NATURAL RESOURCES CONSERVATION SERVICE
PACIFIC ISLANDS AREA

CONSERVATION PRACTICE STANDARD

TERRACE

(Ft.)

CODE 600

DEFINITION

An earth embankment, or a combination ridge and channel, constructed across the field slope.

PURPOSE

This practice is applied as part of a resource management system for one or more of the following purposes:

- Reduce erosion by reducing slope length
- Retain runoff for moisture conservation

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- Soil erosion caused by water and excessive slope length is a problem
- Excess runoff is a problem
- There is a need to conserve water
- The soils and topography are such that terraces can be constructed and reasonably farmed
- A suitable outlet can be provided

CRITERIA

General Criteria Applicable to All Purposes

Terraces shall be planned, designed, and constructed to comply with all Federal, State, and Local laws and regulations.

Various conservation practices can reduce erosion and runoff while improving soil function, permeability, and structure. As appropriate, these practices, such as Conservation Cover (327), Conservation Crop Rotation (328), Cover Crop (340), Forage and Biomass Planting (512), Nutrient Management (590), Residue and Tillage Management, No Till / Strip Till / Direct Seed, (329), Row Arrangement (557), and Vegetative Barrier (601), shall be discussed in detail with the land user.

Terraces are not recommended on land slopes greater than 20 percent.

Spacing. *Locate* terraces at intervals across the slope to achieve the intended purpose. The maximum spacing of terraces for erosion control is that necessary to achieve soil loss tolerance (T). Include both the terrace system with planned as-built slopes and cultural practices such as residue management when determining soil loss. The slope length used when checking soil loss for a proposed terrace spacing is the distance from the terrace ridge to the next lower terrace channel measured along the natural flow direction. Maximum spacing for erosion control based on soil loss tolerance may be increased by as much as 10 percent to provide better location, alignment to accommodate farm machinery, or to reach a satisfactory outlet.

Terrace spacing methods that may be used include;

- the current NRCS accepted erosion prediction technology,
- the Vertical Interval Equation, or
- state developed methods that address unique soil, cropping, or other farming practices that affect terrace spacing.

Refer to the current NRCS accepted erosion prediction software and user guide to determine soil loss. Refer to the Engineering Field Handbook, Chapter 8, Terraces, for use of the Vertical Interval Equation.

Supplemental spacing criteria for Pineapple, Sugarcane, or Orchards. *Maximum horizontal terrace spacing may be determined by* ***Table 1 or Table 2****, but does not have to be less than 200 feet. The flattest field slope above any terrace will be used to determine the horizontal spacing at that point. The horizontal spacing shall not exceed 500 feet for land slopes up to 12%, 400 feet for lands from 12 to 18%, and 300 feet for lands steeper than 18%.*

Terraces spaced with ***Table 1 or Table 2*** *shall also be evaluated with the current NRCS accepted erosion prediction technology to determine the effect of the terrace system in reducing soil loss. Additional practices which will reduce soil loss to accepted limits shall be recommended to the land user.*

Supplemental spacing criteria for Diversified Agriculture. *Refer to the current NRCS accepted erosion prediction software and user guide to determine soil loss. Consider the most intensive use planned and the expected level of management.*

The horizontal spacing shall not exceed 450 feet for land slopes up to 2%, 300 feet for lands of 2 to 4%, 200 feet for slopes of 4 to 6 %, and 150 feet for lands steeper than 6%.

Alignment. To accommodate farm machinery and farming operations, design cropland terraces with long gentle curves. When multiple terraces are used in a field, design the terraces to be as parallel to one another as practicable.

Capacity. Design terraces with enough capacity to control the runoff from a 10-year frequency, 24-hour storm without overtopping. For terrace systems designed to control excess runoff or to function with other structures, choose a larger design storm that is appropriate to the risk associated with the installation. For terraces with underground outlets, the capacity to contain the design storm can be a combination of storage and out-flow through the underground outlet. Increase the capacity of terraces by the estimated 10-year sediment accumulation, unless the Operation and Maintenance Plan specifically addresses *more frequent* removal of sediment *to maintain terrace grade and capacity*.

When the capacity is determined by the formula Q = AV and the V is calculated using Manning's formula, a minimum n value of 0.06 shall be used for bare channels. The National Engineering Handbook Series, Part 650, Engineering Field Handbook, Chapter 8, "Terrace Channel Design Aid" may be used.

Agricultural Handbook Number 667, Stability Design of Grass-lined Open Channels, or equivalent shall be used for vegetated channels with a "B" retardance factor.

