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Engineer Site Identification for the Tactical Environment (ENSITE)

Parameters Used in the Tactical Airfield Siting Selection Module for ENSITE

Joseph A. Gamez, Patrick J. Guertin, Eric L. Kreiger, and
George W. Calfas

September 2018

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Abstract

The Army must have an ability to rapidly plan and locate engineering sites, such as soldier base camps or airfields, for supporting maximum combat effectiveness of deployed forces. By defining mission-specific site requirements prior to force deployment and facility locations and construction, Army commanders and planners are able to optimize various siting and design decisions. This report documents the technical and doctrinal parameters used to develop the Tactical Airport Site Selection (TASS) module in the Engineer Site Identification for the Tactical Environment (ENSITE) computer planning tool. ENSITE/TASS is a remote planning tool designed for field-expedient use and a very specific set of design criteria. This report contains the rationale for why the ENSITE/TASS development process made certain assumptions, how it calculated certain quantities, and which sources of data it incorporated.

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Preface

This study was conducted for Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)) under T45, “Military Facilities Engineering Technology” and Project Number 455009, “Contingency Base Site Identification Tool for the Tactical Environment.” The technical monitor was Mr. Kurt Kinnevan, CEERD-CZT.

The work was performed under supervision of the Environmental Processes Branch (CNE) of the Installation Division (CN), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Mr. H. Garth Anderson was Chief, CEERD-CNE; Ms. Michelle Hanson was Chief, CEERD-CN; and Mr. Kurt Kinnevan, CEERD-CZT was the Technical Director for Infrastructure for Combat Operations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Lance D. Hansen.

COL Ivan P. Beckman was Commander of ERDC, and Dr. David W. Pittman was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
inches	0.0254	meters
miles per hour	0.44704	meters per second
pounds (force) (Kip = 1,000 pounds force)	4.448222	newtons
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter

1 Introduction

1.1 Background

The U.S. Army must have an ability to rapidly plan and locate engineered sites, such as soldier base camps or airfields, for supporting maximum combat effectiveness of deployed forces. By defining mission-specific site requirements prior to force deployment and facility locations and construction, Army commanders and planners are able to optimize various siting and design decisions.

This report documents the technical and doctrinal parameters used to develop the Tactical Airport Site Selection (TASS) module in the Engineer Site Identification for the Tactical Environment (ENSITE) computer planning tool. The overall ENSITE program is dedicated to empowering military planners with the data and knowledge for in-theater construction locations. ENSITE is a computer program that is comprised of various integrated capabilities for siting military construction and infrastructure.

First developed at the Engineer Research and Development Center-Geotechnical Structure Laboratory (ERDC-GSL), TASS is a geographic information systems (GIS)-based methodology for sighting airfields in theater (Anderton et al. 2007). The original TASS methodology included airfield site selection parameters for both existing and improvised airfields. These selection parameters, however, included only site location and runway orientation that were based on local terrain features.

While the recently updated and combined ENSITE/TASS version limits its scope to expedient runways,¹ it includes an expanded set of engineering-based selection parameters. TASS is also now embedded within the ENSITE environment, which enhances applicability because ENSITE incorporates TASS into a system and tool that are designed for field-expedient use. TASS is also coupled with ENSITE's other supporting applications, such as its Climate Means and Engineering Report analysis tools.

¹ This document defines expedient runways as improvised expedient runways; it does not consider taxiways, shelters, and/or other structures associated with airfield design.

1.2 Objective

This report defines the technical and doctrine-derived parameters used to construct the TASS module within the ENSITE planning tool.

1.3 Methodology

Methods used in this report consisted of Department of Defense (DoD) doctrine review, consultations with the original authors of the TASS application, and consultations with airfield design experts in the DoD.

The process of expedient runway design is driven by the following factors: (1) type of aircraft, (2) local climate, (3) prevailing winds, and (4) topography. ENSITE/TASS uses those same design factors, specifically as prescribed in military design manuals such as Training Manual (TM) 3-34.48-2 (2016), Field Manual (FM) 5-430-00-2 (1994), Unified Facilities Criteria (UFC) 3-260-02 (2001), and Engineer Technical Letter (ETL) 09-6 (2009). Thus, ENSITE/TASS designs for a very specific set of circumstances in a very specific way. This document describes that process so the ENSITE/TASS user can understand the design methodology. Specifics are provided via technical parameters and specifications that are detailed in Chapter 2.

