# Runway slope / Landing Area Slope

## Issue identified NPA 2018-06 (B-C-D)

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# Back ground (1/2)

- **Certification of landing systems request to assess Runway slope**

  *CS AWO.A.ALS.107 Aerodrome conditions*

  *[…] the effects of aerodrome conditions (e.g. elevation, ambient temperature, **runway slope** and ground profile under the approach path) are to be investigated […]*

- **Certification request to define limits in AFM, including Runway slope**

  *CS AWO.A.ALS.113 AEROPLANE FLIGHT MANUAL*

  *The AFM shall contain the limitations, procedures and other information pertinent to the operation of the automatic landing system and shall include the following appropriate to the use for which the particular system has been certified*

  *(a) the approved limits established as a result of consideration of the factors listed in CS AWO.A.ALS.106 (a) and **CS AWO.A.ALS.107***

- **Airport Rules request Runway slope to be published**

  *GM1 ADR.OPS.A.005 Aerodrome Data*

  *AERODROME DIMMENSIONS AND RELATED INFORMATION*

  *The following data are measured and described, as appropriate, for each facility provided on the aerodrome:*

  *(a)Runway […]*

  *(6) **Longitudinal slope***



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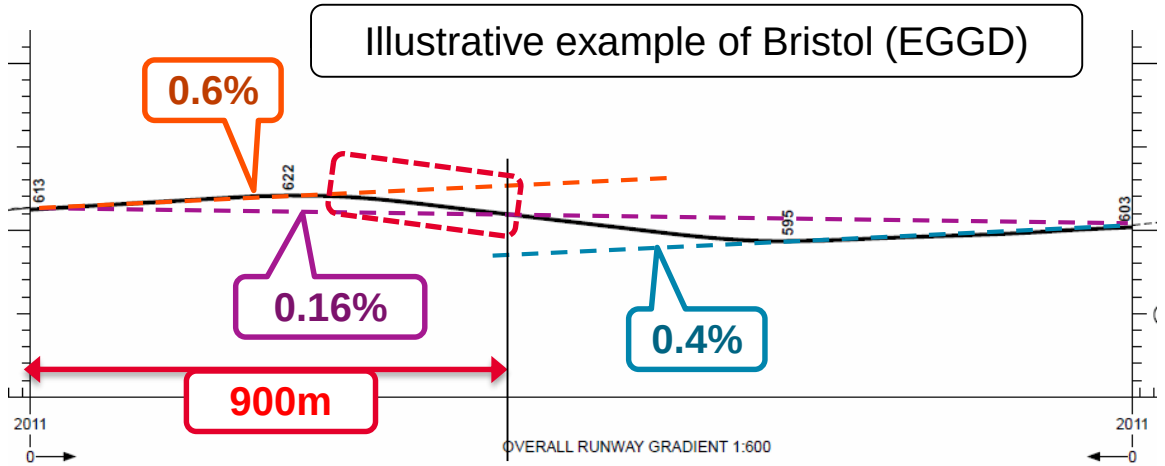
# Back ground (2/2)

- **Certification of landing systems request to assess Runway slope**
- **Certification request to define limits in AFM, including Runway slope**
- **Airport Rules request Runway slope to be published**
- **Runway slope variation are allowed**

*CS ADR-DSN.B.065 Longitudinal slope changes on runways*
*(b) Where slope changes cannot be avoided, a slope change between two consecutive slopes should not exceed:*
*(1) 1.5 % where the code number is 3 or 4; and […]*

*CS ADR-DSN.B.075 Distance between slope changes on runways*
*Undulations or appreciable changes in slopes located close together along a runway should be avoided. The distance between the points of intersection of two successive curves should not be less than:*
*(a) the sum of the absolute numerical values of the corresponding slope changes multiplied by the appropriate value as follows:*
*(1) 30 000 m where the code number is 4; […]*
*(b) 45 m; whichever is greater.*



