elev) x 12

= (*49.57* - *49.43*) x 12 = *1.68* in

Average opportunity time = $\frac{\text{Total opportunity time}}{\text{No. of sample locations}} = \frac{3005}{9} =$ *334* min

1/ Use 24 hour clock time. As a minimum, record times at upper end, mid point

2/ Obtain intake from plotted intake curve.

3/ Water surface elevation must be read to nearest 0.01 ft.

Evaluation Computations - Soil Water Intake Curves

1. Using the Soil Water Intake Curves worksheet or 2 x 2 cycle log paper, plot a two point intake curve as described below. Set the scales up so that Accumulated Intake (inches) is on the left (vertical) scale and Time in Minutes is on the bottom (horizontal scale).

2. The first point is the intersection of the average opportunity time, which is 334 minutes (Worksheet C. Total Opportunity time divided by 9 readings = 3005/9 = 334 min), and gross application depth, at 4.12 inches in the example. (From Worksheets A & B:

   $$\text{Gross application depth} = 18.907 \text{ ac. in} \;/\; \frac{250 \text{ ft } (800 \text{ ft})}{43{,}560 \text{ ft}^2/\text{Ac}}$$

   = 18.907 ac in./4.59 ac. = 4.12 in)

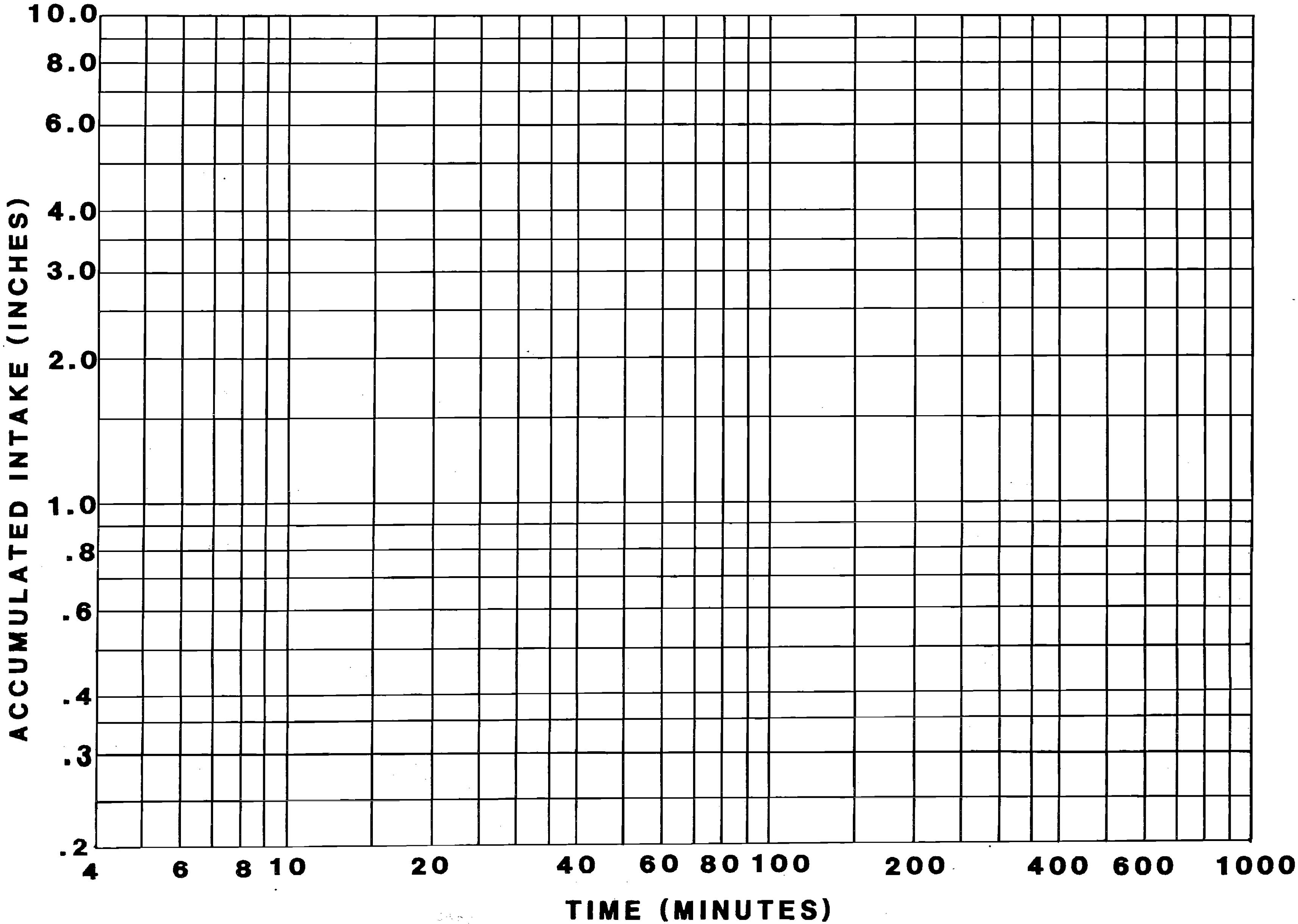
3. The second point to be plotted is the intersection of inflow time, which is 150 minutes in this example (Worksheet B. Total Elapsed Time), and the amount infiltrated during water inflow, which is 2.44 inches in the example. Water infiltrated during water inflow = Gross application depth, 4.12 in, - depth infiltrated after water turnoff, 1.68 in (Worksheet C) = 2.44 in.

4. Draw a straight line through these two points. This is the cumulative soil water intake curve for the basin. Label your curve "Basin Intake".

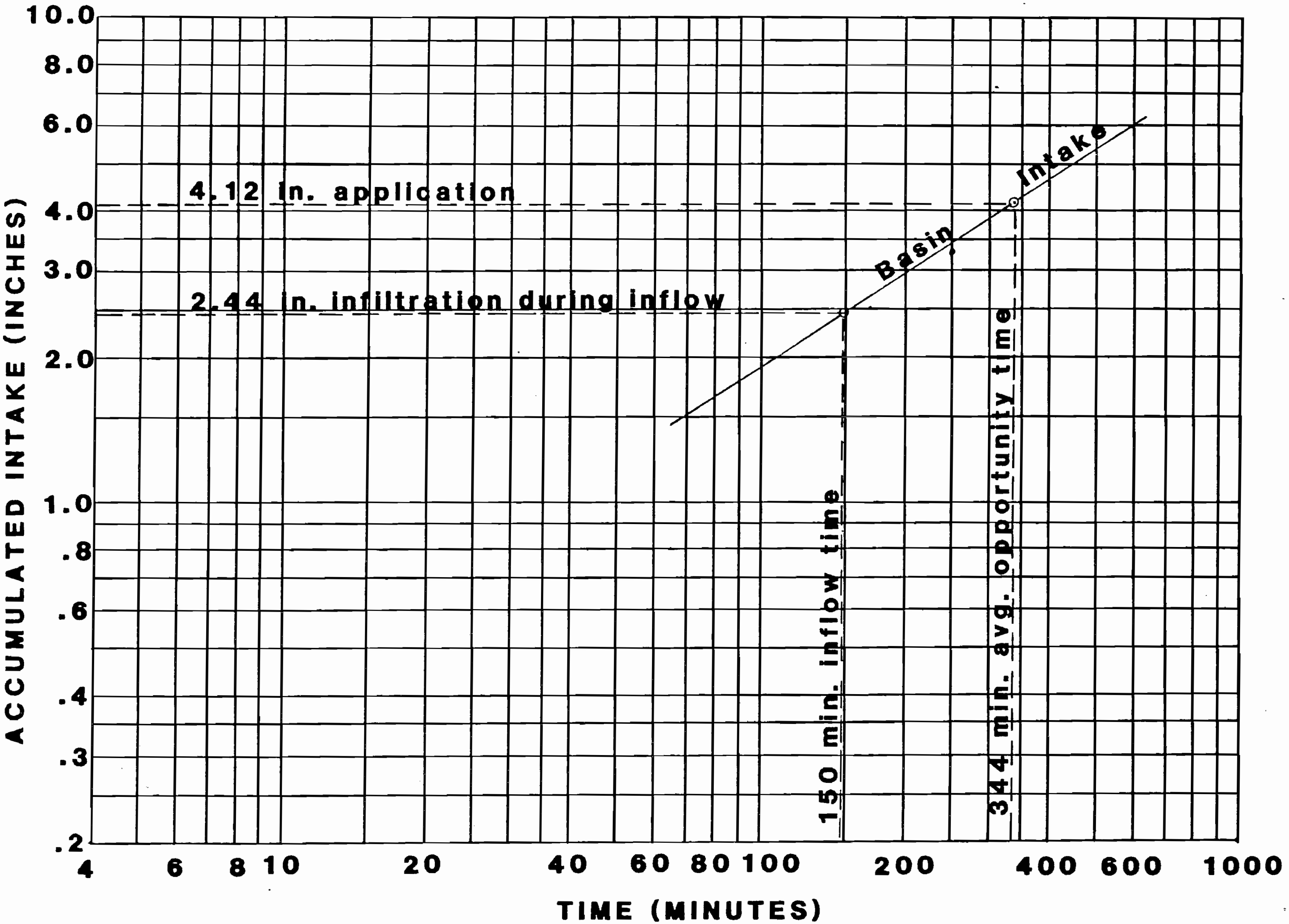
5. You may, at this point, want to overlay a standard set of intake curve families (Figure 1) to see where this curve fits. It best fits the 0.5 in/hr curve.

6. Now, you would normally go back to the Advance-Recession Worksheet (Worksheet C). For our example, we have brought the updated worksheet forward.

Soil Water Intake Curves



Soil Water Intake Curves



Evaluation Computations - Surface System Evaluation Worksheet C - Advance - Recession Data (continued)

To make computations easier, Worksheet C has been brought forward. Normally, you would go back to the original Worksheet to complete it.

1. Using the plotted intake curve, determine the intake depth (inches) for the appropriate Opportunity Time (minutes)

   Read the accumulated intake at the left of the chart. In our example, 353 minutes will have a value of 4.30 inches.

