Chapter 3 -

Airfield Geometry

INTRODUCTION

Improving airfield safety is a key goal of the Federal Aviation Administration (FAA) and this ALP update. Four areas on the airfield have been classified as Hot Spots by the FAA and several taxiway segments do meet current FAA design standards. This section will evaluate design alternatives with the potential to eliminate the Hot Spots and bring all taxiways into compliance with design standards. When evaluating alternatives, potential environmental impacts, implementation complexity, and project costs will be considered.

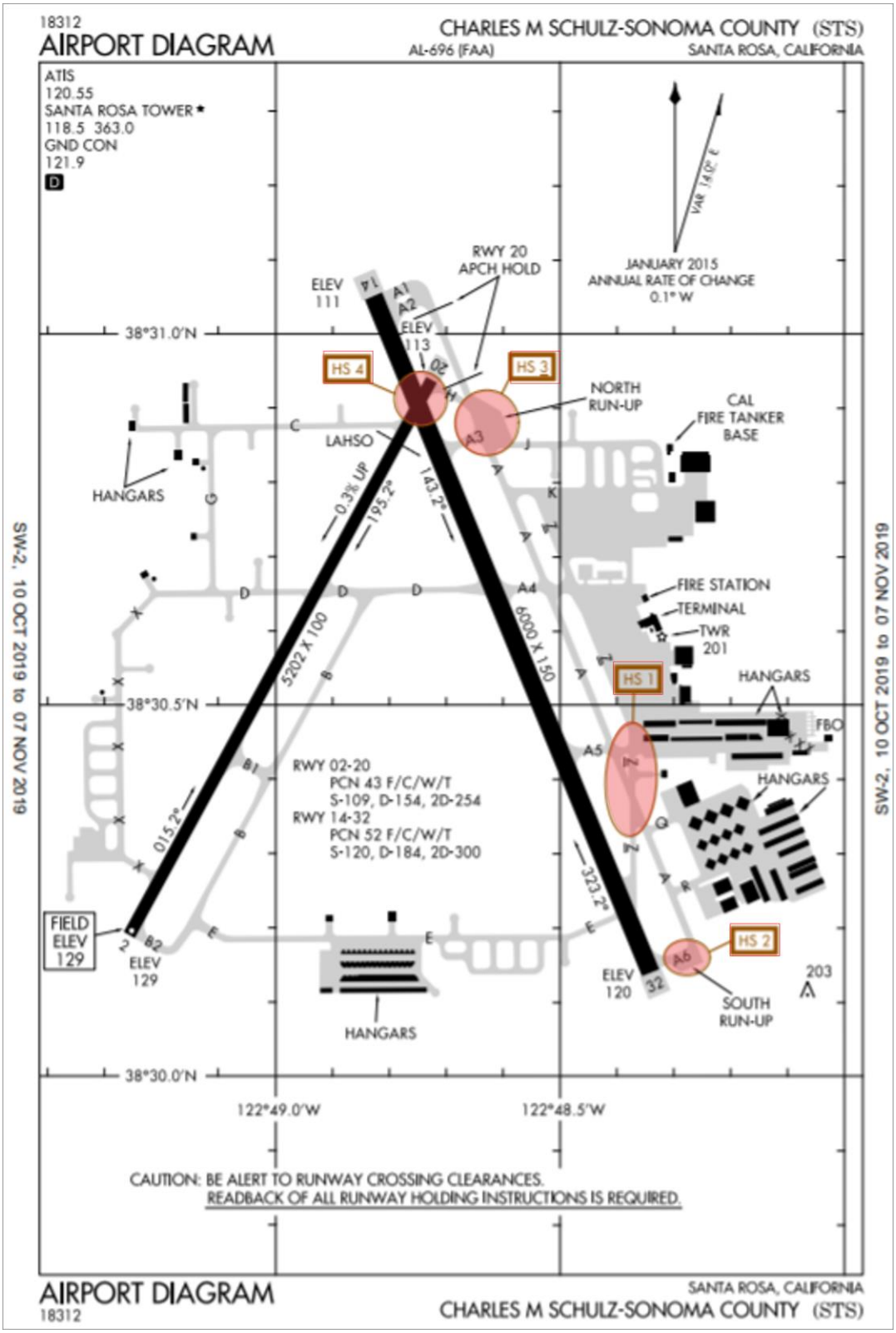
A Hot Spot is a location in an airport movement area with a history of potential risk of collision or runway incursion, and where heightened attention by pilots and drivers is necessary. The FAA designates hot spots, and these are published in the Airports Facility Directory for STS. The four hot spots are illustrated in **Figure 3-1.** The hot spots identified by the FAA are:

- **Hot Spot 1:** Complex intersection in close proximity to Runway 14/32. Aircraft approaching Taxiway A from the Apron C, Apron D, or Taxiway Z sometimes fail to turn onto Taxiway A and instead enter Runway 14/32 without approval.
- **Hot Spot 2:** Run-up apron at Taxiway A6 is not visible from the air traffic control tower (ATCT).
- **Hot Spot 3:** Run-up area east of Taxiway A and Taxiway H intersection in close proximity of Runway 20 approach. The hold area causes pilot confusion.
- **Hot Spot 4:** Wrong runway departure risk. Pilots cleared for takeoff on Runway 20 sometimes turn onto and depart Runway 14. Verify heading and alignment with proper runway prior to departure.

The sections that follow include: Runway 20 incursion mitigation, Taxiway A modification of standard, and taxiway geometry. Goals of this chapter are to:

- Offer solutions to correct and mitigate hot spots.
- Correct taxiway geometry to meet 13A standards.
- Increase situational awareness and operational safety.

Figure 3-1: Airports Facility Directory Hot Spots



Source: Airports Facility Directory, Oct 10 – November 7, 2019

RUNWAY 20 INCURSION MITIGATION

Runway incursions are incidents where people, aircraft, or vehicles end up at risk of collision due to being in a place they do not belong, particularly in the path of aircraft that are landing or taking off. Factors such as unclear signage or markings or the layout of the runways or taxiways can contribute to runway incursions. The FAA has established the Runway Incursion Mitigation (RIM) Program with the intent to address and reduce (or eliminate) risks at airports where particular locations on an airfield have a documented history of incursions.