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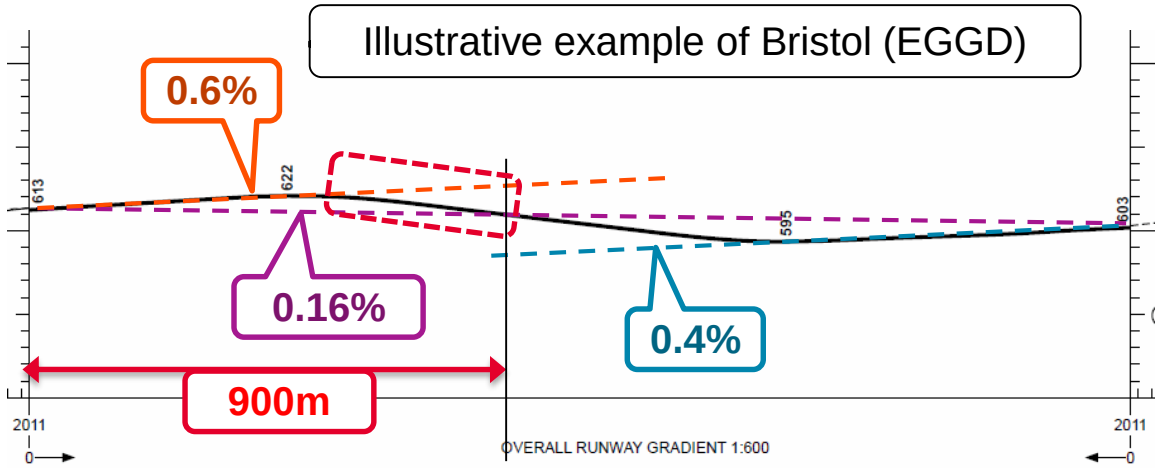
# Issues identified

***Unclear definition of Runway Slope***

***Relevant limits of slopes for landing system differ from relevant limits for performance assessment***

***Slope change in landing area is usually not considered in certification but allowed in Aerodrome design GM***

***HUDLS and EVS-L requires flare guidance, but no mention of Runway slope to be considered in performance / operational assessment***



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# Unclear definition of Runway Slope : Suggested improvements

- Add a definition of « landing area slope » in *CS –AWO*
  - *CS –AWO : General (Applicable to all Landing systems including HUDLS and EVS-L)*

    *The landing area slope is the slope of the runway between threshold up to 900m from runway threshold.*

- Replace « runway slope » by « landing area slope » in CS –AWO for Automatic Landing Systems
  - *CS AWO.A.ALS.107 Aerodrome conditions*
  - *AMC AWO.A.ALS.106 Performance demonstration*

- Add additional information and definition of « landing area slope » in *Part –ADR.AR*
  - *Part –ADR.AR : GM1 ADR.OPS.A.005 Aerodrome Data*

    *(10) landing area slope : slope computed for the runway threshold up to 900m from runway threshold*

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# Relevant limits of slopes for landing system differ from relevant limits for performance assessment : Suggested improvements

- Replace « runway slope » by « landing area slope » in CS –AWO for Automatic Landing Systems
  - *CS AWO.A.ALS.107 Aerodrome conditions*
  - *AMC AWO.A.ALS.106 Performance demonstration*

*Note : Applicable also to HUDLS and EVLS-L (see next slides)*

- *CS AWO.A.HUD.107 Performance demonstration*
- *CS AWO.A.EFVS.109 EFVS performance (h) The lateral and longitudinal touchdown performance of an EFVS-L […]*
- *AMC AWO.A.EFVS.103 EFVS depiction*