2. Determine the stations with minimum and maximum intake depths. Enter the information on the worksheets.

3. Compare your answers with the solution. If you missed any parts, redo this section.

SURFACE SYSTEM EVALUATION WORKSHEET C

LEVEL BORDERS
ADVANCE-RECESSION DATA

Landuser *Joe Example* Date *7/25/84* Field Office *Billings, MT*

Sta.	Elev. (ft)	Advance Time 1/ (hr:min)	Recession Time 1/ (hr:min)	Opportunity Time "To" (min)	2/ Intake (in)	Minimum/ Maximum Intake (in)
0+00	*49.51*	*07:05*	*13:15*	*370*		
1+00	*49.44*	*07:09*	*13:11*	*362*		
2+00	*49.46*	*07:14*	*13:07*	*353*		
3+00	*49.45*	*07:19*	*13:04*	*345*		
4+00	*49.43*	*07:26*	*13:00*	*334*		
5+00	*49.38*	*07:32*	*12:55*	*323*		
6+00	*49.42*	*07:39*	*12:52*	*313*		
7+00	*49.39*	*07:47*	*12:49*	*302*		
8+00	*49.38*	*07:56*	*12:45*	*289*		
Totals	*444.86*			*3005*		

Water surface elevation at water turnoff *49.57* ft 3/

Average field elevation = $\frac{\text{Elevation total}}{\text{No. of elevations}}$ = $\frac{444.86}{9}$ = *49.43* ft

Depth infiltrated after water turnoff
= (Water surface at turnoff - Average field elev) x 12

= (*49.57* - *49.43*) x 12 = *1.68* in

Average opportunity time = $\frac{\text{Total opportunity time}}{\text{No. of sample locations}}$ = $\frac{3005}{9}$ = *334* min

1/ Use 24 hour clock time. As a minimum, record times at upper end, mid point

2/ Obtain intake from plotted intake curve.

3/ Water surface elevation must be read to nearest 0.01 ft.

SURFACE SYSTEM EVALUATION WORKSHEET C

LEVEL BORDERS
ADVANCE-RECESSION DATA

Landuser *Joe Example* Date *7/25/84* Field Office *Billings, MT*

Sta.	Elev. (ft)	Advance Time 1/ (hr:min)	Recession Time 1/ (hr:min)	Opportunity Time "To" (min)	2/ Intake (in)	Minimum/ Maximum Intake (in)
0+00	49.51	07:05	13:15	370	4.50	4.50 max
1+00	49.44	07:09	13:11	362	4.40	
2+00	49.46	07:14	13:07	353	4.30	
3+00	49.45	07:19	13:04	345	4.25	
4+00	49.43	07:26	13:00	334	4.12	
5+00	49.38	07:32	12:55	323	4.10	
6+00	49.42	07:39	12:52	313	3.95	
7+00	49.39	07:47	12:49	302	3.90	
8+00	49.38	07:56	12:45	289	3.75	3.75 min
Totals	444.86			3005		

Water surface elevation at water turnoff *49.57* ft 3/

Average field elevation = $\frac{\text{Elevation total}}{\text{No. of elevations}} = \frac{444.86}{9} = 49.43$ ft

Depth infiltrated after water turnoff
= (Water surface at turnoff - Average field elev) x 12

= (49.57 - 49.43) x 12 = 1.68 in

Average opportunity time = $\frac{\text{Total opportunity time}}{\text{No. of sample locations}} = \frac{3005}{9} = 334$ min

1/ Use 24 hour clock time. As a minimum, record times at upper end, mid point

2/ Obtain intake from plotted intake curve.

3/ Water surface elevation must be read to nearest 0.01 ft.

Evaluation Computations - Surface System Evaluation Worksheet D - Evaluation Computations

1. Calculate the level basin area:
(Example information from Worksheet A)

$$A = \frac{\text{Length of basin x Width of basin}}{43{,}560} = \frac{250 \text{ ft x } 800 \text{ ft}}{43{,}560}$$

= 4.6 acres

2. Calculate gross irrigation application:

$$Fg = \frac{\text{Total irrigation volume (ac-in)}}{\text{A (ac)}}$$

$$= \frac{18.907 \text{ ac-in}}{4.6 \text{ ac}} = 4.12 \text{ inches}$$

(Total irrigation volume is from Worksheet B - Inflow Data.)

3. Amount infiltrated during water inflow:

Vi = Fg (in) - Depth infiltrated after turnoff

= 4.12 - 1.68 = 2.44 inches
(Depth infiltrated after turnoff is from Worksheet C - Advance-Recession data.)

4. Compute deep percolation:

Deep percolation depth is simply gross application depth minus the soil water deficit. If the irrigation was less than the soil water deficit there would not be any deep percolation.

DP = Fg (in) - SWD (in) = 4.12 - 3.3 = 0.82 inches
(SWD is from the Crop and Soil Data section of worksheet A)

Deep percolation as a percentage of the total application would be deep percolation depth divided by gross application.

$$DP\% = \frac{\text{DP (in) x 100}}{\text{Fg (in)}} = \frac{0.82 \text{ x } 100}{4.12} = 19.9\ \%$$

(There is no deep percolation if Fg is equal to or less than SWD)

5. Application efficiency:

The average depth stored in the root zone is required to determine application efficiency (Ea). It is equal to the soil water deficit (SWD) if the entire root zone is filled to field capacity during the irrigation. This is the usual case for level basin irrigation.

If the gross application is less than soil water deficit, then that value would be used. In such a case application efficiency would be 100%, since all water ends up in the root zone.

Distribution may not be good, though. This is the reason that we must also consider distribution efficiency.

$$Ea = \frac{\text{Average depth stored in root zone (fg) x 100}}{\text{Fg (in)}}$$

$$= \frac{3.3 \times 100}{4.12} = 80.1 \text{ percent}$$

6. Compute distribution uniformity low 1/4:

Distribution uniformity is a term for placing a numerical value on the uniformity of application. The "DU" indicates the uniformity of infiltration throughout the basin.

We first must compute the depth infiltrated where lowest 1/4 infiltration took place. A rough estimate is found using the equation as follows:

Depth infiltrated low 1/4

$$= \frac{\text{(max. intake - min. intake)}}{8} + \text{min. intake}$$

$$= \frac{(4.5 - 3.75)}{8} + 3.75 = 3.84 \text{ inches}$$ (data taken from Worksheet C)

A more accurate determination of low 1/4 infiltration would require a grid system of analysis. This would involve a grid of many points where advance and recession times are taken.

Now we can compute the distribution uniformity:

$$DU = \frac{\text{Depth infiltrated low 1/4 x 100}}{\text{Fg (in)}}$$

$$= \frac{3.84 \times 100}{4.12} = 93.2 \text{ percent}$$

7. Application efficiency low 1/4:

We now combine the distribution uniformity and application efficiency to determine the application efficiency low 1/4.

$$Eq = \frac{DU\% \times Ea\%}{100} = \frac{93.2 \times 80.1}{100} = 74.7 \text{ percent}$$

SURFACE SYSTEM EVALUATION WORKSHEET D

LEVEL BORDERS
EVALUATION COMPUTATIONS

Landuser ____________________ Date ________ Field office ________________

1. Basin area (A)

$$A = \frac{\text{Length x Width}}{43{,}560} = \frac{\quad x \quad}{46{,}560} = \underline{\qquad\qquad} \text{ acres}$$

2. Gross application (Fg)

$$Fg = \frac{\text{Total irrigation volume (ac-in)}}{\text{A (ac)}} = \underline{\qquad\qquad} = \underline{\qquad\qquad} \text{ inches}$$

3. Amount infiltrated during water inflow (Vi)

Vi = Gross application - Depth infiltrated after turnoff =

________________ = ________________ inches

4. Deep Percolation (Dp)

DP = Gross application - Soil water deficit (SWD) = ________________ =

________________ inches

$$DP\% = \frac{\text{Deep percolation (DP) x 100}}{\text{Gross application (Fg)}} = \underline{\qquad\qquad} = \underline{\qquad\qquad} \text{ percent}$$

5. Application efficiency (Ea)

(Average depth stored in root zone = Soil water deficit (SWD) if entire root zone depth will be filled to field capacity by this irrigation)

$$Ea = \frac{\text{Av depth stored in root zone x 100}}{\text{Gross application (Fg)}} = \underline{\qquad\qquad} =$$

________________ percent

6. Distribution uniformity (DU)

$$\text{Depth infiltrated low 1/4} = \frac{\text{(max intake - min intake)}}{8} + \text{min intake} =$$

$$= \frac{(\qquad - \qquad)}{} + \underline{\qquad} = \underline{\qquad} \text{ inches}$$

$$DU = \frac{\text{Depth infiltrated low 1/4 x 100}}{\text{Gross application}} = \underline{\qquad\qquad} = \underline{\qquad\qquad} \text{ percent}$$

7. Application efficiency low 1/4 (Eq)

$$Eq = \frac{DU\% \text{ x } Ea\%}{100} = \frac{\qquad\qquad}{100} = \underline{\qquad\qquad} \text{ percent}$$

SURFACE SYSTEM EVALUATION WORKSHEET D

LEVEL BORDERS
EVALUATION COMPUTATIONS

Landuser *Joe Example* Date *7/25/84* Field office *Billings, MT*

1. Basin area (A)

$$A = \frac{\text{Length x Width}}{43{,}560} = \frac{250 \times 800}{46{,}560} = \underline{4.6} \text{ acres}$$

2. Gross application (Fg)

$$Fg = \frac{\text{Total irrigation volume (ac-in)}}{\text{A (ac)}} = \frac{18.907}{4.6} = \underline{4.12} \text{ inches}$$

3. Amount infiltrated during water inflow (Vi)

Vi = Gross application - Depth infiltrated after turnoff =

4.12 - 1.68 = *2.44* inches

4. Deep Percolation (Dp)

DP = Gross application - Soil water deficit (SWD) = *4.12 - 3.3* =

0.82 inches

$$DP\% = \frac{\text{Deep percolation (DP) x 100}}{\text{Gross application (Fg)}} = \frac{.82 \times 100}{4.12} = \underline{19.9} \text{ percent}$$

5. Application efficiency (Ea)

(Average depth stored in root zone = Soil water deficit (SWD) if entire root zone depth will be filled to field capacity by this irrigation)

$$Ea = \frac{\text{Av depth stored in root zone x 100}}{\text{Gross application (Fg)}} = \frac{3.3 \times 100}{4.12} =$$

80.1 percent

6. Distribution uniformity (DU)

$$\text{Depth infiltrated low 1/4} = \frac{\text{(max intake - min intake)}}{8} + \text{min intake} =$$

$$= \frac{(4.5 - 3.75)}{8} + \underline{3.75} = \underline{3.84} \text{ inches}$$

$$DU = \frac{\text{Depth infiltrated low 1/4 x 100}}{\text{Gross application}} = \frac{3.84 \times 100}{4.12} = \underline{93.2} \text{ percent}$$

7. Application efficiency low 1/4 (Eq)

$$Eq = \frac{DU\% \times Ea\%}{100} = \frac{93.2 \times 80.1}{100} = \underline{74.7} \text{ percent}$$

Evaluation Computations – Surface System Evaluation Worksheet E – Level Borders Cost Savings Worksheet

1. Water use under present management:

   The estimated present annual gross irrigation application can be estimated in several ways. In some cases, there will be records based on measured delivery from an irrigation district. In other cases flow is measured to the field, and the irrigator will have a good idea of how much water is applied. In many cases the amount will have to be estimated from the evaluation data and discussions with the irrigator. The later method is used in this example.