Background

In 2014 STS extended Runways 14 and 20 as part of the project to provide standard Runway Safety Areas (RSAs). A second goal of the project was to eliminate runway incursions caused by the airport's two runways overlapping at their apex (see **Figure 3-2**). In its March 24, 2010, *Runway Safety Action Plan*, the FAA's Runway Safety Action Team (RSAT) identified "elevated risk for wrong runway departures due to co-located runway thresholds." The RSAT recommended that "STS pursue and implement alternative runway configuration(s)

projects with the FAA Airports District Office (ADO) Program Manager and Engineering to eliminate the present condition of co-located Runway 14/32 and Runway 1/19 [now called Runway 2/20] thresholds."

Alternative runway-taxiway configurations to clarify the runway ends were evaluated as part of an update of STS's 2012 Airport Master Plan. Runway alternatives included extending Runway 14/32 to various lengths and both extending and shortening Runway 2/20. The configuration that is in place today was selected because it:

- Provided distinct runway end markings for both Runway 14 and 19 [20].
- Provided standard RSAs.
- Minimized environmental impacts by not requiring relocation of creeks in the approach to Runway 19 [20].

The Runway 20 threshold was relocated to the northeast of Runway 14/32 along with relocation of Taxiway H. This action decoupled the runway ends with the intention of reducing the possibility that aircraft may depart on the wrong runway. **Figure 3-3** illustrates the existing configuration.

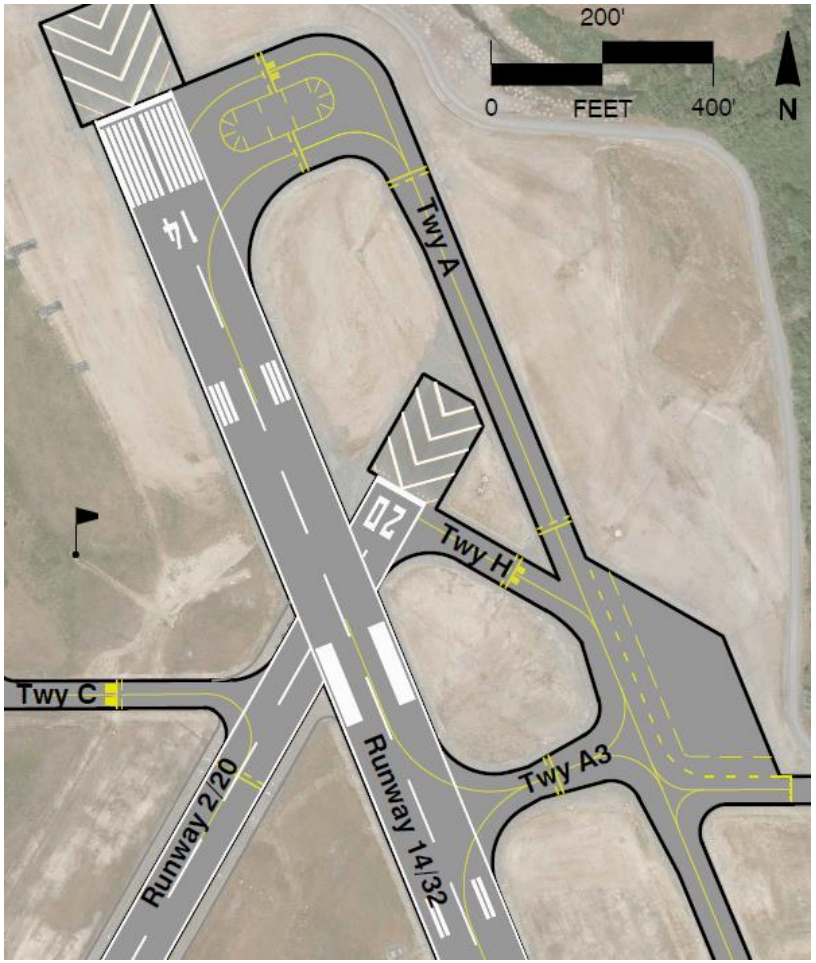
Concerns were expressed at the time by staff from STS, the FAA, and STS's consultant team over the configuration of Taxiways A and H near the end of Runway 20. However, it was believed that signing, marking, and air traffic control procedures would overcome potential problems.

Although the runway-taxiway reconfiguration improved the situation, it did not eliminate all incursions. Documented runway incursions have occurred near the approach end of Runway 20. Some non-local (itinerant) pilots are experiencing confusion related to operational traffic patterns, which has led to incursions. Because of these concerns, STS was included in the Preliminary Inventory of Airport Locations under the FAA's national initiative known as RIM. The RIM program identifies airport risk factors that might contribute to a runway incursion and recommends or develops strategies to help airport sponsors mitigate those risks.

Figure 3-2: Runway 14 & 19 Approach Ends, March 2013

Source: Google Earth, March 2013

Figure 3-3: Runway 20 – Taxiway H Existing Conditions



Source: Mead & Hunt

At STS, the RIM inventory indicates that runway incursions involving the approach end of Runway 20 and Taxiways A, A3, and H have occurred. STS and ATCT staff have been actively evaluating and implementing modifications to airfield markings and signage to reduce the potential for incursions. This Airport Layout Plan (ALP) update evaluates configuration changes to this section of the airfield, along with other measures, with the intention of reducing the potential for runway incursions or departures on an unintended runway.

Runway Incursions

ATCT staff indicated that incursions on Taxiway H – Runway 20 – Runway 14 departures are being made by itinerant pilots unfamiliar with the STS layout. Local pilots familiar with STS and commercial pilots who regularly use the airfield are not committing the incursions.