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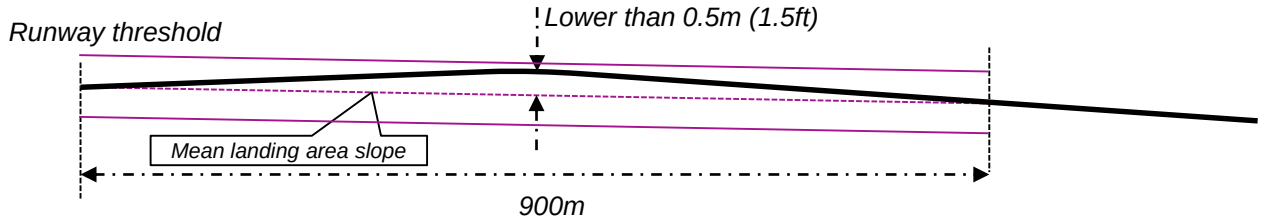
# Slope change in landing area is usually not considered in certification but allowed in  Aerodrome design GM: Suggested improvements

- Add a criteria to define « irregular landing area » in Part –ADR.AR : GM1 ADR.OPS.A.005 Aerodrome Data

*Runway presenting significant change in longitudinal runway slope in the landing area may not be compatible with landing system. If one of the following criteria is not fulfil, then the landing area should be identified as irregular*
*(a) Criteria defined in CS ADR-DSN.B.065 (b) and (c) are respected*
*(b) Criteria defined in CS ADR-DSN.B.075 are respected*
*(c) At any point between 0m and 900m from threshold, the runway elevation should be at an elevation lower that 0.5m above/below the mean landing slope*




- Add « irregular landing area » consideration in AMC3 SPA.LVO.110 ANS- and aerodrome-related requirements

SUITABLE AERODROMES – APPROACH OPERATIONS OTHER THAN EFVS OPERATIONS

*(g) if landing area presents significant longitudinal runway slopes change in excess of limits used to certify aircraft systems providing flare guidance, (refer to GM1 ADR.OPS.A.005 Aerodrome Data ) each aircraft type/equipment/runway combination should be verified by operations in CAT I or better condition (or landing system have demonstrated acceptable performance) before authorising the use of landing system on any runway with irregular landing area.*



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# HUDLS and EVS-L requires flare guidance, but no mention of Runway slope to be considered in performance and operational assessment: Suggested improvements (1/2)

- Add « landing area slope » as factors to be considered for flare guidance (HUD and EFVS-L) in CS-AWO
  - *CS AWO.A.HUD.107 Performance demonstration*
    *Add « the effects of aerodrome conditions (e.g. elevation, landing area slope and ground profile under the approach path) are to be investigated »*
  - *CS AWO.A.EFVS.109 EFVS performance (h) The lateral and longitudinal touchdown performance of an EFVS-L […]*
    *Add « the effects of aerodrome conditions (e.g. elevation, landing area slope and ground profile under the approach path) are to be investigated »*
  - *AMC AWO.A.EFVS.103 EFVS depiction*
    *Flare cue :* add *« When demonstrating performance of flare cue, effect of landing area slope should be considered »*

- Add « irregular landing area » consideration in AMC5 SPA.LVO.110 ANS- and aerodrome-related requirements

VERIFYING THE SUITABILITY OF RUNWAYS FOR EFVS OPERATIONS

*(f) if the system used to preform EFVS operation contains a flare prompt/guidance, each aircraft type/equipment/runway combination should be verified by operations in CAT I or better conditions before authorising the use of EFVS-L system, on any runway with irregular pre-threshold terrain,* ***if landing area presents significant longitudinal runway slopes change (refer to GM1 ADR.OPS.A.005 Aerodrome Data )*** *or other foreseeable or known difficulties.*

**Note: irregular pre-threshold terrain apply also to HUD and EVFS-L that contains flare prompt/guidance**



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# HUDLS and EVS-L requires flare guidance, but no mention of Runway slope to be considered in performance and operational assessment: Suggested improvements (2/2)

- Add « landing area slope » GM4 SPA.LVO.100(c) Low-visibility operations and operations with operational credits EFVS OPERATIONS