For terraces with open outlets, the capacity is based on the terrace channel size and stability. Base the capacity of the channel on a bare earth channel for crop fields or in the case of a permanently vegetated channel, the appropriate vegetation. For bare earth channels use a Manning's *n* value of 0.035 or greater, to calculate capacity. For permanently vegetated channels refer to Conservation Practice Standard (412), Grassed Waterway, for design criteria to determine capacity.

Design level terraces to contain the runoff from a 10-year 24-hour rainfall event, and the expected 10-year sediment accumulation, unless the Operation and Maintenance Plan specifically addresses the annual removal of sediment.

Terrace cross section. Proportion the terrace cross section to fit the land slope, the crops grown, and the farm machinery used. Add ridge height if necessary to provide for settlement, channel sediment deposits, ridge erosion, the effect of normal tillage operations, or safety. At the design elevation, the ridge shall have a minimum width of 3 ft. For terraces with open outlets, design the capacity of the outlet to be equal to or greater than the capacity of the terrace channel.

All farmable terrace slopes shall be no steeper than those on which farm equipment can be operated safely. For non-farmable terrace slopes, the steepest slopes allowable are 2 horizontal to 1 vertical unless an analysis of site specific soil conditions indicate that steeper slopes will be stable.

End closures. Level terraces may have open ends, partial end closures, or complete end closures. Use partial and complete end closures only on soils and slopes where stored water will be absorbed by the soil without appreciable crop damage or where underground outlets are provided.

If terraces with closed or partly closed ends are specified, install the end closures before the terraces are completed. End closures less than or equal to half the effective height of the terrace ridge are considered partial closures while those greater than half the height are considered complete closures. The cross-sectional area of the end closure fill may be less than the terrace cross-section. For level terraces that have end closures that are lower than the terrace ridge elevation, areas downstream from the end closure must be protected from flow that will exit from the closure before the design storm is reached.

Channel grade. Design the terrace channel to be stable with non-erosive velocities but with sufficient grade to prevent damage to crops or to prevent delay of farming activities from prolonged ponding.

For cultivated terraces, base the channel stability on a bare earth condition. The maximum velocity for erosion-resistant soils (clay textural classification) is 2.5 ft/s; for average soils (silt textural classification), 2.0 ft/s; and for easily erodible soils (sand textural classification), 1.5 ft/s. *Use **Table 3** as a guide.* If Manning's equation is used to compute velocity, use a maximum *n* value of 0.035 to determine velocity for channel stability.

Table 3 - Soil Erosion Resistance Group and Maximum Velocity

Soil Erosion Resistance Group[(1)]	*Maximum Velocity (fps)*
I	*5.5*
II	*4.5*
III	*3.5*
IV	*2.5*

(1) Soil erosion resistance groups for Hawaii soils may be found in the National Engineer Handbook, Part 650, Engineering Field Handbook, Chapter 2, as EFH Notice HI-35.

For permanently vegetated channels, base the channel stability on the appropriate vegetation. Refer to Conservation Practice Standard 412, Grassed Waterway for design criteria to determine stability.

For short distances *(up to 100 feet)* in the upper reaches of a channel, grades may be increased to improve alignment. *Channel grades shall not be increased at the outlet.* For terraces with an underground outlet, channel grades can be steeper for short distances *(up to 100 feet)* within the impoundment area.

Channel grades shall not exceed 3% even if maximum calculated velocities are not exceeded. Channel grades may be uniform or variable.

Level terrace length. The volume of water stored in level terraces is proportional to the length. To reduce the potential risk from failure, do not design level terraces with lengths that exceed 3,500 feet unless the channel is blocked at intervals not exceeding 3,500 feet.

Outlets. All terraces must have adequate outlets. The outlet must convey runoff water to a point where it will not cause damage. *Various types of outlets are as shown below:*

1. Vegetated outlets are suitable for gradient or open-end level terraces. Grassed waterways or naturally vegetated drainage ways may be used as a vegetated outlet. Install and stabilize grassed waterways prior to the construction of the terrace so that the terrace will have a stable outlet when it is constructed. The capacity of the vegetated outlet must be large enough so that the water surface in the outlet is below the water surface in the terrace at the design flow.

2. Underground outlets are suitable on gradient or level terraces. The outlet consists of an intake and an underground conduit. Refer to Conservation Practice Standard (620), Underground Outlet, for design criteria. Design the intake structure for the underground outlet to control the flow out of the terrace and to prevent excessive pressure in the underground conduit. *Conduits must be installed deep enough to prevent damage from tillage equipment.*

Design the outlet so that the flow release time does not exceed the inundation tolerance of the planned crops. If sediment retention is a primary design goal, adjust the release rate according to sediment particle size. Locate the inlet for the underground outlet to accommodate farming operations and to allow for sediment accumulation.