   Estimate the present average net application per irrigation. This information can be derived from discussions with the irrigator and from the evaluation. Remember that all irrigations may not be the same amount during the season. In this case the average net application is estimated to be 3.2 inches.

   Calculate the gross annual application. Seasonal application efficiency will have to be estimated based on the "Ea" found in the evaluation and discussions with the irrigator. Efficiency may vary throughout the season due to variations in net requirements per irrigation, variable set times, etc.

   Present annual gross applied

$$= \frac{\text{Net applied per irrig. x Number of irrigations x 100}}{\text{Ea}}$$

$$= \frac{3.2 \times 10 \times 100}{80.1\%} = 40 \text{ inches}$$

2. Potential annual cost savings:

   The annual net irrigation requirement was determined in the Field Data section of the worksheet. In the example the annual requirement for alfalfa is 22.14 inches.

   To determine the potential gross amount of irrigation water applied annually, we must recommend a realistic design efficiency (Edes). This can be obtained from your Irrigation Guide or National Engineering Handbook Section 15, Chapter 4. This efficiency assumes good management and a well designed and maintained system. In this example we estimate 90 percent.

   Potential annual gross applied

$$= \frac{\text{Annual net irrigation requirement x 100}}{\text{Edes}}$$

$$= \frac{22.14 \times 100}{90\%} = 24.6 \text{ inches}$$

The total water conserved during a year can now be computed.

Total annual water conserved

$$= \frac{(\text{present gross applied} - \text{Potential gross applied}) \times A}{12 \text{ in/ft}}$$

$$= \frac{(40.0 - 24.6) \times 40}{12} = 51.3 \text{ acre feet}$$

NOTE: The net irrigation presently being applied is 32 inches (3.2 in x 10) while the annual net irrigation requirement is only 20.1 inches. This is an indication that the landuser needs to better schedule irrigations.

3. Potential annual cost savings:

If a separate pumping plant evaluation has been performed, fuel cost savings can be calculated. To do this requires pumping plant efficiency, unit cost of fuel, and fuel cost per acre foot information.

Fuel cost savings = Fuel cost per AF x AF conserved

In our example we do not have this information.

If there is cost of purchasing water, then we would add these costs to the analysis. In this example it costs the irrigator $12.00 per acre foot, purchased from the irrigation district.

Water purchase cost

= Cost per AF x AF saved per year = $12 x 51.3 = $616

Now we can compute total potential cost savings if management and system changes were made:

Potential cost savings

= Pumping cost + Water cost = 0 + $616 = $616

SURFACE SYSTEM EVALUATION WORKSHEET E

LEVEL BORDERS
COST SAVINGS

Landuser ____________________ Date __________ Field office ____________

1. Present management

Estimated present average net application per irrigation _______ inches

Present annual gross applied = $\frac{\text{Net applied per irrig. x No. irrig. x 100}}{\text{Application efficiency (Ea) 1/}}$

= ____________________ = __________ inches

2. Potential management

Recommended design efficiency (Edes) __________ percent

Potential annual gross applied = $\frac{\text{Annual net irrig. requirements x 100}}{\text{Edes}}$

= ______ x 100 = __________ inches

Total annual water conserved

= $\frac{\text{(Present gross applied - Potential gross applied) x A (ac)}}{\text{12 (in/ft)}}$

= $\frac{(\quad\quad - \quad\quad) \text{ x } \quad\quad}{12}$ = __________ acre feet

3. Annual potential cost savings

From pumping plant evaluation:

Pumping plant efficiency ________ Kind of fuel ______________
Cost per unit of fuel __________ Fuel cost per acre foot $__________

Cost savings = Fuel cost per acre foot x acre feet conserved per year

= ________________ = $ __________ / year

Water purchase cost

Cost per acre foot x acre feet saved per year = __________

= $______________ / year

Potential cost savings

= Pumping cost + water cost = ____________ = $ __________ / year

1/ Use the best estimate of what the application efficiency of a typical irrigation during the season may be. The application efficiency from irrigation to irrigation can vary depending on the SWD, inflow times, etc.

SURFACE SYSTEM EVALUATION WORKSHEET E

LEVEL BORDERS
COST SAVINGS

Landuser *Joe Example* Date *7/25/84* Field office *Billings, MT*

1. Present management

Estimated present average net application per irrigation *3.2* inches

$$\text{Present annual gross applied} = \frac{\text{Net applied per irrig. x No. irrig. x 100}}{\text{Application efficiency (Ea) } 1/}$$

$$= \frac{3.2 \times 10 \times 100}{80.1} = 40.0 \text{ inches}$$

2. Potential management

Recommended design efficiency (Edes) *90* percent

$$\text{Potential annual gross applied} = \frac{\text{Annual net irrig. requirements x 100}}{\text{Edes}}$$

$$= \frac{22.14}{90} \times 100 = 24.6 \text{ inches}$$

Total annual water conserved

$$= \frac{\text{(Present gross applied - Potential gross applied) x A (ac)}}{\text{12 (in/ft)}}$$

$$= \frac{(40.0 - 24.6) \times 40.0}{12} = 51.3 \text{ acre feet}$$

3. Annual potential cost savings

From pumping plant evaluation:

Pumping plant efficiency *NA* Kind of fuel ______
Cost per unit of fuel ______ Fuel cost per acre foot $______

Cost savings = Fuel cost per acre foot x acre feet conserved per year

= ______ = $ ______ / year

Water purchase cost

Cost per acre foot x acre feet saved per year = *$12 x 51.3*

= $ *616* / year

Potential cost savings

= Pumping cost + water cost = *0 + 616* = $ *616* / year

1/ Use the best estimate of what the application efficiency of a typical irrigation during the season may be. The application efficiency from irrigation to irrigation can vary depending on the SWD, inflow times, etc.

Evaluation Computations - Surface System Evaluation Worksheet F - Recommendations

Recommendation Summary

Use field observations, data obtained by discussions with the irrigator, study of the advance recession data, and data obtained by computations, to make some practical recommendations. Remember that the data is not exact; that there are many variables. Changes are a trial and error procedure. After each new trial, the field should be probed to determine penetration and observations should be made to determine distribution, etc. Enough instruction should be given to the operator so he/she can make these observations and adjustments.

For the example, record on the worksheet the following information:

Since it is possible to do so, increase the flow rate to 10 cfs. This will improve distribution uniformity. Cut inflow time as follows:

Required application at Edes = 90%:

Required application volume

$$= \frac{\text{SWD x A x 100}}{\text{Edes}} = \frac{\text{3.3 inches x 4.6 acres x 100}}{90\%} = \text{17.02 ac-in}$$

$$\text{Inflow time} = \frac{\text{Total irr. volume (ac-in) x 60.5}}{\text{Flow rate (cfs)}}$$

$$= \frac{\text{17.02 x 60.5}}{10} = \text{103 min} = \text{1hr 43 min}$$

SURFACE SYSTEM EVALUATION WORKSHEET F

LEVEL BORDERS
RECOMMENDATIONS

Landuser ______________________ Date _________ Field office ____________

RECOMMENDATIONS

SURFACE SYSTEM EVALUATION WORKSHEET F

LEVEL BORDERS
RECOMMENDATIONS

Landuser *Joe Example* Date *7/25/84* Field office *Billings, MT*

RECOMMENDATIONS

Since it is possible to do so, increase the flow rate to 10 cfs. This will improve distribution uniformity. Cut inflow time as follows:

Required application using the Recommended Design Efficiency = 90%

$$= \frac{\text{SWD x acres}}{\text{Efficiency}} = \frac{3.3 \times 4.6}{.90} = 17.02 \text{ ac-in}$$

$$\text{Inflow time (min)} = \frac{\text{Total irr. volume (ac-in)} \times 60.5}{\text{flow rate (cfs)}}$$

$$= \frac{17.02 \times 60.5}{10} = 103 \text{ minutes}$$

$$= \underline{\text{1 hr 43 min}}$$

APPENDIX A

IRRIGATION TRAINING SERIES

LEVEL BORDER SYSTEM EVALUATION

SOLUTION TO ACTIVITY 1

SURFACE SYSTEM EVALUATION WORKSHEET A

LEVEL BORDERS
CROP AND SOIL DATA

Landuser *Joe Example* Date *7/25/86* Field office *Billings, MT*
Observer *Ed Evaluate* Field name/number *West 40*

FIELD DATA INVENTORY

Field area *40* acres
Border location: *3rd border from west side of field*
Crop *Alfalfa* Root zone depth *5* ft MAD *50* % 1/
Stage of crop *2nd cutting - one week after*

Soil-water data for controlling soil:
Soil name *Lohmiller silty clay, gravelly variant*
Location of sample *NW¼, S15, R 18E T2N*
Moisture determination method *Speedy & Ely*

Depth	Texture	AWC (in) 2/	SWD (%) 3/	SWD (in)
0-1'	*silty clay*	*1.6*	*60*	*.96*
1-2'	*silty clay*	*1.6*	*50*	*.80*
2-3'	*loam*	*2.0*	*40*	*.80*
3-4'	*clay loam*	*1.6*	*40*	*.64*
4-5'	*gravelly sand*	*0.5*	*20*	*.10*
	Totals	*7.3*		*3.30*

$$\text{MAD (in)} = \frac{\text{MAD (\%)}}{100} \times \text{total AWC (in)} = \frac{50 \times 7.3}{100} = 3.65 \text{ in}$$