(j) Use of EFVS to touchdown

*"In order for the use of EFVS to touchdown to be approved, the EFVS will provide flare cueing and guidance (EFVS-L). This mitigates the fact that a 2D image and a narrow FOV displayed by the EFVS may cause erroneous perceptions of depth or height. The EFVS will also display height above the runway by the use of a radio altimeter or other device capable of providing equivalent performance. Unless the operator has verified that the terrain ahead of the threshold* ***and landing area slope*** *is suitable for the use of a radio altimeter, such a system should not be relied upon to provide accurate information about the height of the aircraft above the runway threshold until the aircraft is over the runway surface."*

- Replace "Automatic Landing" by "Landing" in **GM1 SPA.LVO.105 LVO approval Specific approval criteria**

CRITERIA FOR A SUCCESSFUL APPROACH AND ~~AUTOMATIC~~ LANDING

*The criteria of successful landing apply to HUD flare Guidance and not only to Automatic AP coupled landing.*



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# Backup Slides

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# Existing CS AWO.A.ALS.107

**CS AWO.A.ALS.107 Aerodrome conditions**

Expected Aerodrome conditions (e.g. elevation, ambient temperature, **runway slope** and ground profile under the approach path) shall be considered and appropriate limitations entered in the AFM. (AMC AWO.A.ALS.106, paragraph 5).

**AMC AWO.A.ALS.106 Performance demonstration**

1.3 In accordance with CS AWO.A.ALS.107, the effects of aerodrome conditions (e.g. elevation, ambient temperature, **runway slope** and ground profile under the approach path) are to be investigated and, if necessary, appropriate limitations derived for inclusion in the aeroplane flight manual AFM. Guidance is given in paragraph 5.

5.2 Ground profile

5.2.1 Where use is made of radio altimeter signals in the automatic landing system, any effects of ground profile before the runway or **along the runway** on the performance of the system should be examined.

5.2.2 The family of profiles to be investigated should take due account of the way in which the system uses the radio altimeter signals at different heights on the approach. Terrain and runway up slopes, down slopes and other terrain irregularities should be investigated.

NOTE: The information on characteristics of aerodromes is contained in ICAO Annex 14. Examination of a number of airports used for automatic landing has shown that the following features may be encountered:

**a. sloping runway — slopes of 0.8 %;**

b. hilltop runway — 12.5 % slope up to a point 60 m prior to the threshold; or

c. sea-wall — 6 m (20 ft) step up to threshold elevation at a point 60 m prior to the threshold.

# Existing **CS ADR-DSN.B.060 and CS ADR-DSN.B.065**

**CS ADR-DSN.B.060 Longitudinal slopes of runways**

(a) The safety objective of limiting the longitudinal runway slope is to enable stabilized and safe use of runway by an aircraft.

(b) The slope computed by dividing the difference between the maximum and minimum elevation along the runway centre line by the runway length should not exceed:

(1) 1 % where the code number is 3 or 4; and

(2) 2 % where the code number is 1 or 2.

(c) Along no portion of a runway should the longitudinal slope exceed:

(1) 1.25 % where the code number is 4, except that for the first and last quarter of the length of the runway where the longitudinal slope should not exceed 0.8 %;

(2) 1.5 % where the code number is 3, except that for the first and last quarter of the length of a precision approach runway Category II or III where the longitudinal slope should not exceed 0.8 %; and

(3) 2 % where the code number is 1 or 2.

**CS ADR-DSN.B.065 Longitudinal slope changes on runways**

(a) The safety objective of limiting the longitudinal runway slope changes is to avoid damage of aircraft and to enable safe use of runway by an aircraft.

(b) Where slope changes cannot be avoided, a slope change between two consecutive slopes should not exceed:

(1) 1.5 % where the code number is 3 or 4; and

(2) 2 % where the code number is 1 or 2.

(c) The transition from one slope to another should be accomplished by a curved surface with a rate of change not exceeding:

(1) 0.1 % per 30 m (minimum radius of curvature of 30 000 m) where the code number is 4;

(2) 0.2 % per 30 m (minimum radius of curvature of 15 000 m) where the code number is 3; and

(3) 0.4 % per 30 m (minimum radius of curvature of 7 500 m) where the code number is 1 or 2.