3. Soil infiltration may be used as the outlet for level terraces. Soil infiltration rates, under average rainfall conditions, must permit infiltration of the design storm from the terrace channel within the inundation tolerance of the planned crops.

4. Stable earth outlets may be used in areas where soils have proven resistance to erosion in that type of application. Usually, these outlets will be limited to soils in erosion-resistant groups I and II.

5. A combination of soil infiltration and nonerosive outlet may be used for level terraces with partial end closures.

Combinations of different outlet types may be used on the same terrace system to optimize water conservation, improve water quality, accommodate farming operations, or to provide for economical installation.

Vegetation. Stabilize all areas planned for vegetation as soon as possible after construction. Refer to Conservation Practice Standard (342) Critical Area Planting for seeding criteria.

Steep backslope terraces (and steep frontslope, if used) shall be established to acceptable vegetation as soon as practicable after construction. Terraces constructed in fields with multiple year crops, such as pineapple, sugarcane, and macadamia nuts, that provide canopy cover to the steep portion of the terrace, may not be practicable to establish vegetatively. No trees shall be planted below the flow depth of gradient terraces.

Drainage. Install subsurface drainage to stabilize soils and improve terrace function as needed. Refer to Conservation Practice Standard 606, Subsurface Drain, for design and installation criteria.

Additional Criteria Applicable to Retaining Runoff for Moisture Control

For terraces installed to retain moisture, perform a water budget analysis to determine the volume of water that must be collected to meet the requirements of the water budget. As a minimum the terrace must still meet the design storm and sediment volume requirements in the **Capacity** section of this standard.

CONSIDERATIONS

An Underground Outlet (620), while facilitating sediment storage, will also reduce the necessary capacity for a particular terrace, downstream of the underground outlet. Contour Farming (330) or Hillside Ditch (423), may serve as an alternative to terraces. Land Smoothing (466) and Precision Land Forming (462), may facilitate terrace installation.

One of the keys to a successful terrace system is to make sure that the terrace layout fits the farm equipment. This includes making curves long and gentle and spacing terraces so that the operator can make an even number of trips between terraces so that they end up on the same side of the field on which they started.

Terrace ridges and cut slopes can introduce steep and potentially hazardous slopes into a crop field. Where slopes will be farmed, make sure they can be safely negotiated with the operator’s equipment. Where steep slopes are unavoidable make sure the operator is aware of the location and potential danger of the slopes.

The soil survey can be a valuable resource when planning and designing terrace systems. The soil survey can identify potential problems such as the presence of limiting layers to plant growth in the soil profile. Field investigations can then identify problem areas to avoid such as shallow bedrock or dense, acid or saline layers that will adversely affect plant growth if construction brings them into the root zone.

Steep sided terraces that are in permanent vegetation can provide significant areas of habitat for wildlife. Consider planting native species that provide food and cover for wildlife. Do not mow these areas until after the nesting season to improve wildlife production.

Hillside seeps in a crop field can cause cropping problems. Consider aligning terraces and/or installing subsurface drainage to intercept and correct seepage problems.

Erosion can be a problem at the outfall of an underground outlet. To ensure an adequate outlet, protect the outfall of the underground outlet so that it is stable.

Outlets from terraces can provide a direct conduit to receiving waters for contaminated runoff from crop land. Terraces should be installed as part of a conservation system that addresses issues such as nutrient and pest management, residue management and filter areas.

Inlets for underground outlets can be easily damaged during cultivation, planting and harvesting operations. Using brightly colored inlets, barriers around the inlet or otherwise clearly marking the inlet will help prevent damage.

For terraces that will be farmed or otherwise revegetated, the stripping and stockpiling of topsoil from the construction area prior to excavation and then spreading the topsoil on the completed terrace will improve the growth of vegetation after construction.

PLANS AND SPECIFICATIONS

Prepare *site-specific designs (drawings and* specifications) for terraces that describe the requirements for applying the practice according to this *Conservation Practice Standard and the Conservation Practice Specification*. As a minimum, the plans and specifications shall include:

1. A plan view of the layout of all the terraces in the system, *with land slopes, horizontal spacing, and terrace length(s).*
2. Typical cross sections of the terrace(s).
3. Profile(s) or planned grade of the terrace(s).
4. Details of the outlet system.
5. If underground outlets are used, details of the inlet and profile(s) of the underground outlet.
6. Seeding requirements, if needed.
7. Site specific construction specifications that describe in writing the installation of the terrace system.