2 Technical Parameters and Specifications

2.1 Expedient airfield design overview

It should first be noted that the phrase “expedient airfield design” is generally a misnomer because the design process (including calculations, design charts, etc.) for an expedient airfield relates only to the runway. Additionally, FM 5-430-00-2 (1994, pg. 1-10, para. 1-44) states that for an expedient airfield, “[s]helter and utilities are provided by organic equipment” saying again that the design is strictly related to the runway. It should also be noted there are a number of different terms in different military technical manuals that are used to describe expedient runways (e.g., semi-improved, unsurfaced, expedient). To standardize nomenclature in this report, only the term “expedient” will be used.

An expedient runway design will give the engineer the location, length, and alignment of a runway. The design process for airfields in general is summed up by TM 3-34.48-2 (2016, pg. 2-9, para. 2-24). Since expedient airfields are a specialized type of airfield, however, steps were added to the design process (making 16 steps) to reflect the additional considerations required for expedient airfields. Since ENSITE/TASS is a remote planning tool, it should be noted that not all steps of the combined design process are applicable for remote planning. ENSITE/TASS incorporates only 8 of the 16 steps from the modified design process, which are subsequently listed and noted in sections 2.1–2.8 of this report. For full context, the remaining 8 steps are briefly covered in Section 2.9, with reference sources cited.

(Note that a component below that is followed by an asterisk (*) means the component is included in ENSITE/TASS, and ** means it is *not* included.)

1. Select the runway location.*
2. Determine the design aircraft.*
3. Determine the in-place soil strength.*
4. Determine the required number of passes.*
5. Determine the allowable number of passes and surface type.*
6. Outline corrective actions to increase service list as necessary.**
7. Determine the runway length and width.*
8. Determine approach zones and imaginary surfaces.*
9. Determine the runway orientation based on the wind rose.*
10. Design vertical slopes.**

11. Design transverse slopes.**
12. Design taxiways and aprons.**
13. Design required drainage structures.**
14. Select visual and nonvisual aids to navigation.**
15. Design logistical support facilities.**
16. Design aircraft protection facilities.**

2.2 Select the runway location

Expedient runways are used for tactical movement of personnel and supplies. Thus, when considering the location of a expedient runway, ENSITE/TASS users should take into account a number of factors that balance the practicality of construction and intended life span of the runway. That is to say, since the location of tactical operations and the military requirements to support those operations are likely to change quickly, only minimal resources should be committed to constructing an expedient runway. With the considerations in mind, TM 3-34.48-2 (2016, pg. 4-7, para. 4-27) suggests “natural areas such as deserts, dry lake beds, and flat valley floors” as viable options.

Wherever the user may select, the process of determining runway location has been partially automated in ENSITE/TASS. Since ENSITE/TASS is a remote planning tool, a single, specific runway cannot be selected. Rather, a geographic region can be selected based on mission, enemy, terrain and weather, troops and support available, time available, and civil considerations. ENSITE/TASS will then analyze the geographic region and suggest a location and an orientation for the expedient runway.

2.3 Determine the design aircraft

The design aircraft is the aircraft that represents the “most extreme load distribution characteristics” of all aircraft that will be utilizing the runway (TM 3-34.48-2 2016, pg. 4-5, para. 4-22). For ENSITE/TASS, the design aircraft will either be a C-17 or C-130. The ENSITE/TASS user will select one of these two aircraft based on the mission requirements given from higher headquarters.

The aircraft’s gross weight, which is the basis for determining the needed pavement thickness, is the aircraft’s maximum allowable weight during takeoff, and Table 1 shows that data for both aircraft types. It should be noted that TASS does not use these weights for preliminary level siting and

design of expedient runways. Rather, these weights are provided as a benefit, in case the ENSITE/TASS user may want to estimate the number of passes for an aircraft of a certain type. ENSITE/TASS users can find more information on this topic in TM 3-34.48-2 (2016, pg. 4-5, para. 4-44).

Table 1. Design aircraft gross weight for use in expedient runway design (modified from FM 5-430-00-2 [1994]).