Comments about soils *Dense, compact layer 9 to 12 inches. Surface cracks evident throughout field.*

Typical irrigation duration *2½* hr, Irrigation frequency *12* days *(max)*
Annual net irrigation requirements *22.14* inches for *Alfalfa* (crop)
Typical number of irrigations per year *10*

Type of delivery system (Earth ditch, concrete ditch, pipeline) *Earth ditch from main ditch. Max allowed diversion 10 cfs.*

Type and size of turnouts (automated turnout, manual screw gate, alfalfa valve etc.)
24" CMP pipe with slide gate on headwall

Size of basin: Width *250* ft, Length *800* ft

FIELD OBSERVATIONS

Crop uniformity *Crop uniform throughout basin*

Salinity problems

Other observations

1/ MAD = Management allowed deficit 2/ AWC = Available water capacity
3/ SWD = Soil water deficit

SURFACE SYSTEM EVALUATION WORKSHEET B

LEVEL BORDERS
INFLOW DATA

Landuser *Joe Example* Date *7/25/84* Field Office *Billings, MT*

Type of Measuring device *36" sharp-crested trapezoidal weir in supply ditch*

Clock 1/ Time (hr:min)	Elapsed Time (min)	ΔT (min)	ΔH (Ft)	Flow Rate (cfs)	Avg. Flow: Rate (cfs)	2/ Volume (ac-in)	Cum. Volume (ac-in)
Turn on		///////			////////	////////	////////
(07:05)	/////////		.78	6.90			
		5			6.97	.5761	.5761
07:10	5		.79	7.04			
		8			7.11	.9402	1.5163
07:18	13		.80	7.18			
		18			7.46	2.2196	3.7359
07:36	31		.84	7.73			
		29			7.80	3.7391	7.4750
08:05	60		.85	7.87			
		30			7.80	3.8680	11.343
08:35	90		.84	7.73			
		31			7.66	3.9252	15.2682
09:06	121		.83	7.59			
		29			7.59	3.6384	18.967
Turn off							
(09:35)		///////	.83	7.59			

Total Volume (ac-in) *18.907*

Average flow rate =

$$\frac{\text{Total irrigation volume (ac-in)} \times 60.5}{\text{Inflow time (min)}} = \frac{18.907 \times 60.5}{150} = 7.63 \text{ cfs}$$

Unit flow:

$$qu = \frac{\text{Average flow rate (cfs)}}{\text{Border spacing (ft)}} = \frac{7.63}{250} = 0.03 \text{ cfs/ft}$$

1/ Use a 24-hour clock reading; i.e., 1:30 p.m. should be recorded as 1330

2/ Flow rate to volume factors:

To find volume using cfs:
volume (ac-in) = .01653 x time (min) x flow (cfs)

To find volume using gpm:
volume (ac-in) = .00003683 x time (min) x flow (gpm)

SURFACE SYSTEM EVALUATION WORKSHEET C

LEVEL BORDERS
ADVANCE-RECESSION DATA

Landuser *Joe Example* Date *7/25/84* Field Office *Billings, MT*

Sta.	Elev. (ft)	Advance Time 1/ (hr:min)	Recession Time 1/ (hr:min)	Opportunity Time "To" (min)	2/ Intake (in)	Minimum/ Maximum Intake (in)
0+00	49.51	07:05	13:15	370	4.50	4.50 max
1+00	49.44	07:09	13:11	362	4.40	
2+00	49.46	07:14	13:07	353	4.30	
3+00	49.45	07:19	13:04	345	4.25	
4+00	49.43	07:26	13:00	334	4.12	
5+00	49.38	07:32	12:55	323	4.10	
6+00	49.42	07:39	12:52	313	3.95	
7+00	49.39	07:47	12:49	302	3.90	
8+00	49.38	07:56	12:45	289	3.75	3.75 min
Totals	444.86			3005		

Water surface elevation at water turnoff *49.57* ft 3/

Average field elevation = $\frac{\text{Elevation total}}{\text{No. of elevations}} = \frac{444.86}{9} = 49.43$ ft

Depth infiltrated after water turnoff
= (Water surface at turnoff - Average field elev) x 12

= (*49.57* - *49.43*) x 12 = *1.68* in

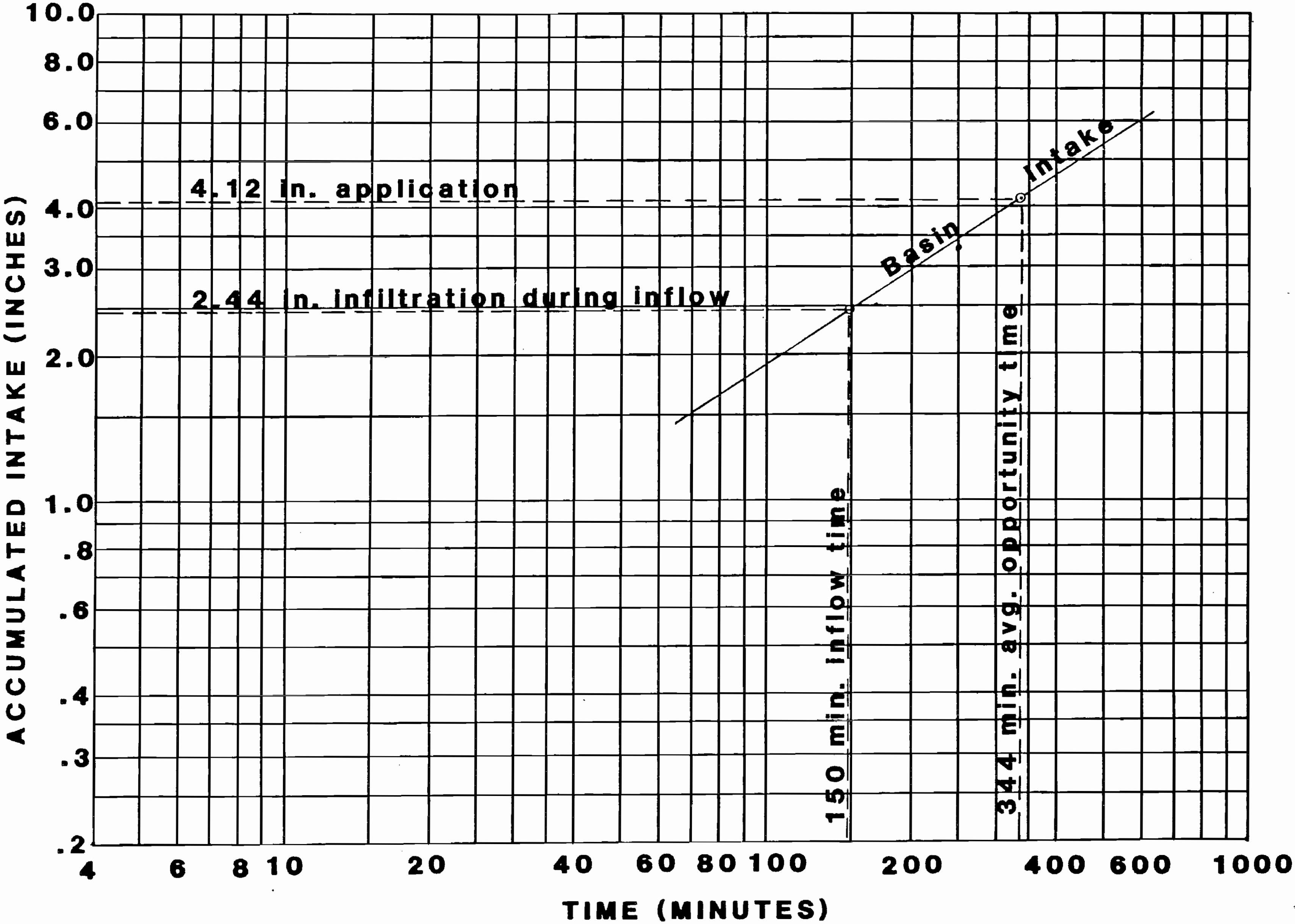
Average opportunity time = $\frac{\text{Total opportunity time}}{\text{No. of sample locations}} = \frac{3005}{9} = 334$ min

1/ Use 24 hour clock time. As a minimum, record times at upper end, mid point

2/ Obtain intake from plotted intake curve.

3/ Water surface elevation must be read to nearest 0.01 ft.

Soil Water Intake Curves



SURFACE SYSTEM EVALUATION WORKSHEET D

LEVEL BORDERS
EVALUATION COMPUTATIONS

Landuser *Joe Example* Date *7/25/84* Field office *Billings, MT*

1. Basin area (A)

$$A = \frac{\text{Length x Width}}{43{,}560} = \frac{250 \times 800}{46{,}560} = \underline{4.6} \text{ acres}$$

2. Gross application (Fg)

$$Fg = \frac{\text{Total irrigation volume (ac-in)}}{\text{A (ac)}} = \frac{18.907}{4.6} = \underline{4.12} \text{ inches}$$

3. Amount infiltrated during water inflow (Vi)

Vi = Gross application - Depth infiltrated after turnoff =

4.12 - 1.68 = *2.44* inches

4. Deep Percolation (Dp)

DP = Gross application - Soil water deficit (SWD) = *4.12 - 3.3* =

0.82 inches

$$DP\% = \frac{\text{Deep percolation (DP) x 100}}{\text{Gross application (Fg)}} = \frac{.82 \times 100}{4.12} = \underline{19.9} \text{ percent}$$

5. Application efficiency (Ea)

(Average depth stored in root zone = Soil water deficit (SWD) if entire root zone depth will be filled to field capacity by this irrigation)

$$Ea = \frac{\text{Av depth stored in root zone x 100}}{\text{Gross application (Fg)}} = \frac{3.3 \times 100}{4.12} =$$

80.1 percent

6. Distribution uniformity (DU)

$$\text{Depth infiltrated low 1/4} = \frac{\text{(max intake - min intake)}}{8} + \text{min intake} =$$

$$= \frac{(4.5 - 3.75)}{8} + \underline{3.75} = \underline{3.84} \text{ inches}$$

$$DU = \frac{\text{Depth infiltrated low 1/4 x 100}}{\text{Gross application}} = \frac{3.84 \times 100}{4.12} = \underline{93.2} \text{ percent}$$