Although specific incursion incidents during Runway 20 departures vary in detail, they follow a common pattern. Aircraft intending to depart on Runway 20 continue a turn from Taxiway H across Runway 20 onto Runway 14. The prescribed route for departures on Runway 20 for aircraft to follow is: Taxi from the Taxiway H hold bars onto Runway 20, line up on the runway's centerline, and then depart. Incursions are happening when aircraft follow the prescribed route but make a left turn greater than 90 degrees onto Runway 14. **Figure 3-4** illustrates the preferred route in green and the incursion route in red. This area is identified by the FAA as Hot Spot #4.

Pavement geometry and topography may be contributing to the lack of situational awareness:

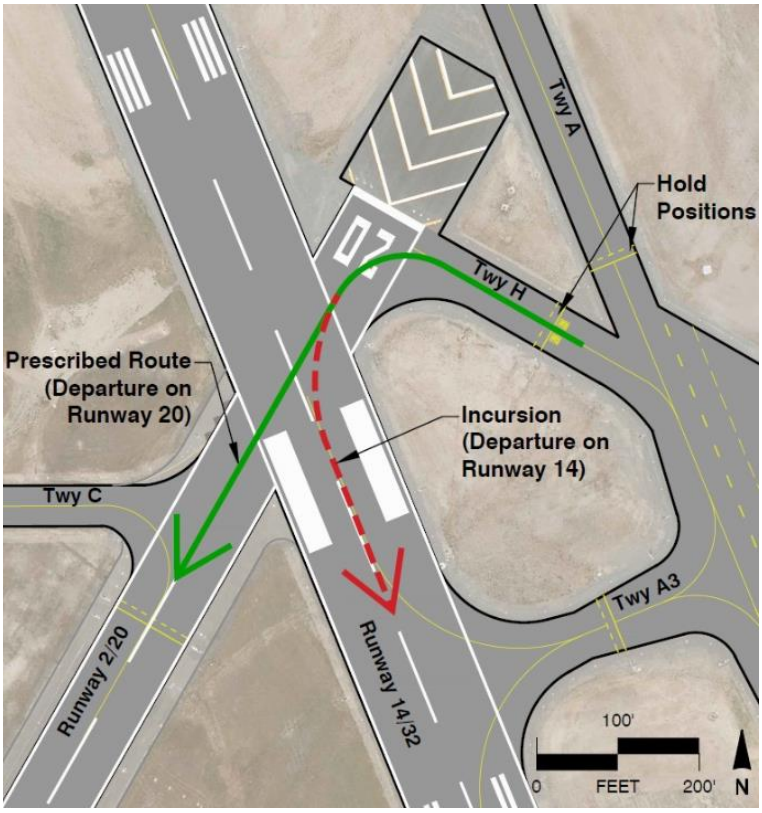
- Expanse of pavement with Taxiway A, A3, H and the runway intersection being interconnected.
- Location of the '20' designation on a short stub of runway pavement.
- The crown of Runway 14/32 making it harder to see Runway 2/20.

STS and the FAA have worked together for the past couple of years to mitigate incursions at Taxiway H – Runway 20 – Runway 14 and have implemented several measures:

- Painting a standard curved lead-in taxiway centerline from the hold bars at Taxiway H to Runway 20.
- Repainting the lead-in taxiway centerline from a curved turn to a straight line. This is a non-standard marking that the FAA Airports District Office (ADO) approved.
- Addition of the intersection to the Aviation Data Integration System (ADIS).
- Creation of an informational bulletin illustrating the wrong-runway departure issue. This bulletin was printed and made available at fixed base operators. It is also posted on the Airport's website in the section dedicated to pilots. Airport staff intend to periodically reprint and distribute copies of this bulletin.

Even with these measures in place, the ATCT documented an incursion in April 2019. Through increased vigilance, ATCT staff have observed and stopped potential incursions before aircraft take-off on the wrong runway.

Figure 3-4: Runway 20 – Taxiway H Incursion Diagram



Source: Mead & Hunt

Objectives and Organization

This study evaluates alternatives that reconfigure the pavement geometry, add or alter marking and signing, and modify operational practices. The goal of this study is to define modifications that reduce the potential for runway incursions, either through improving the pavement geometry, increasing situation awareness, or a combination of the two. The ultimate goal will be for the FAA designated Hot Spots #3 and #4 to be eliminated from the STS Airports Facility Directory.

One possibility may be enhancing pavement geometry by reducing ambiguity in intersections and providing better context for pilots. A possibility to improve pilot situational awareness may be through markings or signage to help identify Runway 20 versus Runway 14/32 and Taxiway H. It is important for STS to maintain Runway 2/20 for operations by commercial aircraft when weather conditions dictate or when Runway 14/32 is non-operational from construction or unforeseen events.

Alternatives will be evaluated based on their likelihood to reduce incursions, the time required for implementation, their possible environmental impacts, and estimated cost. A short-list of potentially useful measures will then be arranged in the order that they should be implemented, with priority given to measures that can be implemented quickly. Should the quickest measures prove effective, there would be no reason to implement more complex and costly measures. Should the quickest measures not prove effective, more complex measures would be implemented. Ultimately, measures that would change airfield geometry, signs, or markings will need to be approved by the FAA and added to the ALP for future design and construction.

The Runway 20 Incursion Mitigation is separated into two sections: permanent geometry design and interim modification of standards (MOS). The permanent geometry looks at solutions that will correct taxiway and runway geometry at the Runway 20 approach through construction and realigning pavement where needed. The interim MOS studies potential sign and marking additions to the Runway 20-Taxiway A-H area that may help limit incursions prior to implementation of the preferred permanent geometry design.

Permanent Geometry Design

- **Alternative 1 Group:** Extend or realign Runway 20 threshold to the northeast of the runway intersection.
- **Alternative 2:** Displace Runway 20 threshold to the southwest of Runway 14/32 intersection.
- **Alternative 3:** Shorten Runway 2/20 to decouple runways.