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# Existing **CS ADR-DSN.B.070 and CS ADR-DSN.B.075**

**CS ADR-DSN.B.070 Sight distance for slopes on runways**

(a) The safety objective of minimum runway sight distance values is to achieve the necessary visibility to enable safe use of runway by an aircraft.

(b) Where slope changes on runways cannot be avoided, they should be such that there should be an unobstructed line of sight from:

(1) any point 3 m above a runway to all other points 3 m above the runway within a distance of at least half the length of the runway where the code letter is C, D, E, or F;

(2) any point 2 m above a runway to all other points 2 m above the runway within a distance of at least half the length of the runway where the code letter is B; and

(3) any point 1.5 m above a runway to all other points 1.5 m above the runway within a distance of at least half the length of the runway where the code letter is A.

**CS ADR-DSN.B.075 Distance between slope changes on runways**

Undulations or appreciable changes in slopes located close together along a runway should be avoided. The distance between the points of intersection of two successive curves should not be less than:

(a) the sum of the absolute numerical values of the corresponding slope changes multiplied by the appropriate value as follows:

(1) 30 000 m where the code number is 4;

(2) 15 000 m where the code number is 3; and

(3) 5 000 m where the code number is 1 or 2; or

(b) 45 m;

whichever is greater.

# Existing **GM1 SPA.LVO.105 Specific approval criteria**

**GM1 SPA.LVO.105 Specific approval criteria**

CRITERIA FOR A SUCCESSFUL APPROACH AND AUTOMATIC LANDING

(c) An automatic landing may be considered to be successful if:

[…]

(4) longitudinal touchdown is beyond a point on the runway 60 m after the threshold and before the end of the TDZ light (900 m from the threshold);

[…]



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# Existing **CS ADR-DSN.B.070 and CS ADR-DSN.B.075**

**GM1 ADR-DSN.B.060 Longitudinal slopes on runways**

Slopes should be so designed as to minimise impact on aircraft and so not to hamper the operation of aircraft. For precision approach runways, slopes in a specified area from the runway end, and including the touchdown area, should be designed so that they should correspond to the characteristics needed for such type of approach.

**GM1 ADR-DSN.B.065 Longitudinal slopes changes on runways**

(a) Slope changes are so designed as to reduce dynamic loads on the undercarriage system of the aeroplane. Minimising slope changes is especially important on runways where aircraft move at high speeds.

(b) For precision approach runways, slopes in a specified area from the runway end, and including the touchdown area, are so designed that they should correspond to the characteristics needed for such type of approach

**GM1 ADR-DSN.B.070 Sight distance for slopes of runways**

Runway longitudinal slopes and slopes changes are so designed that the pilot in the aircraft has an unobstructed line of sight over all or as much of the runway as possible, thereby enabling him to see aircraft or vehicles on the runway, and to be able to manoeuvre and take avoiding action.



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# Existing **CS ADR-DSN.B.070 and CS ADR-DSN.B.075**

**GM1 ADR-DSN.B.075 Distance between slope changes on runways**

The following example illustrates how the distance between slope changes is to be determined (see Figure GM-B-2):

D for a runway where the code number is 3 should be at least:

15 000 ($|x - y| + |y - z|$) m

$|x - y|$ being the absolute numerical value of $x - y$

$|y - z|$ being the absolute numerical value of $y - z$

Assuming $x = +0.01$

Assuming $y = -0.005$

Assuming $z = +0.005$

then $|x - y| = 0.015$

then $|y - z| = 0.01$

To comply with the specifications, D should be not less than:

that is, 15 000 (0.015 + 0.01) m,

that is, 15 000 × 0.025 = 375 m

When a runway is planned that should combine the extreme values for the slopes and changes in slope permitted, as prescribed in CS ADR-DSN.B.060 to CS ADR-DSN.B.080, a study should be made to ensure that the resulting surface profile should not hamper the operation of aeroplanes.