Design Aircraft	Gross Weight (kips)
C-130	130
C-17	447

2.4 Determine the in-place soil strength

TM 3-34.48-2 (2016, pg. 4-8, para. 4-29) describes determining soil strength as “significant” in the process of expedient runway design. Ironically, this step represents a limitation with the current state-of-the-art for remote sensing of soil strength and, thus, a limitation of ENSITE/TASS capabilities. That is to say, there is no current technology that can remotely obtain the shear strength of soil. ENSITE/TASS, however, has a geographic database of Unified Soil Classification System (USCS) soil types (Table 2) that can be used to obtain an approximation of shear strength of soil in terms of California Bearing Ratio (CBR), the engineering parameter used ENSITE/TASS for pavement thickness design. This correlation of values is presented in Table 3.

In addition to estimating shear strength, ENSITE/TASS methodology assumes that the soil’s shear strength is uniform to a depth of 24 in., which is the depth required for analysis.

Table 2. Unified Soil Classification System (modified from ETL 97-9 1997, Atch. 1, pg. 44, para. A.1).

Major Divisions			Symbol
Coarse-grained Soils More than half of material is larger than than No. 200 Sieve	Gravels More than half of coarse fraction is larger than No. 4 sieve	Gravels <5% Fines	GW
			GP
		Gravels >12% Fines	GM
			GC
	Sands More than half of coarse fraction is smaller than No. 4 sieve	Sands >5% Fines	SW
			SP
		Sands <12% Fines	SM
			SC
Fine-grained Soils More than half of material is smaller than No. 200 sieve	Silts and Clays LL <50		ML
			CL
			OL
	Silts and Clays LL >50		MH
			CH
			OH
Highly Organic Soils			Pt

Table 3. Estimated CBR values for USCS classified soils
(modified after ARA, Inc.-ERES Division 2001, pg. CC 1-10, Table 5).

USCS Symbol	Estimated CBR
GW	64
GP	53
GM	52
GC	19
SW	36
SP	28
SM	39
SC	16
ML	11
CL	8
MH	5
CH	3

2.4.1 Discussion on the relationship between USCS soil type and CBR

When estimating CBR based on USCS soil type, TM 3-34.48-2 (2016, pg. 4-66, para. 4-233) recommends using the lowest value given by Table B-4 in TM 3-34.43 (2015, pg. B-20), which is presented below as Table 4. Using the lowest value will give a conservative estimate of CBR. The issue, however, is that the estimate may be overly conservative and may preclude potentially viable airfield orientations during the planning process, based on nothing other than the desire to be conservative. Thus, the values presented in Table 2 are provided to give a reasonable estimate based on empirical work.

In addition to Table 4 being presented as Table B-4 in TM 3-34.43 (2015, pg. B-20), it is also available as Table 5-3 in TM 3-34.64 (2012, pg. 5-13).

Table 4. Characteristics of soil groups pertaining to roads and airfields
(modified from TM 3-34.43 [2015]).

Value As Base When not Subject to Frost Action (9)	Potential Frost Action (10)	Compressibility and Expansion (11)	Drainage Characteristics (12)	Compaction Equipment (13)	Dry Unit Weight (pcf) (14)	Typical Design Values	
						CBR (15)	Subgrade Modulus k (lb per cu in) (16)
Good	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	125 -140	40 - 80	300 - 500
Fair to Good	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	110 -140	30 - 60	300 - 500
Fair to Good	Slight to medium	Very slight	Fair to poor	Rubber-tired roller, sheepfoot roller; close control of moisture	125 -145	40 - 60	300 - 500
Poor to not suitable	Slight to medium	Slight	Poor to practi- cally impervious	Rubber-tired roller, sheepfoot roller	115 -135	20 - 30	200 - 500
Poor to not suitable	Slight to medium	Slight	Poor to practi- cally impervious	Rubber-tired roller, sheepfoot roller	130 -145	20 - 40	200 - 500
Poor	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	110 -130	20 - 40	200 - 400
Poor to not suitable	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	105 -135	10 - 40	150 - 400
Poor	Slight to high	Very slight	Fair to poor	Rubber-tired roller, sheepfoot roller; close control of moisture	120 -135	15 - 40	150 - 400
Not suitable	Slight to high	Slight to medium	Poor to practi- cally impervious	Rubber-tired roller, sheepfoot roller	100 -130	10 - 20	100 - 300
Not suitable	Slight to high	Slight to medium	Poor to practi- cally impervious	Rubber-tired roller, sheepfoot roller	100 -135	5 - 20	100 - 300
Not suitable	Medium to very high	Slight to medium	Fair to poor	Rubber-tired roller, sheepfoot roller; close control of moisture	90 -130	15 or less	100 - 200
Not suitable	Medium to high	Medium	Practically impervious	Rubber-tired roller, sheepfoot roller	90 -130	15 or less	50 - 150
Not suitable	Medium to high	Medium to high	Poor	Rubber-tired roller, sheepfoot roller	90 -105	5 or less	50 - 100
Not suitable	Medium to very high	High	Fair to poor	Rubber-tired roller, sheepfoot roller	80 -105	10 or less	50 - 100
Not suitable	Medium	High	Practically impervious	Rubber-tired roller, sheepfoot roller	90 -115	15 or less	50 - 150
Not suitable	Medium	High	Practically impervious	Rubber-tired roller, sheepfoot roller	80 -110	5 or less	25 - 100
Not suitable	Slight	Very high	Fair to poor	Compaction not practical	-	-	-