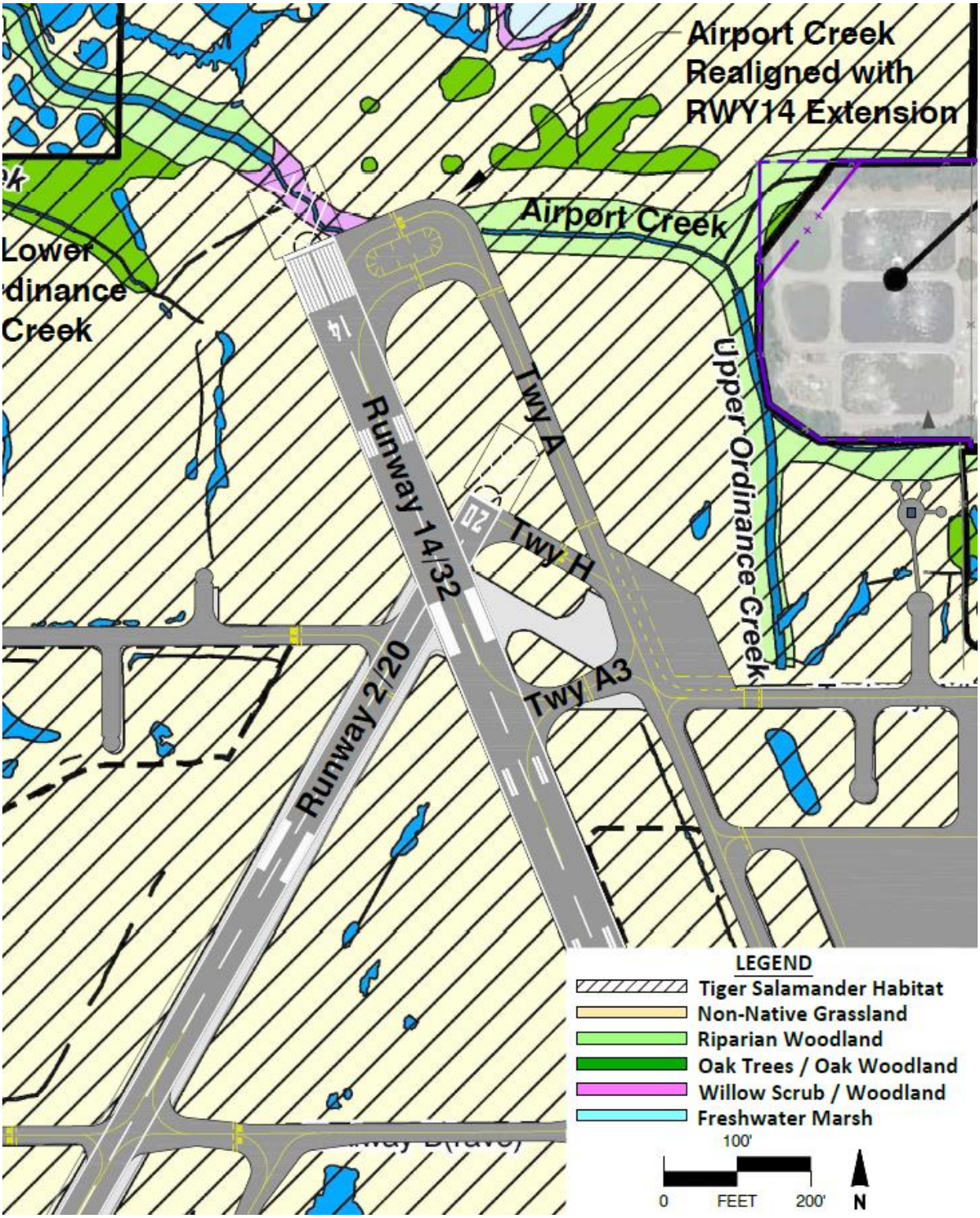
Interim Modification of Standards

- **Alternative 4 Group:** Add non-standard runway or taxiway markings or signs on TW H - RW 20.
- **Alternative 5 Group:** Add non-standard runway or taxiway markings or signs on Taxiway A.

Environmental Constraints

Several environmental factors constrain alternatives that call for construction beyond existing pavement. The unpaved areas in the vicinity of the approach end of Runway 20 are suitable habitat for the California Tiger Salamander. This salamander is designated as Federal *endangered* and State *threatened*. Other protected animal and plant species have been identified on the Airport (e.g., Burke's Goldfields). However, none are known to exist in the area northeast of the approach end of Runway 20. About 500 feet northeast of Taxiway A along the extended centerline of Runway 2/20 is Upper Ordnance Creek. Two tributary creeks, Redwood Creek and Airport Creek, join Upper Ordinance Creek nearby. These creeks have been formally delineated as *waters of the US* under the Clean Water Act. Areas adjacent to the creeks are classified as riparian, which has statutory protections through their contribution to the creeks' biological vitality. **Figure 3-5** shows the location of these biological features relative to the end of Runway 20.

Figure 3-5: California Tiger Salamander Habitat



Source: LSA, STS Biological Resources Report, Figure 13.
Current airport base map with Runway 14/32 extension shown. Environmental map shows previous Airport Creek configuration prior to Runway 14/32 extension.