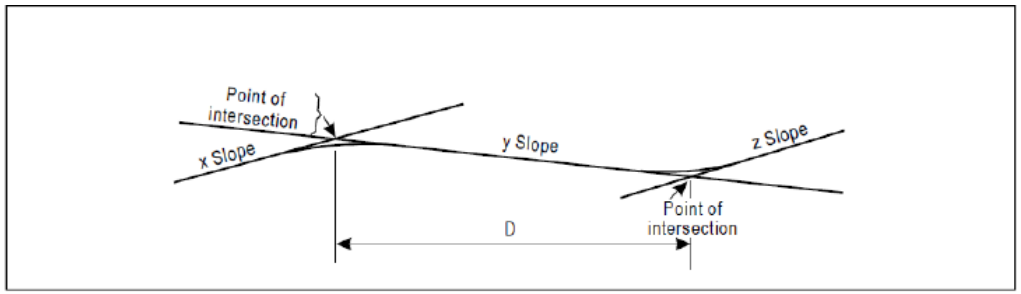


Figure GM-B-2. Profile on centre line of runway



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# Existing **GM1 ADR.OPS.A.005 Aerodrome data**

## GM1 ADR.OPS.A.005 Aerodrome data

AERODROME AND RUNWAY ELEVATIONS

The following should be measured and reported to the aeronautical information services:

(a) The aerodrome elevation and geoid undulation at the aerodrome elevation position to the accuracy of one-half metre or foot;

(b) For non-precision approaches, the elevation and geoid undulation of each threshold, the elevation of the runway end and any significant high and low intermediate points along the runway, to the accuracy of one-half metre or foot;

(c) For precision approach runway, the elevation and geoid undulation of the threshold, the elevation of the runway end and the highest elevation of the touchdown zone, to the accuracy of one-quarter metre or foot.

AERODROME DIMENSIONS AND RELATED INFORMATION

The following data are measured or described, as appropriate, for each facility provided on the aerodrome:

(a) Runway

(1) true bearing to one-hundredth of a degree;

(2) designation number;

(3) length;

(4) width;

(5) displaced threshold location to the nearest metre or foot;

(6) longitudinal slope;

(7) surface type;

(8) type of runway; and

(9) for a precision approach runway category I, the existence of an obstacle free zone when provided.



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# ICOA Annex 14 Volume 1

## 2.5 Aerodrome dimensions and related information

2.5.1 The following data shall be measured or described, as appropriate, for each facility provided on an aerodrome:

a) runway — true bearing to one-hundredth of a degree, designation number, length, width, displaced threshold location to the nearest metre or foot, slope, surface type, type of runway and, for a precision approach runway category I, the existence of an obstacle free zone when provided;



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# ED-77A/DO-201B

**4.1.1.4.5.2 Touchdown Zone Slope**

| | |
|---|---|
| Definition: | Indicates an overall gradient of the Touchdown zone in percent, from runway threshold to the end of the touchdown zone.<br>*Note: Differs from ICAO PANS-AIM – Incomplete. Altered to explain how slope is conveyed.* |
| References: | ICAO PANS-AIM<br>RTCA DO-272/EUROCAE ED-99, Section 4.1.1.3 |
| Additional considerations/ requirements: | Since the length of the touchdown zone is not reported, users **should [NAV-D015]** take into consideration that the full context of this data element is unknown (i.e., the basis of the slope computation cannot be determined). |

**4.1.1.4.6 Slope**

| | |
|---|---|
| Definition: | Indicates an overall gradient of the runway in percent, measured from the start of take-off roll end of the runway.<br>*Note: Differs from ICAO PANS-AIM – Incomplete. Altered to explain how slope is determined.* |
| References: | ICAO PANS-AIM<br>ICAO Annex 14, Vol I, Chapter 2.5.1(a)<br>ICAO Annex 15, App 1 AD 2.12(7)<br>ARINC 424, Chapter 5, Ref 5.212 |
| Additional considerations/ requirements: | State-provided values are not always an average slope between both runway ends |