2.5 Determine the required number of passes

The required number of passes² is determined from mission requirements. For expedient runways without a parallel taxiway, which is often the case, the required passes should be multiplied by 2 to account for aircraft using the runway for taxiing operations (TM 3-34.48-2 2016, pg. 4-6, para. 4-24). The number of required passes is used as a metric of whether a potential runway can sustain the mission's need for aircraft operations. That is, the required passes are checked against the allowable number of passes to determine suitability.

2.6 Determine the allowable number of passes and surface type

The allowable number of passes is determined by using the data shown in Figure 1, producing a graph of allowable passes by aircraft type.

² A pass herein is defined as one takeoff and one landing.

Figure 1. Plot correlating passes and CBR
(modified from TM 3-34.48-2 [2016]), pg. 4-7, para. 4-29).

If the *required* number of passes exceeds the *allowable* number of passes, then geosynthetics (i.e., matting) or soil stabilization methods will be required to strengthen the expedient runway's surface. At the time of this writing, runway design that requires soil modification via geosynthetics or stabilization is not included in ENSITE/TASS. It should be noted that geosynthetics were left out of this writing because they represent a level of effort and training that is outside the intended use of ENSITE/TASS as well as outside the capability of the typical military engineering unit.

2.7 Determine the runway length and width

What is commonly referred to collectively as a "runway" is actually composed of a number of different areas or zones (e.g., runway, shoulders, and overrun). When considering the length and width of a runway, the so-called "imaginary surfaces" (e.g., primary surface, approach-departure surface, inner horizontal surface) that are associated with airfields should also be considered. These surfaces represent boundaries in the airspace surrounding the airfield that must be clear of obstructions to aircraft (refer to Figure 4–Figure 6).

Expedient runways, however, have different imaginary surfaces than other types of runways. These imaginary surfaces are discussed in subsection 2.7.2. Runway design in ENSITE/TASS is focused on C-130s and C-17s in the decisive and support areas within the theater of operations.

Runway length, which is generally referred to as “takeoff ground run” (TGR) and runway width are based on designed charts for specific aircraft and airfield types. Runway length is determined by adjusting the minimum TGR for pressure altitude, temperature, and effective gradient as well as applying a safety factor. It should be noted that, once TGR length is determined, that length is augmented with overruns and a number of imaginary surfaces which then extends the total length of the runway. ENSITE/TASS calculates TGR by using the following procedure quoted from TM 3-34.48-2 (2016), pg. 2-10, para. 2-2:

1. Determine the standard TGR for an aircraft from Table 2 in ETL 09-6 (2009, Atch. 2, pg. 4).
2. Correct for pressure altitude. Add the pressure altitude of the site, which can be obtained from Figure 2, to the geographic altitude. Increase TGR by 10% for each 1,000 ft increase in altitude above 1,000 ft. No reduction in TGR is permitted if the pressure altitude is less than 1,000 ft.
3. Correct for temperature. If the pressure-corrected TGR is equal to or greater than 5,000 ft, increase the pressure-corrected TGR by 7% for each 10°F increase in temperature above 59°F (from [Figure 3]). If the pressure-corrected TGR is less than 5,000 ft, increase the pressure-corrected TGR by 4% for each 10°F increase above 59°F. Never decrease the runway length if the temperature is less than 59°F.
4. Adjust for safety. Multiply the temperature corrected TGR by 1.5 for sustaining area airfields and by 1.25 for support and decisive area airfields.
5. Correct for effective gradient. Increase the safety-corrected TGR by 8% for each 1% increase of effective gradient over 2%. No reduction in TGR is permitted if the effective gradient is flatter than 2%.
6. Round off the gradient-corrected TGR to the next higher 100 ft.
7. Compare the computed value of the TGR with the minimum require runway length. Use the higher of the two values.