Cost Considerations

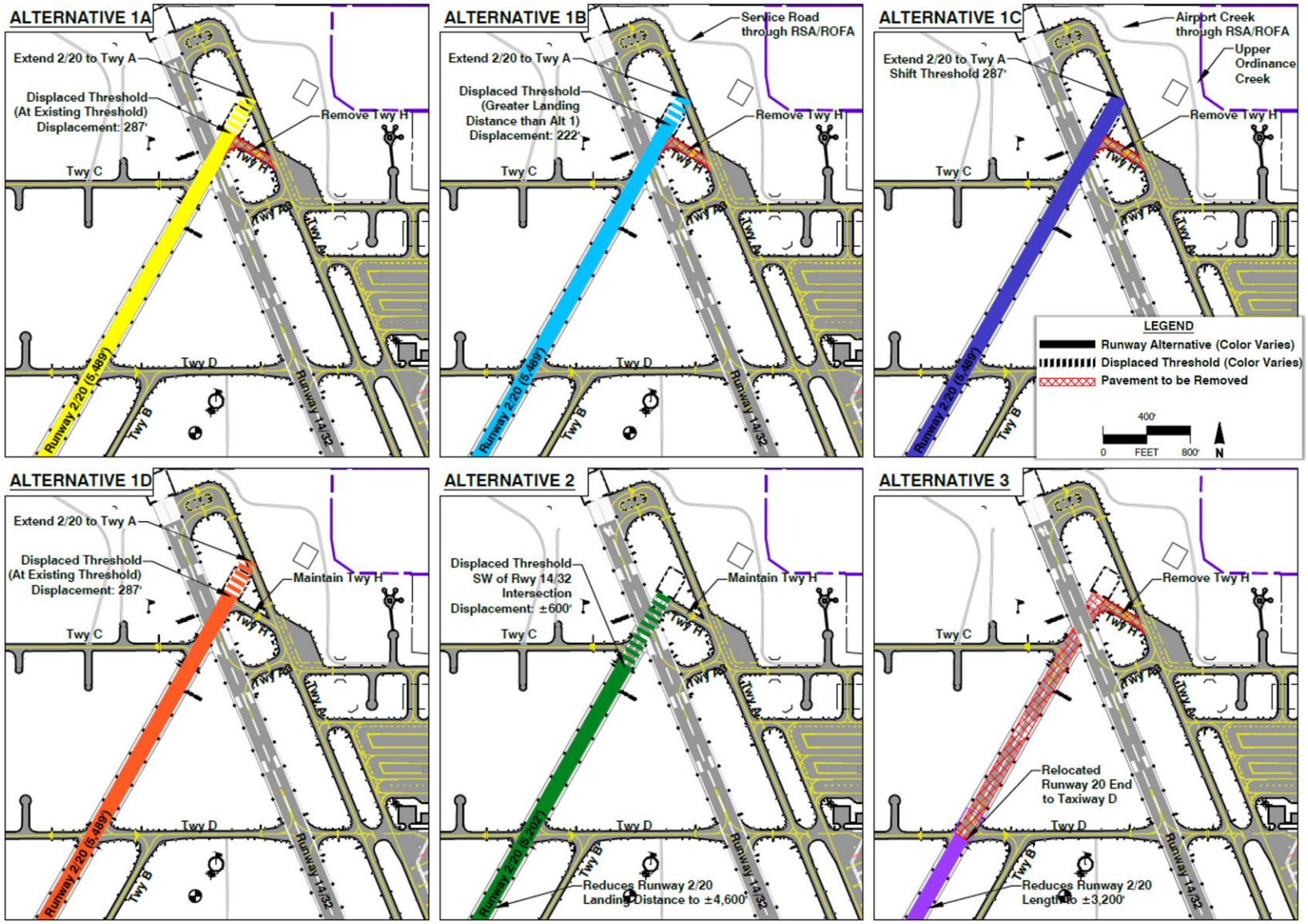
The cost estimates contained in this document enable comparison of alternatives and are order-of-magnitude only. The estimates include the major components of design, construction, environmental processing, and mitigation. The level of precision of these cost estimates make them unsuitable to use for capital improvement planning or grant preparation. More detailed cost estimates will need to be prepared for any alternative being considered for implementation.

RIM PRELIMINARY ALTERNATIVES – PERMANENT GEOMETRY DESIGN

Six preliminary alternatives for permanent geometry design were presented for initial consideration. A short description of the geometry for each alternative is presented below, with thumbnail sketches in **Figure 3-6**. The primary components for each alternative can be summarized as follows:

- Options that STS and Mead & Hunt developed together
- Ideas that the FAA presented during a preliminary RIM meeting conference call (April 16, 2019)
- Alternatives presented during preparation of the Environmental Assessment (approved 2013) and Environmental Impact Report (approved 2012) for the Airport Master Plan and associated RSA improvements.

Figure 3-6: Runway 20 RIM – Preliminary Alternatives



Alternative 1A: Extend Runway 2/20 to Taxiway A and Retain the Existing Landing Threshold

This alternative proposes extending Runway 2/20 northeast to Taxiway A, increasing the runway's length by 287 feet to a total of 5,489 feet. The landing threshold for Runway 20 would remain in the current location with a displaced landing threshold of 287 feet and the additional runway pavement would be marked as a displaced threshold. This would permit the additional runway length to be used for takeoffs on Runway 20. Declared distances would be used to retain the current runway length for operations on Runway 2.

Taxiway H would be eliminated. Aircraft departing on Runway 20 would enter Runway 2/20 from Taxiway A. Enhanced hold line markings would be placed on Taxiway A to reinforce the need for pilots to stop if they have not received a clearance to cross Runway 20.