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for the operator. *Deliver and discuss the plan with the operator.* The minimum requirements to be addressed in a written operation and maintenance plan are:

1. Periodic inspections, especially immediately following significant runoff events.
2. Prompt repair or replacement of damaged components.
3. Maintenance of terrace ridge height, channel profile, terrace cross-sections and outlet elevations.
4. *As per the design, periodic* removal of sediment that has accumulated in the terrace channel to maintain capacity and grade.
5. Regular cleaning of inlets for underground outlets. Repair or replacement of inlets damaged by farm equipment. Removal of sediment *near* inlets to ensure that the inlet remains the lowest spot in the terrace channel.
6. Where vegetation is specified, *periodic* mowing and control of trees and brush.
7. Notification of hazards concerning machinery and steep slopes on the terrace

The Pacific Islands Area Terrace (600) Conservation Practice Operation and Maintenance Plan shall be used to record the operation and maintenance of the practice on the client's treatment unit.

REFERENCES

USDA, NRCS. 2004. Revised Universal Soil Loss Equation, Ver. 2 (RUSLE2).

USDA, NRCS. National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 8.

TABLE 1
MAXIMUM TERRACE SPACING - FT
HYDROLOGIC **CLASS A** SOILS

RAINFALL 10-yr, 24Hr (inches)	SOIL EROSION RESISTANCE GROUP	FIELD SLOPE (ft/ft)								
		0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
7	I	500	500	500	500	500	400	400	400	300
	II	500	500	500	500	500	400	400	400	300
	III	500	500	500	470	420	380	350	340	300
	IV	430	350	300	270	260	230	200		
8	I	500	500	500	500	500	400	400	400	300
	II	500	500	500	500	500	400	400	400	300
	III	500	500	460	400	350	320	290	280	260
	IV	370	290	250	220	210	200			
9	I	500	500	500	500	500	400	400	400	300
	II	500	500	500	500	480	400	390	380	300
	III	500	480	390	340	300	280	260	250	230
	IV	320	260	220	200					
10	I	500	500	500	500	500	400	400	400	300
	II	500	500	500	480	420	380	350	340	300
	III	500	420	350	300	270	240	220	220	200
	IV	280	220	200						
11	I	500	500	500	500	500	400	400	400	300
	II	500	500	500	430	380	340	310	300	280
	III	500	380	310	270	240	220	200		
	IV	250	200							
12	I	500	500	500	500	500	400	400	390	300
	II	500	500	460	390	340	310	280	280	250
	III	470	340	280	240	210	200			
	IV	230	200							
13	I	500	500	500	500	470	400	390	360	300
	II	500	500	420	360	320	280	260	250	230
	III	430	320	260	220	200				
	IV	210	200							
14	I	500	500	500	500	430	390	360	330	300
	II	500	490	390	330	290	260	240	230	220
	III	400	290	240	210	200				
	IV	200								
15	I	500	500	500	470	400	360	340	310	290
	II	500	450	360	310	270	240	220	220	200
	III	370	270	220	200					
	IV	200								
16	I	500	500	500	440	380	340	310	290	270
	II	500	430	340	290	260	230	210	200	
	III	350	260	210						
	IV	200								

TABLE 2
MAXIMUM TERRACE SPACING - FT
HYDROLOGIC **CLASS B-C-D** SOILS

RAINFALL 10-yr, 24Hr (inches)	SOIL EROSION RESISTANCE GROUP	FIELD SLOPE (ft/ft)								
		0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
7	I	500	500	500	500	500	400	400	400	300
	II	500	500	500	480	420	370	340	330	300
	III	500	420	340	300	260	240	220	210	200
	IV	270	220	200						
8	I	500	500	500	500	500	400	400	400	300
	II	500	500	490	420	370	330	300	290	270
	III	500	370	300	260	230	210	200		
	IV	240	200							
9	I	500	500	500	500	490	400	400	380	300
	II	500	500	440	380	330	300	270	260	250
	III	450	330270	240	210	200				
	IV	220	200							
10	I	500	500	500	500	450	400	370	340	300
	II	500	500	400	340	300	270	250	240	220
	III	410	300	250	210	200				
	IV	200								
11	I	500	500	500	480	410	360	340	310	300
	II	500	460	370	310	280	250	230	220	210
	III	370	280	230	200					
	IV	200								
12	I	500	500	500	450	380	340	320	290	280
	II	500	430	340	290	260	230	210	210	200
	III	350	260	210	200					
	IV	200								
13	I	500	500	490	420	360	320	300	270	250
	II	500	400	320	270	240	210	200		
	III	320	240	200						
	IV	200								
14	I	500	500	460	400	340	300	280	250	240
	II	500	380	300	260	220	200			
	III	310	220	200						
	IV	200								
15	I	500	500	430	370	320	280	260	240	230
	II	490	360	290	240	210	200			
	III	290	210	200						
	IV	200								
16	I	500	500	410	360	300	270	250	230	220
	II	470	340	280	240	210	200			
	III	280	200							
	IV	200								