For planning and computational purposes, the effective gradient in TASS is assumed to be 3, which is the maximum gradient of a expedient runway in the decisive area.

Runway width is primarily determined by (1) the safety of operating aircraft in conditions of reduced visibility and (2) the lateral stability and control of the aircraft during final approach and landing (TM 3-34.48-2 2016, pg. 2-12, para. 2-30). The airfield type (i.e., decisive area, support area) is a secondary consideration. For a runway located in the decisive or support areas, the runway width is 90 ft for a C-17 and 60 ft for a C-130, plus an additional 10 ft on either side, making the total widths 110 or 80 ft, respectively (ETL 09-6 2009, Atch. 2, pg. 4, Table 2).

2.7.1 Runway length design example.

- Problem: Consider a C-17 operating near Champaign, IL.
- Assumptions:
 - Effective gradient, i_e , = 0.015
 - Geographic altitude, H , = 764 ft
 - Runway is in the decisive area
- Find: Required takeoff ground run (TGR; i.e., runway length)
- Solution:
 - The standard TGR for a C-17 was obtained from Table 2 in (ETL 09-6 2009, Atch. 2, pg. 2-2) and is 3,500 ft.
 - The pressure altitude, dH , was obtained from Figure 2 (page 13) and is approximately 350 ft. Adding the geographic altitude and the pressure altitude gives the following computations:

$$H_t = H + dH$$

$$H_t = 764 \text{ ft} + 350 \text{ ft}$$

$$H_t = 1114 \text{ ft}$$

The procedure for correcting TGR for pressure altitude is to increase the TGR by 10% for each 1,000 ft increase above 1,000 ft. The difference between the reference altitude and the total altitude is 114 ft (i.e., 1,114 ft – 1,000 ft = 114 ft). This is less than the 100 ft threshold, so no correction is warranted for pressure altitude in this example.

The maximum average temperature was obtained from Figure 3 (page 14) and is approximately 85°F. The difference between the reference average maximum temperature and the geographic average maximum temperature is 26°F (i.e., 85°F – 59°F = 26°F). This temperature is above the 10°F threshold. Considering that the pressure-corrected TGR is less than 5,000 ft, the TGR will then be increased by 8% (i.e., 4% for every 10°F above 59°F for pressure-corrected TGRs less than 5,000 ft). The TGR is now calculated as follows:

$$TGR = 3500 \text{ ft} * 1.08$$

$$TGR = 3780 \text{ ft}$$

Since the runway is in the decisive area, the safety factor is 1.25. The TGR is now calculated as follows:

$$TGR = 3780 \text{ ft} * 1.25$$

$$TGR = 4725 \text{ ft}$$

The difference between the reference effective gradient and the assumed effective gradient is 1% (i.e., 3% - 2% = 1%). The TGR will then be increased by 1%. The TGR is now:

$$TGR = 4725 \text{ ft} * 1.01$$

$$TGR = 4772.25 \text{ ft}$$

which, when rounded up to the next 100 ft, is 4,800 ft. Because this distance is greater than the minimum required, the TGR is thus 4,800 ft.

Figure 2. Isopleths of pressure altitude (from TM 3-34.48-2 [2016], p. 2-11).

ISOPLETHS OF dh (in feet)

- NOTES: 1 The boundaries shown on this chart are approximate and should not be regarded as having official significance.
- 2 Isopleths of dh are lines of equal pressure value. The values of dh in feet shown on this map should be added to the geographic elevation at the airfield site to obtain the pressure altitude.

Figure 3. Isopleths of average maximum temperature
(from TM 3-34.48-2 [2016], p. 2-12).