7. Application efficiency low 1/4 (Eq)

$$Eq = \frac{\text{DU\% x Ea\%}}{100} = \frac{93.2 \times 80.1}{100} = \underline{74.7} \text{ percent}$$

SURFACE SYSTEM EVALUATION WORKSHEET E

LEVEL BORDERS
COST SAVINGS

Landuser *Joe Example* Date *7/25/84* Field office *Billings, MT*

1. Present management

Estimated present average net application per irrigation *3.2* inches

$$\text{Present annual gross applied} = \frac{\text{Net applied per irrig.} \times \text{No. irrig.} \times 100}{\text{Application efficiency (Ea) } 1/}$$

$$= \frac{3.2 \times 10 \times 100}{80.1} = 40.0 \text{ inches}$$

2. Potential management

Recommended design efficiency (Edes) *90* percent

$$\text{Potential annual gross applied} = \frac{\text{Annual net irrig. requirements} \times 100}{\text{Edes}}$$

$$= \frac{22.14}{90} \times 100 = 24.6 \text{ inches}$$

Total annual water conserved

$$= \frac{(\text{Present gross applied} - \text{Potential gross applied}) \times \text{A (ac)}}{12 \text{ (in/ft)}}$$

$$= \frac{(40.0 - 24.6) \times 40.0}{12} = 51.3 \text{ acre feet}$$

3. Annual potential cost savings

From pumping plant evaluation:

Pumping plant efficiency *NA* Kind of fuel ________
Cost per unit of fuel ________ Fuel cost per acre foot $________

Cost savings = Fuel cost per acre foot x acre feet conserved per year

= ________ = $ ________ / year

Water purchase cost

Cost per acre foot x acre feet saved per year = *$12 x 51.3*

= $ *616* / year

Potential cost savings

= Pumping cost + water cost = *0 + 616* = $ *616* / year

1/ Use the best estimate of what the application efficiency of a typical irrigation during the season may be. The application efficiency from irrigation to irrigation can vary depending on the SWD, inflow times, etc.

SURFACE SYSTEM EVALUATION WORKSHEET F

LEVEL BORDERS
RECOMMENDATIONS

Landuser *Joe Example* Date *7/25/84* Field office *Billings, MT*

RECOMMENDATIONS

Since it is possible to do so, increase the flow rate to 10 cfs. This will improve distribution uniformity. Cut inflow time as follows:

Required application using the Recommended Design Efficiency = 90%

$$= \frac{\text{SWD x acres}}{\text{Efficiency}} = \frac{3.3 \times 4.6}{.90} = 17.02 \text{ ac-in}$$

$$\text{Inflow time (min)} = \frac{\text{Total irr. volume (ac-in)} \times 60.5}{\text{flow rate (cfs)}}$$

$$= \frac{17.02 \times 60.5}{10} = 103 \text{ minutes}$$

$$= \underline{1 \text{ hr } 43 \text{ min}}$$

APPENDIX B

IRRIGATION TRAINING SERIES

LEVEL BORDER SYSTEM EVALUATION

GLOSSARY OF TERMS USED IN MODULE

GLOSSARY OF TERMS, DEFINITIONS AND EXPLANATIONS

Accumulated Intake:
The amount of water (inches) that has infiltrated into the soil since water was first applied.

Acre Foot:
The volume of water that would cover an area of one acre in size one foot deep.

Acre Inch:
The volume of water that would cover an area of one acre in size one inch deep.

Advance, Border:
The movement of the border stream from the head or upper end of the basin toward the tail or opposite end of the basin.

Advance Curve:
A curve that illustrates the rate of advance of the irrigation water down the field with surface flood irrigation. It is drawn by plotting a number of advance distances (horizontal axis) against elapsed time (vertical axis) from the beginning of the irrigation.

Advance Time:
The time it takes water to advance from the upper end to a selected station along the border, or the lower end; frequently called travel time, (minutes or hours).

Annual Irrigation Requirement:
The amount of irrigation water that is needed for a crop. The annual or seasonal crop water requirement less effective rainfall.

Application Efficiency:
The ratio of the average depth of the irrigation water stored in the root zone to the average depth of irrigation water applied.

$$Ea = \frac{\text{Average depth of water stored in root zone}}{\text{Average depth of water applied}}$$

Ea gives no indication of the adequacy of the irrigation nor the uniformity of application. With under-irrigation it can equal 100 percent. Ea merely shows the fraction of applied water stored within the root zone that is potentially accessible for evaporation and transpiration.

Application Rate:
The rate at which water is applied to a given area. Usually expressed in inches of depth per hour or in gallons per minute.

Application Time:
The actual amount of time that water is applied to an irrigation set (minutes or hours).

Automation:
Automation as it relates to level border irrigation is the use of timers, radio controllers, computers or other devices to automatically open and/or close a gate which controls flow into a basin.

Available Soil Water Capacity (AWC):
The water that can be held in the soil's root zone between field capacity and wilting point (inches of water).

Available Soil Water (ASW):
The difference at any given time between the actual water content in the soil's root zone and the wilting point (inches of water).

Average Depth Infiltrated:
The average depth of irrigation water infiltrated (intake) in the border strip.

Average Intake Curve:
The curve drawn from the average accumulated intake (horizontal axis) from a number of cylinder infiltrometer tests plotted against elapsed time (vertical axis) from the beginning of the tests.

Border Dikes:
The dikes on all sides of a basin that contain the irrigation water in the basin.

Border Spacing:
The space between the center of the border dikes on both sides of the basin.

cfs:
Cubic feet per second (flow rate).

Consumptive Use:
Another term for Evapotranspiration (see Evapotranspiration).

Cumulative Intake Curve:
The curve drawn from the accumulated intake (vertical axis) vs. various elapsed time (horizontal axis) intervals from the beginning of the cylinder infiltrometer test. It is plotted on log-log paper.

Cylinder Infiltrometer:
A cylinder that is driven into the soil and filled with water. The loss of water, due to infiltration into the soil, is measured at various elapsed time intervals. The test is used to determine the intake characteristics of the soil under

surface flood irrigation.

Deep Percolation:
The water that percolates below the root-zone depth. It is lost to the plants and frequently contributes to the buildup of the groundwater level.

Delta (Δ):
A symbol that is used to indicate the difference or change between two values: the Δ time (minutes) between 9:10 and 9:33 is 23 minutes.

Depth Infiltrated:
The amount of irrigation water that has infiltrated (moved) into the soil.

Depth Infiltrated, Lower 1/4 (LQ):
The average amount of irrigation water that has infiltrated into the "1/4 of the basin" that infiltrates the least.

Design Efficiency (Edes):
The efficiency that an irrigator should be able to obtain from an irrigation.

Distribution Uniformity (DU):
The ratio of the minimum depth of irrigation water infiltrated to the average depth of the irrigation water infiltrated.

$$DU = \frac{\text{Minimum depth of water infiltrated}}{\text{Average depth of water infiltrated}}$$

The minimum depth can be determined as the average of the lowest one-fourth of measured values of water stored, where each measured value represents an equal area. DU is a useful indicator of distribution problems. A low DU indicates that deep percolation losses are excessive if adequate irrigation is supplied to all areas.

Duration of Irrigation:
The amount of time that irrigation water is applied to the border strip. Also known as set time.

Erosive Stream Size:
A furrow stream that produces a velocity that exceeds the non-erosive velocity that is dependent on the erodibility of the soil (gpm).

Evapotranspiration (ET):
The sum of the transpiration and evaporation from an area covered by vegetation. It is composed of four factors: evaporation from water surfaces, soil-water evaporation, evaporation from the surface of plants, and transpiration.

Field Capacity (FC):

Water remaining in a soil following wetting and natural drainage until free drainage has practically ceased. The time required for cessation of free drainage varies with soil textures and structure and the rate of water used by crops (inches of water).

Final Intake Rate:

The rate at which the soil absorbs water when the infiltration velocity has become nearly constant (inches per hour).

gpm:

Gallons per minute (flow rate).

Gross Application (Fg):

The total amount of irrigation water that is applied to the basin to provide the net irrigation requirement. The net irrigation requirement + losses (deep percolation).

Head of Field:

The end of the field where the water is applied.

Initial Intake:

The depth of water absorbed by a soil during the period of rapid or comparatively rapid intake following the initial application (inches).

Initial Intake Rate:

The average rate at which water is absorbed by a soil during a period of rapid or comparatively rapid intake following the initial application of water (inches per hours).

Infiltration (intake):

The absorption of the water from the furrow stream into the soil.

Infiltration Rate (intake rate):

The rate at which the water is absorbed by the soil. The rate varies with time (inches per hour).

Intake Family of Curves:

A family or group of accumulated intake curves that represent the intake characteristics of most irrigated soils having similar intake characteristics.

Irrigation Time:

The irrigation time is the total time the water is being applied to a set or sets, includes ontime and offtime with surge irrigation.

Intake, Family Curves:

A series of intake-family curves have been developed that relate cumulative depth of intake to opportunity time. Each type of soil has unique intake characteristics. Many soils differ so little that, for practical purposes, they can be grouped in one of a number of intake families.

Laser Controlled Leveling:

A method of land leveling wherein laser controlled machinery is used to grade the basins. Laser control is provided by a rotating laser light beam in a plane which, in turn, is intercepted by a receiver on the control equipment. This allows very precise control of the grading.

Leaching:

Moving salts downward in the soil profile by irrigation or rainwater.

Level Basin Irrigation:

See Level Border Irrigation.

Level Border Irrigation:

Level border irrigation is the application of a predetermined depth of water into a basin with a level bottom. The basin is surrounded by border dikes. The basin may be any shape, but is most often rectangular. This method is also called level basin irrigation.

Management Allowed Deficit (MAD):

The desired soil moisture deficit at the time of irrigation. It can be expressed as the percentage of available soil water capacity or as the depth of water that has been depleted from the root zone. In arid areas, the ideal irrigation is generally scheduled to just cancel MAD if no leaching is required. In humid areas, ideal supplemental irrigations are often scheduled only to partly cancel MAD, ie., to leave some root-zone capacity for the storage of anticipated rainfall.

Non-erosive Stream Size:

A stream size that produces a velocity that is less than the maximum non-erosive velocity that is dependent on the erodibility of the soil (gpm).

Opportunity Time:

Opportunity is the time that water stands on the surface enabling water to penetrate or infiltrate the soil. It is computed for stations by finding the difference between advance time and recession time (minutes or hours).