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# ED-77A/DO-201B

#### 4.1.1.4.5 Touchdown Zone

The portion of a runway, beyond the threshold, where it is intended landing airplanes first contact the runway. [ICAO PANS-AIM]

*Note: Typically, for fixed wing aircraft touchdown zone lights extend from the threshold for a longitudinal distance of 900 meters, except that on runways less than 1800 meters in length, the touchdown zone is shortened so that it does not extend beyond the midpoint of the runway. The length of the touchdown zone is typically not reported, and there is no standard way to derive it from lights or markings.*





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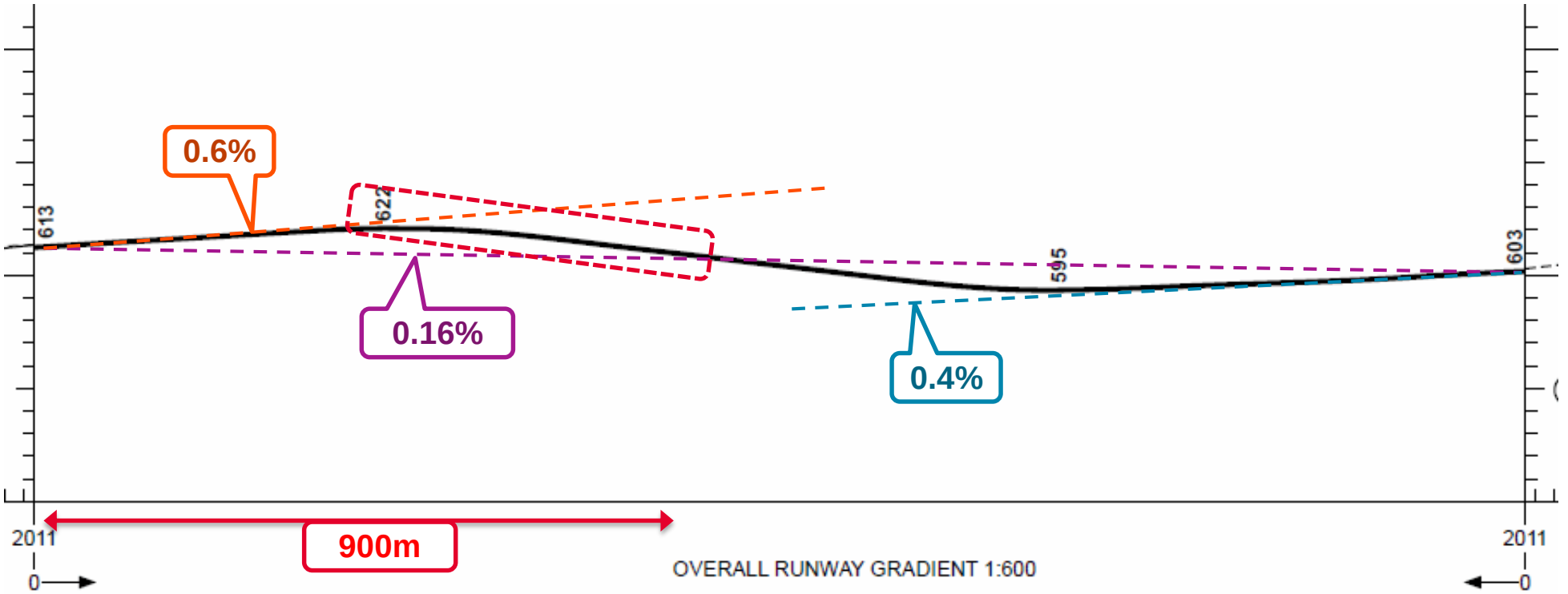
# Issue for runway with variations of slopes

Illustrative exemple of Bristol (EGGD)