2.7.2 Determine approach zones and imaginary surfaces

A runway is composed of a number of elements, such as the TGR, overruns, and other imaginary surfaces. Expedient runways do not have the

same elements as runways at established airfields. The elements of expedient runways are described by TM 3-34.48-2 (2016, pg. 2-8) and are presented verbatim below:

1. Accident potential zone-LZ. An accident potential zone-LZ is a land use control area beyond the clear zone of an LZ that possesses a significant potential for accidents; therefore, land use is a concern.
2. Clear zone landing zone (LZ). A clear zone LZ is a surface on the ground or water, beginning at the runway threshold and symmetrical about the extended runway centerline. It is graded to protect aircraft operation in which only properly sited [navigational aids] are allowed.
3. Overruns. An overrun is an area that is the width of the runway, plus prepared shoulders, extending 300 feet from the end of the runway into the clear zone. This portion is a prolongation of the runway and is constructed to support aircraft traffic.
4. Primary surface. A primary surface is an imaginary surface that is symmetrically centered on the runway. The elevation of any point on the primary surface is the same as the elevation of the nearest point of beginning for the runway and airspace imaginary surfaces will be determined.
5. Approach-departure clearance surfaces. An approach-departure clearance surface is an imaginary surface that is an inclined plane or combined inclined and horizontal planes arranged symmetrically about the extended runway centerline. Objects that penetrate this surface are considered obstructions to air navigation and should be removed if possible. If they are not removed, they must be mapped, marked, and lighted as obstructions. The first segment or the beginning of the inclined plane coincides with the ends and edges of the primary surface and the elevation of the centerline at the runway end. This surface flares outward and upward from these points.

These zones increase the space requirements of a runway and are presented in Figure 4–Figure 6 below.

Figure 4. Runway end detail in plan view (from ETL 09-6 [2009], Atch. 1, pg. 1).

Figure 5. Runway end detail in profile view (from ETL 09-6 [2009], Atch. 1, pg. 1).

Figure 6. Runway end details in plan view showing the accident-potential zone (from ETL 09-6 [2009], Atch. 1, pg. 2).

2.7.3 Turnarounds

It is likely that an expedient runway will *not* have taxiways, as does a more permanent airfield. Thus, turnarounds must be constructed at both ends of the runway (ETL 09-6 2009, pg. 11, para. 8.1.5). These turnarounds must be sized for the design aircraft. Turnarounds for the C-17 should be 180 x 165 ft with 45° fillets and, for the C-130, a turnaround needs to be 75 ft in diameter (Figure 7; (ETL 09-6 2009, Atch. 2, pg. 4).

Figure 7. Schematic diagram of a turnaround (after ETL 09-6 [2009], Atch. 1, pg. 3).

2.8 Determine the runway orientation

Runways are oriented with consideration to the prevailing winds in the area (TM 3-34.48-2 2016, pg. 2-15, para. 2-50). Under ideal conditions, a minimum of 10 years of data is used to determine wind direction, velocity, and frequency of occurrence. Using this 10 years of data, the runway would be oriented such that there is 80% wind coverage and a maximum beam wind of 13 mph (TM 3-34.48-2 2016, pg. 2-15, para. 2-51).

Since ENSITE/TASS is a remote planning intended for use in tactical environments, it does contain limited wind data (e.g., wind speed for engineering design), though it does not contain wind data at every level of detail. To work around this limitation, the runway orientation in ENSITE/TASS is controlled by the 13 mph beam wind and determined by using the wind vector. Further discussion and an example are given in subsections 2.8.1 and 2.8.2.

The criteria for orienting the runway given in the preceding paragraphs (i.e., 80% wind coverage and 13 mph beam wind) are related to the operating capacity of an aircraft and its pilot. In addition to operating capacity,

the direction of the prevailing winds is also considered because of hazards created by dust (TM 3-34.48-2 2016, pg. 2-15, para. 2-51). If dusty conditions pose a hazard to safe operation on the runway, the runway may be oriented 10° off the prevailing wind so that dust will be blown away from the runway (TM 3-34.48-2 2016, pg. 2-15, para. 2-51). TASS does not account for dust hazards when suggesting a runway orientation, however, since that type of information can only reasonably be ascertained by on-site personnel.

2.8.1 Discussion and further guidance on the 13 mph beam wind criterion

The 13 mph beam wind criteria is given in TM 3-34.48 (2016, pg. 2-15, para. 2-51) without citation. That is to say, the origin of this wind criterion is unclear. Without a clear understanding of the criterion's intent, it can be difficult for ENSITE/TASS users to determine the optimal expedient runway orientation. Thus, a brief discussion on this criteria is presented here, in case ENSITE/TASS users require more flexibility when siting an expedient runway.