Percolation:

The movement of water through the soil.

Permeability (as used in describing soils):

The readiness with which water penetrates or passes through soil pores.

Recession Time:
The descending part of a stream flow or the time lapse after water application has stopped until the water recedes or disappears from the surface at selected stations along the furrow (minutes or hours).

Root Zone:
The soil depth that is managed to store the available water for the crop. The depth of root zone is generally the depth from which the crop is currently capable of extracting soil water. However, it may also be expressed as the depth from which the crop can extract water when mature or the depth from which a crop to be planted in the future can extract soil water (expressed in inches).

Slope:
The grade or drop in the direction of irrigation. Usually expressed in feet per foot or %.

Soil Water Deficit (SWD):
The difference between field capacity and the actual moisture in the soil root zone at any given time. It is the amount of water required to bring the soil in the root zone to field capacity.

Soil Water Storage:
The water that is stored in the soil for the use of crops.

Stream Size, Border:
The flow rate of water that is applied to the border (cfs).

Surface Flood Irrigation:
The application of irrigation water by flooding the soil surface.

Surface Storage, Border:
The water that is on the border strip surface and is available for infiltration.

Tail of Field:
The bottom, or lower, end of the field where excess irrigation or rainwater accumulates if not removed.

Tailwater (Runoff):
The water that accumulates and is drained off at the tail end of the field.

Wilting Point (WP):
The water content in the soil's root zone at which plants can no longer extract water at a sufficient rate for survival.

APPENDIX C

IRRIGATION TRAINING SERIES

LEVEL BORDER IRRIGATION EVALUATION

VIDEO NARRATIVE

IRRIGATION TRAINING SERIES
LEVEL BORDER IRRIGATION EVALUATION

AUDIOVISUAL NARRATIVE - PART A

Welcome to our presentation on how to evaluate a level border irrigation system. In a moment, you will see how to do both a simple and detailed evaluation. Later, your facilitator will show you step-by-step how to take the data gathered during these evaluations and perform the necessary calculations so that you can recommend to the irrigator how irrigation methods can be improved. But first...Let's define a level border irrigation system.

Level border irrigation is often called level basin irrigation. It is a gravity method. Water is supplied to level ground over a short period. The basin may be of any shape. It's surrounded by a control barrier called a dike. The water is confined within this area until it's absorbed by the soil.

Level basins have been used for centuries for rice production.

Small contour basins have been used for many years in orchards.

Recently, level border systems have become popular in the arid portions of the Southwestern United States for the Irrigation of flat-bed and and furrow crops.

Our evaluations will deal primarily with straight-sided borders. This method is used for growing alfalfa, hay and grain.

As with any irrigation system, level border irrigation has several advantages and disadvantages. These are described in detail in your field guide.

When designing or modifying a level border system, there are five major factors to consider. They are: the water intake rate of the soil... the available flow rate... resistance of the crop to the flow... the quantity, or depth, of water application... and the topographic characteristics of the field, or how level is the ground.

When you know this information, the shape and size of the basin can be designed for the best efficiency. You can find detailed design data in the soil conservation service's National Engineering Handbook.

A system evaluation can provide you with the information needed to improve the management of a level border system, and to refine or modify its design.

There are two types of system evaluations of level borders... simple and detailed.

Often, a simple evaluation is all that is necessary to solve an irrigation problem. A simple evaluation should be performed on all systems. It doesn't take much time, and the data collected becomes the first step to a detailed evaluation. Before you begin, study your field guide for background information.

Here's how to perform a simple level border evaluation.

First, gather some basic data from the irrigator on how the system works and how it is managed. Consult your field guide for a list of questions you should ask. Record the responses in your notebook or on the evaluation worksheet.

Next, look around the field... observe the farm in operation... and make notes. A list of things to look for is included in your field guide.

Now it's time to obtain some soil samples. Be sure the irrigator comes along with you, so that you can explain procedures, point out problems and suggest solutions. The only equipment you'll need is a soil auger.

Walk around the field and bore holes at several locations. If the soil is too rocky for an auger, use a shovel to dig a trench.

Analyze the soil and talk with the irrigator about the soil profile found at each spot. Look for hardpans, texture changes, root penetration and moisture content.

Determine if there is a water table within the potential root zone. Try to determine if it fluctuates. Motteling, root penetration, and comments by the irrigator will give you clues.

Log the soil texture by depth. Make your best judgement whether the material is low, medium or high density. Be sure to note any restrictive layers, such as hardpans, gravel layers or mineralizations.

Estimate the soil water deficit using the "feel and appearance" method. Make judgments about the tilth, structure, organic content and water content of the soil. This is a good opportunity to demonstrate the "feel and appearance" method of moisture determination to the irrigator. It will later aid him in the management of his system.

This completes your simple evaluation. Now it's time to check your notes and discuss your findings with the irrigator. If you have enough information, you can make recommendations on how level border irrigation methods can be improved.

Yet, sometimes after making a simple evaluation, you don't have enough information to make suggestions for irrigation improvements. That's when it becomes necessary to make a detailed evaluation.

As you will see in a moment, a detailed evaluation starts with the same procedures just performed for a simple evaluation. But before you begin, you should be familiar with certain terms and computations. Your Field Guide will help you with these.

After you've gathered the necessary equipment listed in the guide, it's back to the field to begin the detailed evaluation. Don't forget personal comfort items like insect repellent, a hat and your lunch!

When doing a detailed evaluation, all information about the crop, soil and irrigation system is recorded on the evaluation worksheet.

First, choose a basin to be irrigated. The Basin's size and shape should be typical of the others in the field. The soil should be typical, too. If there is a wide variance, more than one basin should be evaluated. It's important to have the same soil conditions for the test, so perform your evaluation at the time the field would normally be irrigated.

Our procedure will be to treat the field as if it were one big infiltrometer to determine how fast the water enters the soil. To do this, the inflow volume and the volume of water on the basin will be measured. Because a small difference in the water level in the basin can represent a rather large volume of water, measuring water level changes accurately is important.

This procedure will yield a two-point average intake curve. The first point on the curve will be plotted at the time the water is turned off. The second point will be defined by plotting the gross application of water at the average opportunity time. If a more detailed curve is needed, make a cylinder infiltrometer test as is done in a graded border evaluation.

Because of low spots and soil variations within the basin, determining exact values of distribution uniformity and application efficiency is impractical. But one good way is to set stakes in the basin to determine advance and recession times--or the time of opportunity--at each station. To do this, arrange a line of stakes at 50 to 100-foot intervals down the center of the basin, and number each one. These stakes will be used to mark opportunity times.

Next, take level rod readings on the average ground level at each station. Readings should be taken to the nearest five one-hundredths to one one-hundredths of a foot. Take care to make readings at average ground level at each measurement point. If the field has been recently cultivated, this procedure should not be done.

There are several other things that must be done in the field before starting the irrigation test.

First, interview the irrigator and obtain information about the system... How it operates, how it is managed, and what the problems are.

Next, estimate the soil water deficit at several locations throughout the basin. You can do this by making the measurements on a previously irrigated strip that has the same soil characteristics. Use the "feel and appearance", the Ely Volumeasure/Speedy Moisture Meter, Madera Sampler, or other method. Then pick one location as being typical for the basin to be irrigated and log the soil texture by depth on your worksheet.

Make a note of the soil profile conditions, such as depth to water table, apparent rooting depth, compaction, mineral layers, hardpans or bedrock, and soil texture changes.

Finally, record your observations about the field, including the condition of the dikes, uneven or discolored crops, weed patches, salt-affected areas, erosion problems, leaky ditches and pipes, poorly maintained equipment, and so forth.

Measure and record... The border width--which is the distance from center to center of the border dikes... and the strip width--which is the distance from toe to toe of the dikes. Also not on your worksheet the type of delivery system and the type and size of the turnouts.

Set flumes, weirs, flow meters or other measuring devices at the upper end of the border strip.

One final point before we begin to irrigate. When the water is shut off to the basin after the test, you must make an accurate measurement of the elevation of water surface. This can be difficult if the water is not calm.

A stilling basin can be constructed to buffer any wave action while the water is being measured. Simply cut the top and bottom out of a gallon or larger can, and punch small holes an inch or so above the bottom.

Firmly press the can into place in a location away from the inflow point where any disturbance will be minimal. If possible, the ground surface should be a low place in the field, and the holes in the can should be close to the ground.

Now it's time to begin the irrigation. Record the start time, and irrigate with the flow rate that is normally used.

At five to ten minute intervals, check the flow until it reaches a constant rate. Each time the flow is checked, record the rate and time of measure. If there is considerable fluctuation in the flow rate, frequent checks should be made. Periodically, check the inflow rate and record it on the worksheet.

Observe and record a description of how the water advances across the basin. Record the time the leading edge of the water reaches each station.

Record the time that water is turned off at the head end of the field.

Then immediately use the level and rod to take water surface elevation. Make this reading as accurately as possible, because even a small error can make a big difference in water volume. Record this measurement on the worksheet.

Observe the recession of the water in the basin. Record the time when water has receded past each station. This requires good judgment. Assume that recession has taken place when not more than 10% of the water in the vicinity of the station point is still visible on the surface.

It's likely that there will be some low spots in the basin. You should make a sketch to show the areas still containing surface water. This will give an indication of uniformity of leveling in the basin.

This almost finishes your in-field evaluation. But before leaving, use a probe or auger to check depth of penetration to see if water has already percolated too deeply.

If possible, check for adequacy and uniformity of irrigation when the soil profile has reached the field capacity moisture level. Sandy soils can be checked about twenty-four hours after irrigation so that gravitational water has drained.

This completes the gathering of field data. Now for the computations. Your facilitator will discuss how to fill our your worksheet and perform the calculations in a moment.

After completing the computations, you'll be ready to give the irrigator some practical recommendations.

Just remember that even after a detailed evaluation, your data is not perfect. Any changes that you suggest are a "trial and error" procedure.

When you go over the results of your evaluation with the irrigator, also give him instructions on how he can make his own evaluations and adjustments to ensure the most efficient and cost-effective way of irrigating by the level border method.