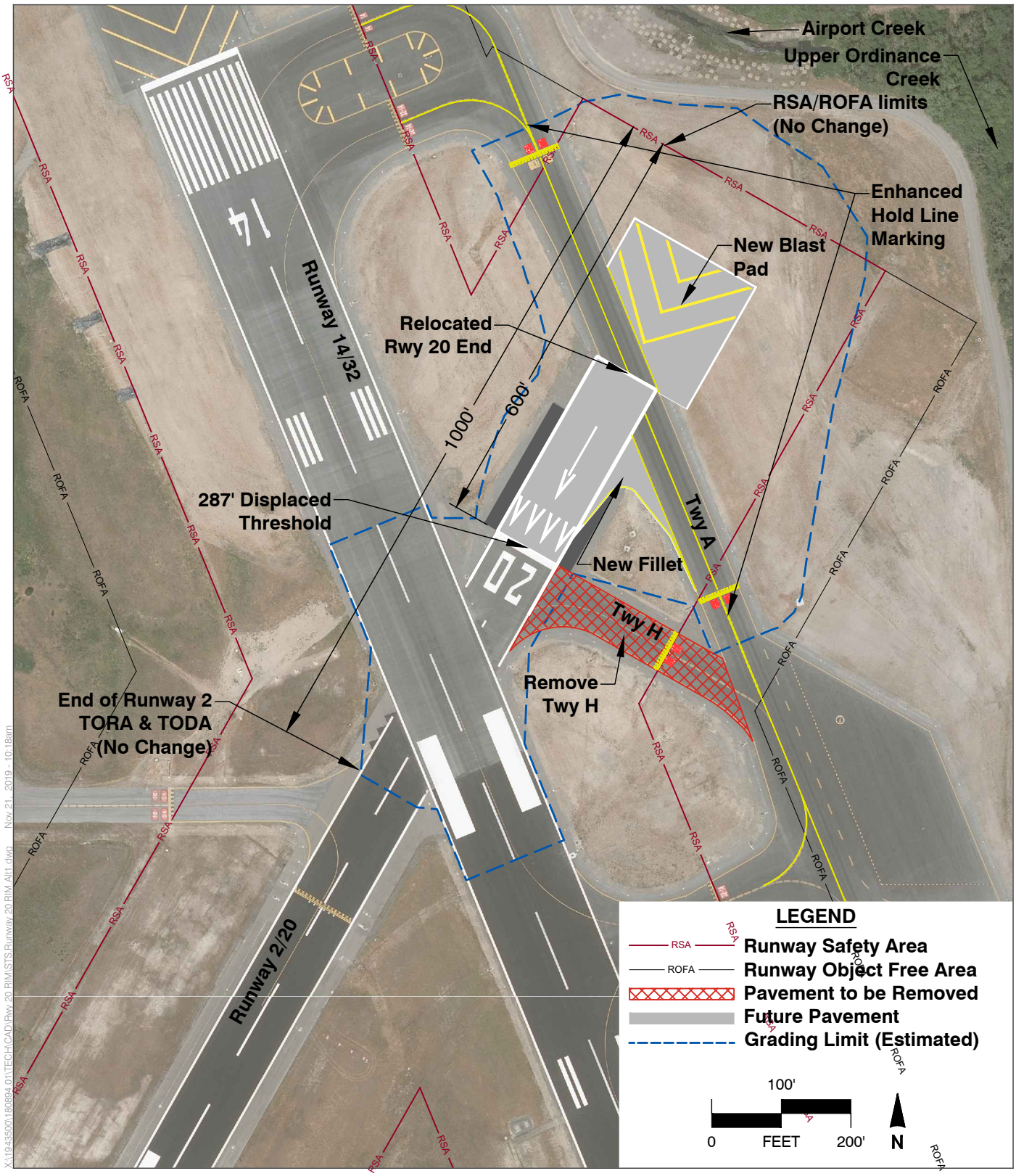
The combination of a displaced threshold for Runway 20 and declared distances on Runway 2 means that the RSA for this runway would not change with this alternative. This eliminates the need to extend the RSA to the northeast into Airport and Upper Ordinance Creeks.

To meet runway centerline gradient requirements, the new end of Runway 20 (and a segment of Taxiway A) would need to be raised about 5 feet. This would require reconstruction of the intersection of the two runways, raising an approximately 850- to 900-foot-long segment of Taxiway A, and regrading to provide the RSA and shoulders with standard gradients.

A preliminary estimate of the cost to design and build this alternative is $5.5 million. Preparation of California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) documents and follow-on permitting would cost an additional $500,000. Total mitigation costs for temporary impacts to California tiger salamander habitat, plus other mitigation measures to address water quality, erosion, emission and air quality would be an additional $115,000. The total estimated cost to implement this alternative is about $6.1 million. This alternative would be expected to take three to five years to implement. A detailed plan of Alternative 1A is shown in **Figure 3-7** with the displaced threshold and connection to Taxiway A.

- **Incursion Mitigation Value:** (1) Elimination of Taxiway H requires aircraft to enter Runway 2/20 from Taxiway A. (2) The displaced threshold centerline arrows would extend about 250 feet along the runway. This would provide greater orientation for pilots than the existing configuration. (3) Departing aircraft would have higher speeds when crossing Runway 14/32; this would make it less likely that they would turn onto that runway.
- **Implementation Cost:** Total costs to implement were estimated to be $6.1 million.
- **Implementation Timetable:** Approval of ALP, design, environmental mitigation and construction would take an estimated three to five years.
- **Environmental Impacts:** Extensive, temporary impacts would occur to California tiger salamander habitat.

Figure 3-7: Runway 20 RIM Alternative 1A



Alternative 1B: Shift Runway 20 Threshold Northeast

Alternative 1B was proposed by the FAA during the call on April 16, 2019. This scenario is similar to Alternative 1A in that it proposes to increase the length of Runway 2/20 287 feet to a total of 5,489 feet. However, this alternative would shift the Runway 20 landing threshold as far northeast as possible – 65 feet – until the point the RSA would reach Airport and Upper Ordinance Creeks. The limiting factors are the runway object free area (ROFA) and RSA, which must remain 600 feet from the landing threshold. The proposed shift would cause the perimeter service road to breach the ROFA and RSA. Vehicles would require ATCT clearance before entering this section of the service road.