It should first be noted that expedient runway orientations outside those suggested by ENSITE/TASS may still be feasible options. Indeed, (TM 3-34.48-2 2016, pg. 2-15, para. 2-51) states, with regard to the 80% wind coverage and 13 mph beam wind criteria, "[these requirements] should not cause rejection of a site that is otherwise favorable." Conversely, a discussion with the Air Force Civil Engineer Center (AFCEC) Pavements Engineer revealed that the runway orientation should stay within the given criteria "to the maximum extent possible"³. Ultimately, if a runway must be oriented such that it does not meet the given criteria, the runway orientation should be done for reasons of military necessity and in collaboration with an aviation subject matter expert.

2.8.2 Runway orientation example

Problem: Consider an 18 mph wind coming from 020° (Figure 8).

³ Phone conversation by author Gamez with Craig Rutland of AFCEC in February 2018.

Figure 8. Wind vector example (ERDC-CERL).

Find: Determine the maximum angle from the wind that a expedient runway can be oriented.

Solution: The maximum angle from the wind that a expedient runway can oriented can be found by considering the 13 mph beam wind. In other words, the maximum wind perpendicular to the runway should not exceed 13 mph. To determine the angle at which this occurs, break down the wind vector into its components (Figure 9). The angle θ^4 gives the maximum angle from the wind that a runway should be oriented.

Figure 9. Wind vector components (ERDC-CERL).

⁴ A plane angle in geometry; an unknown variable in trigonometry.

The value of θ can be obtained in a number of ways. In this example, it is found by using the trigonometric equation sequence below:

$$\sin \theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\sin \theta = \frac{13 \text{ mph}}{18 \text{ mph}}$$

$$\theta = \sin^{-1}\left(\frac{13 \text{ mph}}{18 \text{ mph}}\right)$$

$$\theta = 46.2^\circ \approx 46^\circ$$

Given that $\theta = 46^\circ$, the runway can be oriented up to 46° off the direction of the predominant wind (Figure 10). Therefore the runway can be oriented 46° either clockwise or counterclockwise from the direction of the wind (i.e., 066° or 334° in this example).

Figure 10. Determination of runway orientation (ERDC-CERL).

2.8.3 True north vs. magnetic north

It should be noted that wind direction is given with regard to the true north (TM 3-34.48-2 2016, pg. 2-23, para. 2-64). Runway directional numbers, however, are given with regard to magnetic north. Thus, ENSITE/TASS users must ensure that runway directional numbers are correctly assigned during the appropriate part of the design process.

2.9 Design components excluded from consideration

By their nature, expedient airfields are short-term, quickly designed facilities without an expected long-term operational life span. Because of this, several design components associated with more permanent airfield installations are excluded. Additionally, ENSITE/TASS is a remote planning tool, and several design components require on-site survey data that is not remotely available; components needing such data were also omitted. A list of omitted design components and their related references are presented below in Table 5.

Table 5. Airfield design components eliminated from consideration in TASS.

Number	Component	Reference
6	Outline corrective actions to increase service list as necessary.	TM 3-34.48-2 (2016, pg. 4-7, para. 4-29)
10	Design vertical slopes.	TM 3-34.48-2 (2016, para. 2-65)
11	Design transverse slopes.	TM 3-34.48-2 (2016, para. 2-71).
12	Design taxiways and aprons.	TM 3-34.48-2 (2016, pg. 2-28, paras. 2-76 and 2-81)
13	Design required drainage structures.	TM 3-34.48-2 (2016, pg. 4-44, para. 4-107)
14	Select visual and nonvisual aids to navigation.	TM 3-34.48-2 (2016, pg. 3-1, para. 3-5)
15	Design logistical support facilities.	TM 3-34.48-2 (2016, pg. 2-9, para. 2-24)
16	Design aircraft protection facilities.	TM 3-34.48-2 (2016, pg. 2-9, para. 2-24)

3 Summary

In summary, this document provides the technical data required to code and implement the TASS module for the ENSITE tool. Requirements are focused around the 8 (of 16 total) design components outlined in TM 3-34.48-2 (2016) that relate to expeditious aircraft.

Not all criteria apply because expeditious design criteria differ from more permanent airfield design criteria by focusing solely on the runway and not on any supporting infrastructure or surfaces. Additionally, because ENSITE/TASS is a remote planning tool, it does not support some data that require data from a non-remote field survey. For these reasons, this document provides technical guidance for only 8 of the 16 design components, as outlined section 2.1.

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