IRRIGATION TRAINING SERIES
LEVEL BORDER IRRIGATION EVALUATION
AUDIOVISUAL NARRATIVE - PART B

A. (voice over live video)

Level border irrigation is often called level basin irrigation. Level basins have been used for centuries, especially for rice production. Small contour basins have also been used for many years in orchards. Recently, the procedure has gained importance for irrigation of flat bed and row crops in the water short southwestern part of the United States. This gravity method supplies water to level soil surfaces in a short period. The basin may be any shape, surrounded by a control barrier such as a dike.

Water application is accomplished by ponding. The border strips have no slope in the direction of irrigation, and they are closed at the end so that water is retained and absorbed into the soil. The irrigation stream must be large enough to cover the entire strip in a relatively small time so the soil can absorb the desired amount of water. The stream is turned off when the desired volume of water has been applied to the strip.

The next few slides will help explain the hydraulic principles of level border irrigation. Water is applied at one end of a border strip at a rate that will provide coverage of the entire strip in a relatively short time. We apply the water in a short period to provide a more equal opportunity time for the water to infiltrate into the soil from the entrance to the opposite end of the border. The orange bullet shaped line illustrates both the profile of the water on the surface of the border and the profile of the water that is beginning to infiltrate into the soil surface at the end of eight minutes. Water has advanced down field about one-fourth of the distance. The scale above the surface shows that there is five inches of water in the border, indicating that a large stream size has been applied.

The yellow line illustrates where the water has advanced to at the end of 23 minutes, or about half of the length of this basin. Water is still being applied to the basin at this point. Additional water has infiltrated into the surface at the upper end and is beginning to infiltrate into the field to the half way point.

The blue line illustrates the water surface profile and the infiltration profile at the end of 40 minutes. We can see that the water level has dropped at the head end of the basin, indicating that the water has been shut off. In other words, all the water that will be applied to the border has been applied.

The blue line shows that, at the end of 60 minutes, water has reached the opposite end of the level basin and has begun to level out. The blue line also indicates the amount of water that has infiltrated into the field at this time.

This illustrates the advancement of the wetting front in the soil at the end of the irrigation. At this point there is no more water on the surface to infiltrate into the field. The brown area with the blue dots shows the depth of soil that we intend to irrigate. We must have enough water to properly irrigate the far end but, by doing so, we over-irrigate the upper end. This is illustrated by the brown area with the red dots and identified as deep percolation. As is evident, the faster we can advance the water from the head of the field to the tail of the field, the more equal will be the opportunity time and we will have less deep percolation. If it were possible to cover the whole field simultaneously with water, we would not have deep percolation. We could obtain one-hundred percent irrigation application because, in level basins we do not have runoff. If we can control deep percolation, we have an efficient irrigation system.

In surface irrigation evaluations, which include furrows, graded borders, and level borders, we use advance and recession curves to help us understand what is going on in the field. The advance curve starts at time zero and distance zero. The right end represents the end of the field. The blue line is the amount of time it would take for water to advance to the end.

This is the recession curve, or the time when the water leaves the surface of the field. This is caused by both infiltration and, for graded irrigation, flowing down the slope. This curve starts at the time water recedes at the surface. This will be after the water has been turned off for the irrigation. This curve illustrates a typical recession curve on graded irrigation. On level basin irrigation we like this curve to perfectly flat.

Here we have both the advance and recession curves on the same chart. This distance between the two curves represents the amount of opportunity time at that position in the field.

This orange dashed line is the time of water cutoff, or when the irrigation time has been completed. The gray dashed line that parallels the blue advance curve is called the irrigation curve. It represents the time that is necessary for the water to infiltrate at each point down the field. If the recession curve follows the irrigation curve, we would not have deep percolation because the opportunity time would be just right.

This illustrates level basin, or level border, irrigation. We have an advance curve showing that it takes a certain time for water to reach the opposite end of the field. We also have an irrigation curve that parallels the advance curve, illustrating the time we need to get the proper amount of water infiltrated into the soil. The recession curve is flat, which, ideally, it should be if we have a perfectly flat grade and a very consistant soil characteristic in the field. The area between the irrigation curve and the recession curve shows over-irrigation and represents the amount of deep percolation that would occur in this field.

In actual field conditions, we would not have a perfectly flat recession curve. We do not have that much control over the field surface or the soil. So, under normal field conditions, we would expect to find a recession curve that is irregular in shape. We may have water disappearing from the field first in the center, half way down, or at any location in the border. So, the red recession line represents a more typical type of recession curve, reflecting non-perfect conditions in the field.

To much water was applied to this field. At the end of the necessary opportunity time, there was still water on the surface. This shows excess irrigation or over-irrigation above what we intended to apply.

Not enough water was applied to this field. Recession occurred before the opposite end of the field was irrigated. Therefore, a portion of the field was under-irrigated. We still had some deep percolation or over-irrigation at the inlet end of the field, but we did not have enough water to completely irrigate the bottom end. These curves can help you in the evaluation of a level border irrigation system.

B. (voice over live video)

Every method of irrigation has its advantages and, in most cases, disadvantages. At this time, let's discuss them for level border irrigation.

If a system is properly designed and managed, deep percolation losses can be minimized and high application efficiencies can be obtained. As in any irrigation system, we must have a good design as well as good management to obtain these high efficiencies.

There is no runoff. Level basins are completely enclosed with a dike, and all water is retained on the field. None is allowed to run off. Rainfall is also controlled in a like manner. We do not have rainfall runoff with enclosed basins.

Leaching of salts is easier with level border irrigation than with other surface methods. The water uniformly covers and remains static over the entire surface. It has the opportunity to penetrate evenly to reduce residual salts that often remain with sloping types of border irrigation. Also, because rainfall will not run off, it helps with leaching.

The guess work in applying the right amount of water is easier because there is no surface runoff. All the water applied to the basin is used within the basin.

Relatively light applications of water are possible with level basin irrigation.

Automation can be conveniently applied for the following reasons: The time of set and the amount of water can be controlled directly with a time clock. Only a few outlet structures are needed (one for each level basin). No tail-water exists for further handling.

Large streams of water can be used, which reduces irrigation time and labor. Level borders can be designed for whatever size streams of water are available.

Level basin areas as large as 40 acres can be irrigated if a large stream of water is available and soil intake is low. Fields this large can be easily farmed with large machinery.

Increased yields can result because optimal amounts of water can be applied. Even distribution results in improved germination, improved plant environment, and even growth. Leaching of plant nutrients is controlled.

There are a number of limitations to level border irrigation. Precision leveling is required for even water distribution. In level basin or level border irrigation, we must have a level field.

Use of laser leveling equipment is essential if the degree of levelness required is to be obtained. Laser equipment is about the only way we can get the levelness that we need for good efficient irrigation.

The correct amount of water must be applied. Over-application of water may lead to excessive innundation, leaching of nutrients, and crop damage. As in any method of irrigation, we must apply the correct amount for efficient irrigation.

Earthwork volumes are often greater than for other surface irrigation methods. We must level to a flater grade for level basin irrigation. This generally requires greater earthwork volumes.

Variable soils within the basin may create water distribution problems. If we have a variance in the infiltration rate of the soils within the basin, we will have more intake or infiltration in one location than another. This results in uneven water distribution.

Large inflows require erosion control measures at the point where they enter the field. Because we can use large stream sizes, we must be careful that we do not cause erosion where these large flows enter the field.

A means of emergency drainage should be provided for protection against irrigator's error, over irrigation, and where rainfall must be diverted from the field. Because we generally have a closed dike around the field, we should provide an emergency outlet in case of over-irrigation or excess rainfall.

There are 5 design considerations we must be aware of in level border irrigation. A major consideration in the design of level basin irrigation is the water intake rate of the soil. We must know this to determine the opportunity time and application rate required to get uniform distribution.

We must know the available flow rates. The available flow rate is needed to determine the size of basin that can be irrigated at one time. We must apply the water rapidly to get fast advance across the field.

The flow resistance of the crops must be known. When we have crops in the fields, the advance of the water will be slowed. We must take that into consideration in the design of level basin irrigation.

Quantity of water to apply. We must be able to determine the proper quantity of water to apply to irrigate the field and reduce unavoidable deep percolation or over-irrigation at the upper end.

The topography of the site. Topography is important in the design of level basin irrigations because we must level the field to a flat grade. Slope and undulation must be considered in keeping leveling expenses to a minimum.

This completes our discussion of level border irrigation. When the tape ends, rewind it and return to your study guide text.

C. (Live video)

[Use live video and superimpose closing titles and logo.]

APPENDIX D

IRRIGATION TRAINING SERIES

LEVEL BORDER IRRIGATION EVALUATION

BLANK WORKSHEETS FOR DUPLICATION

SURFACE SYSTEM EVALUATION WORKSHEET A

LEVEL BORDERS
CROP AND SOIL DATA

Landuser ______________ Date _______ Field office ______________________
Observer ________________ Field name/number ____________________________

FIELD DATA INVENTORY

Field area __________ acres
Border location: ____
Crop ______________________ Root zone depth _____ ft MAD _____% 1/
Stage of crop ____

Soil-water data for controlling soil:
Soil name ____
Location of sample ____
Moisture determination method ________________________________

Depth	Texture	AWC (in) 2/	SWD (%) 3/	SWD (in)
	Totals			

$$\text{MAD (in)} = \frac{\text{MAD (\%)}}{100} \times \text{total AWC (in)} = \frac{\_\_\_ \times \_\_\_}{100} = \_\_\_\_\_ \text{ in}$$

Comments about soils ____
____
____

Typical irrigation duration _____ hr, Irrigation frequency _________ days
Annual net irrigation requirements ______ inches for ___________ (crop)
Typical number of irrigations per year __________

Type of delivery system (Earth ditch, concrete ditch, pipeline) __________
____

Type and size of turnouts (automated turnout, manual screw gate, alfalfa valve etc.)
____

Size of basin: Width _______ ft, Length ________ ft

FIELD OBSERVATIONS

Crop uniformity ____
____
Salinity problems ____
____
Other observations ____
____
____

1/ MAD = Management allowed deficit 2/ AWC = Available water capacity
3/ SWD = Soil water deficit

SURFACE SYSTEM EVALUATION WORKSHEET B

LEVEL BORDERS
INFLOW DATA

Landuser ____________ Date ________ Field Office ____________

Type of Measuring device ____________________

Clock 1/ Time (hr:min)	Elapsed Time (min)	T (min)	H ( )	Flow Rate ( )	Avg. Flow: Rate ( )	2/ Volume (ac-in)	Cum. Volume (ac-in)
Turn on		///////			///////////////////////////		
( )	/////////						
Turn off							
( )		///////					