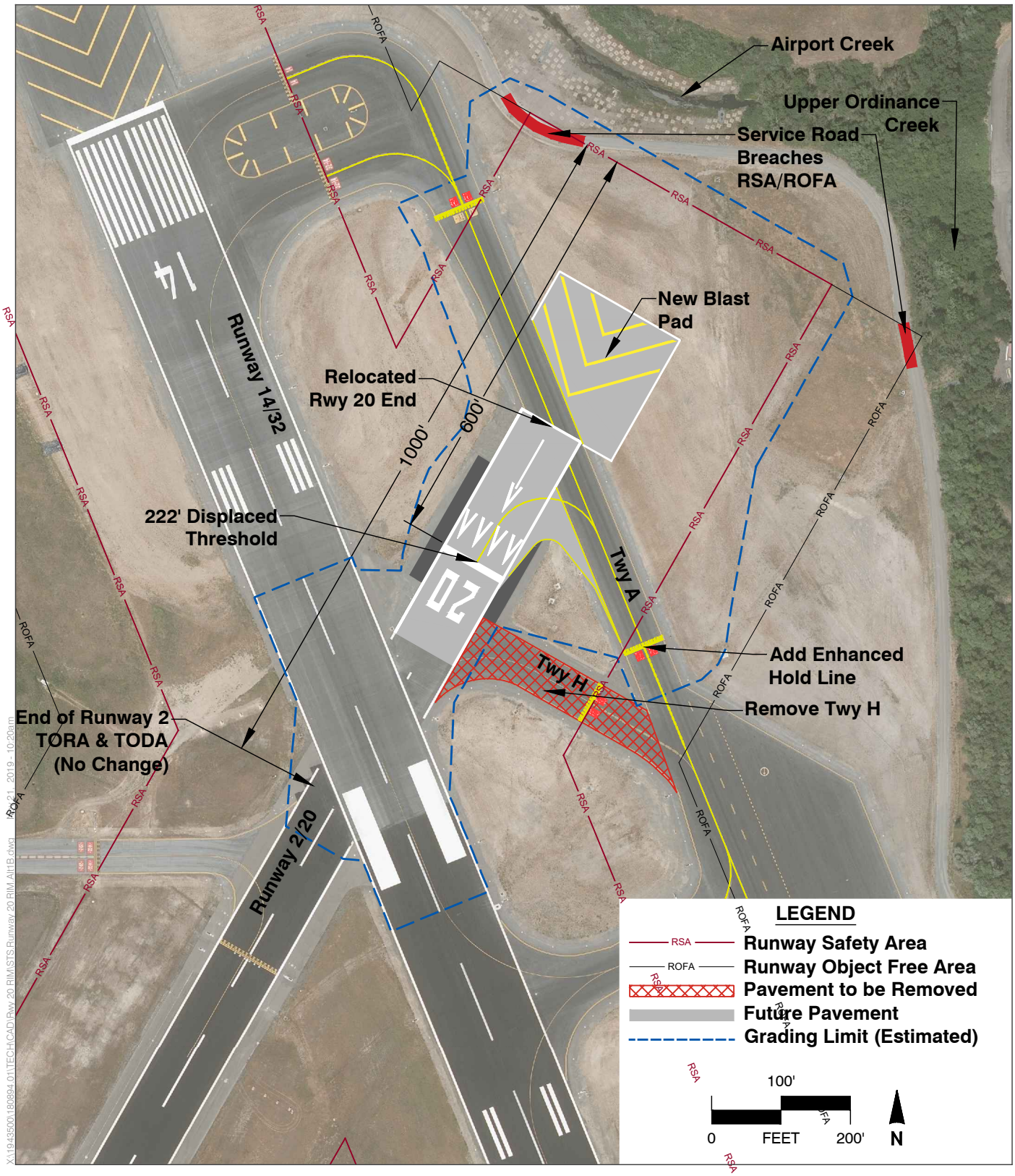
Like Alternate 1A, aircraft departing on Runway 20 would enter Runway 2/20 from Taxiway A and eliminate the need for Taxiway H. Declared distances for operations on Runway 20 would be increased by 65 feet.

This alternative would require all the same modifications to Runway 2/20 and Taxiway A as in Alternative 1A. Additionally, the 65-foot shift in the landing threshold would necessitate extension of the RSA and require both additional surface grading and modification of a segment of the service road to meet RSA gradient requirements.

A preliminary estimate of the cost to design and build this alternative is $5.9 million. Preparation of CEQA and NEPA environmental documents and follow-on permitting would cost an additional $500,000. Mitigation costs for temporary impacts to California tiger salamander habitat, plus other mitigation measures to address water quality, erosion, emission and air quality would be an additional $120,000. The total estimated cost to implement this alternative is about $6.5 million. This alternative would be expected to take three to five years to implement. Alternative 1B is illustrated in **Figure 3-8** with the proposed displaced threshold, impacts to the RSA and ROFA, and the service road.

- **Incursion Mitigation Value:** (1) Elimination of Taxiway H requires aircraft to enter Runway 2/20 from Taxiway A. (2) The additional 65 feet of runway would provide a longer centerline stripe that would make it easier for pilots to orient their aircraft correctly. (3) Departing aircraft would have higher speeds when crossing Runway 14/32; this would make it less likely that they would turn onto that runway.
- **Implementation Cost:** This alternative would cost slightly more than Alternative 1A because of the larger RSA and the need to reconstruct two sections of Taxiway A to meet gradient standards. Costs were estimated to be $6.5 million.
- **Implementation Timetable:** Approval of ALP, design, environmental mitigation and construction would take an estimated three to five years. The largest impact would be temporary impacts to California tiger salamander habitat. Extensive consultations with resource agencies would not be expected.
- **Environmental Impacts:** This alternative has the slightly higher impacts than Alternative 1A.