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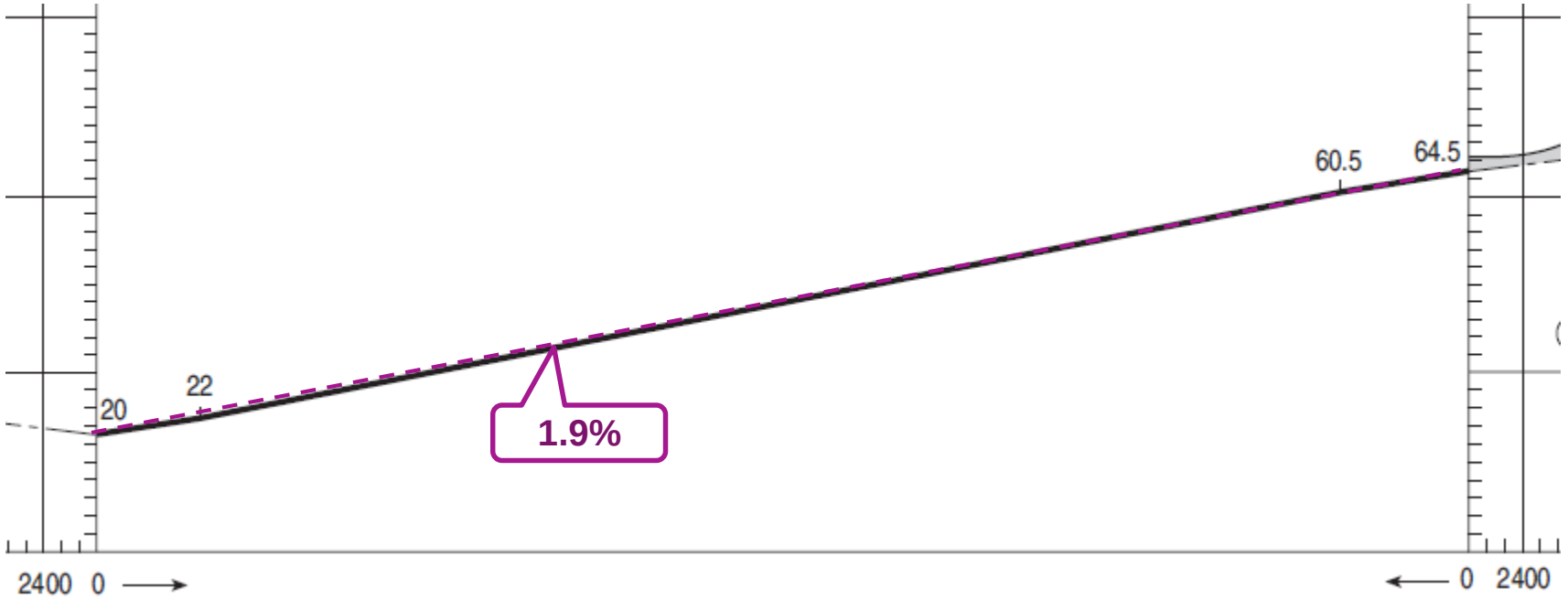
# Issue for runway with variations of slopes

Illustrative exemple of Calvi (LFKC)



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# Radio Altimeter standard accuracy

***STD-ED30-016***

The accuracy of height information shall be measured under standard conditions for each height output. The errors must not be in excess of those set forth in Table 1, hereafter.

Every parasitic effect which might affect the accuracy, such a doppler shift, step error of height lag, shall be included in the accuracy assessment.

The measurement conditions need not be applied simultaneously but may be combined by analytical methods.

TABLE 1

| ACCURACY REQUIREMENTS | | |
|---|---|---|
| Height range | Accuracy of height information displayed to the crew (1) | Accuracy of electrical height data output |
| 3 to 100 feet (1 to 30m) | ± 5 feet (1.5m) | ± 3 feet (0.9m) |
| 100 to 500 feet (30m to 150m) | ± 5% of true height | ± 3% of true height |
| 500 feet (150m) to the maximum of the scale (1) | ± 7% of true height | ± 5% of true height |



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