Total Volume (ac-in) ________

Average flow rate =

$$\frac{\text{Total irrigation volume (ac-in)} \times 60.5}{\text{Inflow time (min)}} = \_\_\_\_\_\_\_\_ = \_\_\_\_\_\_ \text{cfs}$$

Unit flow:

$$qu = \frac{\text{Average flow rate (cfs)}}{\text{Border spacing (ft)}} = \_\_\_\_\_\_ = \_\_\_\_\_\_ \text{cfs/ft}$$

1/ Use a 24-hour clock reading; i.e., 1:30 p.m. should be recorded as 1330

2/ Flow rate to volume factors:

To find volume using cfs:
volume (ac-in) = .01653 x time (min) x flow (cfs)
To find volume using gpm:
volume (ac-in) = .00003683 x time (min) x flow (gpm)

SURFACE SYSTEM EVALUATION WORKSHEET C

LEVEL BORDERS
ADVANCE-RECESSION DATA

Landuser ____________ Date ____________ Field Office ____________

Sta.	Elev. (ft)	Advance Time 1/ (hr:min)	Recession Time1/ (hr:min)	Opportunity Time "To" (min)	2/ Intake (in)	Minimum/ Maximum Intake (in)
Totals						

Water surface elevation at water turnoff ________ ft 3/

Average field elevation = $\frac{\text{Elevation total}}{\text{No. of elevations}}$ = ____________ = ____________ ft

Depth infiltrated after water turnoff
= (Water surface at turnoff - Average field elev) x 12

= (________ - ________) x 12 = ____________ in

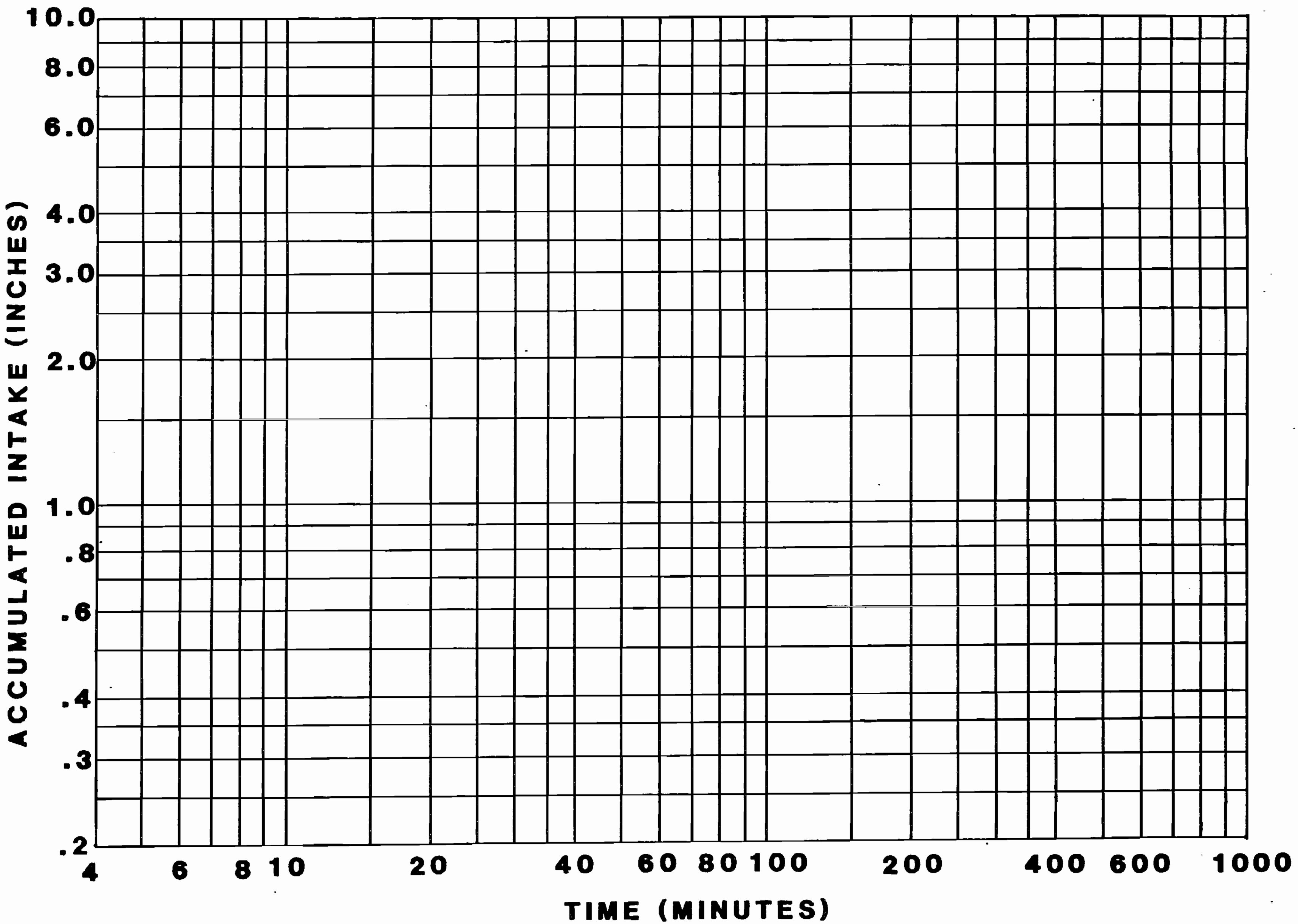
Average opportunity time = $\frac{\text{Total opportunity time}}{\text{No. of sample locations}}$ = ________ = ________ min

1/ Use 24 hour clock time. As a minimum, record times at upper end, mid point

2/ Obtain intake from plotted intake curve.

3/ Water surface elevation must be read to nearest 0.01 ft.

Soil Water Intake Curves



SURFACE SYSTEM EVALUATION WORKSHEET D

LEVEL BORDERS
EVALUATION COMPUTATIONS

Landuser ____________________ Date ________ Field office ________________

1. Basin area (A)

$$A = \frac{\text{Length x Width}}{43{,}560} = \frac{\quad x \quad}{46{,}560} = \underline{\qquad\qquad} \text{ acres}$$

2. Gross application (Fg)

$$Fg = \frac{\text{Total irrigation volume (ac-in)}}{\text{A (ac)}} = \underline{\qquad\qquad} = \underline{\qquad\qquad} \text{ inches}$$

3. Amount infiltrated during water inflow (Vi)

Vi = Gross application - Depth infiltrated after turnoff =

________________ = ________________ inches

4. Deep Percolation (Dp)

DP = Gross application - Soil water deficit (SWD) = ________________ =

________________ inches

$$DP\% = \frac{\text{Deep percolation (DP} \quad \text{x 100}}{\text{Gross application (Fg)}} = \underline{\qquad\qquad} = \underline{\qquad\qquad} \text{ percent}$$

5. Application efficiency (Ea)

(Average depth stored in root zone = Soil water deficit (SWD) if entire root zone depth will be filled to field capacity by this irrigation)

$$Ea = \frac{\text{Av depth stored in root zone x 100}}{\text{Gross application (Fg)}} = \underline{\qquad\qquad}$$

________________ percent

6. Distribution uniformity (DU)

$$\text{Depth infiltrated low 1/4} = \frac{\text{(max intake - min intake)}}{8} + \text{min intake} =$$

$$= \frac{(\qquad - \qquad)}{} + \underline{\qquad} = \underline{\qquad} \text{ inches}$$

$$DU = \frac{\text{Depth infiltrated low 1/4 x 100}}{\text{Gross application}} = \underline{\qquad\qquad} = \underline{\qquad\qquad} \text{ percent}$$

7. Application efficiency low 1/4 (Eq)

$$Eq = \frac{\text{DU\% x Ea\%}}{100} = \frac{\qquad\qquad}{100} = \underline{\qquad\qquad} \text{ percent}$$

D/2

SURFACE SYSTEM EVALUATION WORKSHEET E

LEVEL BORDERS
COST SAVINGS

Landuser ______________ Date __________ Field office ______________

1. Present management

Estimated present average net application per irrigation _______ inches

Present annual gross applied = $\frac{\text{Net applied per irrig. x No. irrig. x 100}}{\text{Application efficiency (Ea) 1/}}$

= ________________ = __________ inches

2. Potential management

Recommended design efficiency (Edes) __________ percent

Potential annual gross applied = $\frac{\text{Annual net irrig. requirements x 100}}{\text{Edes}}$

= ______ x 100 = __________ inches

Total annual water conserved

= $\frac{\text{(Present gross applied - Potential gross applied) x A (ac)}}{\text{12 (in/ft)}}$

= $\frac{(\qquad - \qquad) \times \qquad}{12}$ = __________ acre feet

3. Annual potential cost savings

From pumping plant evaluation:

Pumping plant efficiency __________ Kind of fuel ______________
Cost per unit of fuel __________ Fuel cost per acre foot $__________

Cost savings = Fuel cost per acre foot x acre feet conserved per year

= ______________ = $ __________ / year

Water purchase cost

Cost per acre foot x acre feet saved per year = __________

= $______________ / year

Potential cost savings

= Pumping cost + water cost = ______________ = $ __________ / year

1/ Use the best estimate of what the application efficiency of a typical irrigation during the season may be. The application efficiency from irrigation to irrigation can vary depending on the SWD, inflow times, etc.

SURFACE SYSTEM EVALUATION WORKSHEET F

LEVEL BORDERS
RECOMMENDATIONS

Landuser ____________________ Date __________ Field office ____________

RECOMMENDATIONS

IRRIGATION TRAINING SERIES

MODULE 910

LEVEL BORDER IRRIGATION EVALUATION

CERTIFICATION OF COMPLETION

This is to certify that ____
(full name)
completed Module 910, Level Border Irrigation Evaluation,

on ____________________________ and should be credited with training hours

as follows:

______ Study Guide and Facilitator's Example Problem (12 Hours)

______ Field Evaluation (16 Hours)

Total Training: ________ Hours

Signed ___________________________________ ___________________________________
Supervisor/Trainer Participant

Completion of Module 910, Level Border Irrigation Evaluation (as recorded above) is acknowledged and documented in the above named employee's record.

Signed ___________________________________ ___________________________________
Training Officer Date