Figure 3-8: Runway 20 RIM Alternative 1B



Alternative 1C: Shift Runway 20 Threshold Northeast to Taxiway A

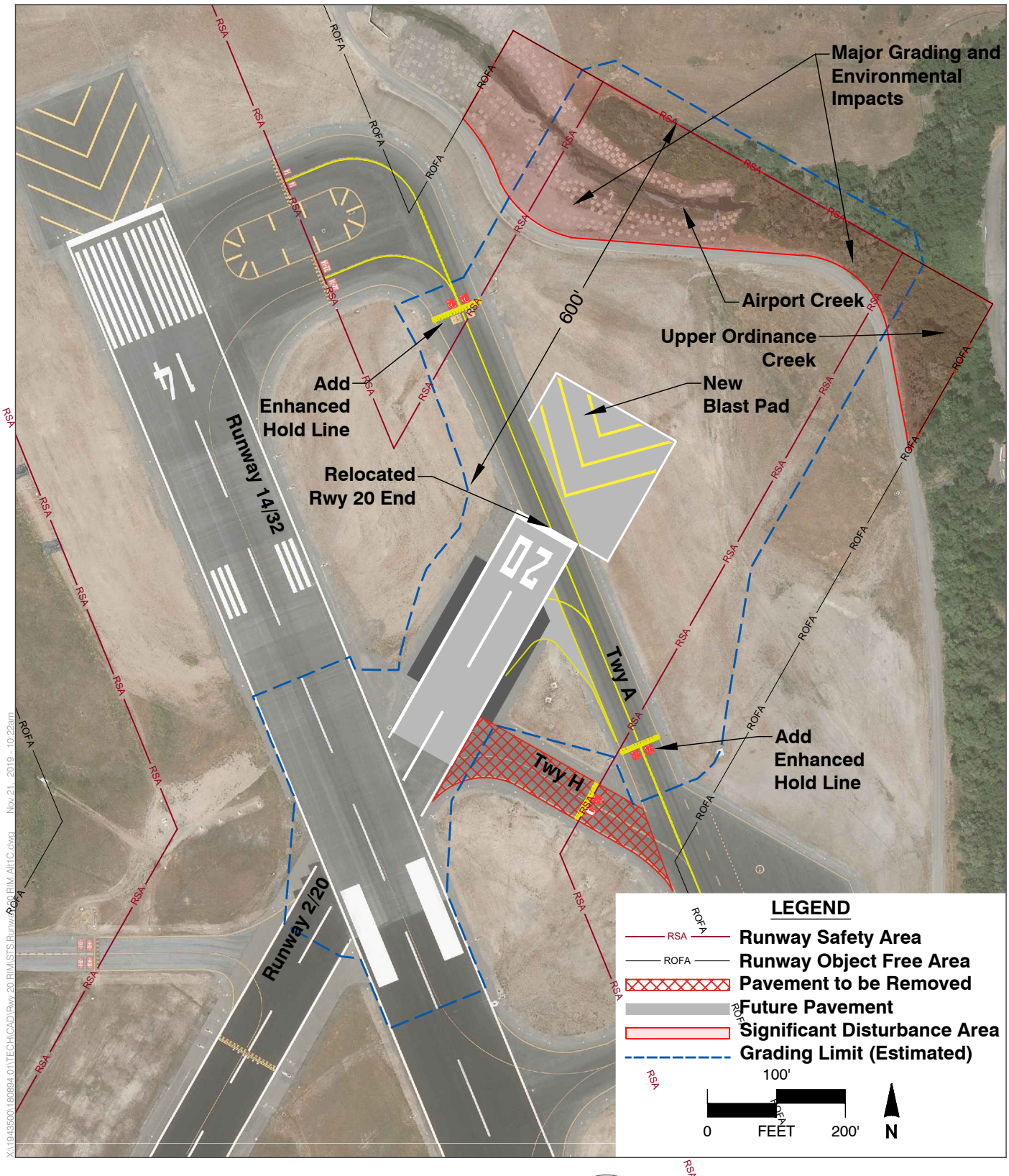
Alternative 1C proposes shifting the Runway 20 landing threshold 287 feet to Taxiway A for a total runway length of 5,489 feet and eliminating the displaced threshold. The RSA and ROFA would extend 600 feet beyond the end of the approach end of the runway, and the shift of the landing threshold would shift the RSA and ROFA into Airport and Upper Ordinance Creeks. The RSA would have to be cleared and graded and the ROFA would need to be clear of non-frangible objects. Extending these design surfaces would require significant fill, creek relocation, and realignment of the service road. This alternative would also potentially require modification of the adjacent sewage treatment ponds.

Aircraft departing on Runway 20 would enter Runway 2/20 from Taxiway A. This alternative would eliminate the need for Taxiway H, like Alternatives 1A and 1B. Declared distances for operations on Runway 20 would be increased by 287 feet.

The estimated order-of-magnitude cost to design and construct this alternative is $9.8 million. Preparation of CEQA and NEPA environmental documents (including an exhaustive analysis of alternatives) and subsequent permitting would cost an additional $750,000. Mitigation costs for impacts to California tiger salamander habitat, wetlands, riparian habitat and related features would be an additional $2 million. With the additional mitigation measures, the total estimated cost to implement this alternative is about $12.6 million. This alternative would be expected to take four to six years to implement. However, to a greater extent than other alternatives, this schedule would be subject to extension due to protracted negotiations over alternatives and environmental mitigations. **Figure 3-9** illustrates Alternative 1C and the likely impacts of runway extension, creek relocation, and RSA grading.

- **Incursion Mitigation Value**: (1) Elimination of Taxiway H requires aircraft to enter Runway 2/20 from Taxiway A. (2) The centerline arrows would extend about 300 feet along the runway. This would provide greater orientation for pilots than the existing configuration. (3) Departing aircraft would have higher speeds when crossing Runway 14/32; this would make it less likely that they would turn onto that runway.
- **Implementation Costs:** This would be the most expensive alternative to implement. Costs associated with Alternative 1C not included in Alternatives 1A and 1B include either placing segments of Airport and Upper Ordinance Creeks in a culvert or relocating adjacent sewage treatment basins. This complication would increase the costs to develop and review alternatives, associated CEQA and NEPA documentation, permitting, and mitigation costs. Total implementation costs would be about $12.6 million.
- **Implementation Timetable:** Airspace review, approval of an ALP update, design, and construction, environmental review and mitigation would take an estimated four to six years.
- **Environmental Impacts:** This alternative would have the greatest impacts. It is the only alternative that would impact wetlands and riparian habitat.
- **Operations:** The amount of runway available for departures on Runway 20 would be increased by 287 feet. This length is just large enough to have the potential to provide some benefit to operations by large jets.

Figure 3-9: Runway 20 RIM Alternative 1C



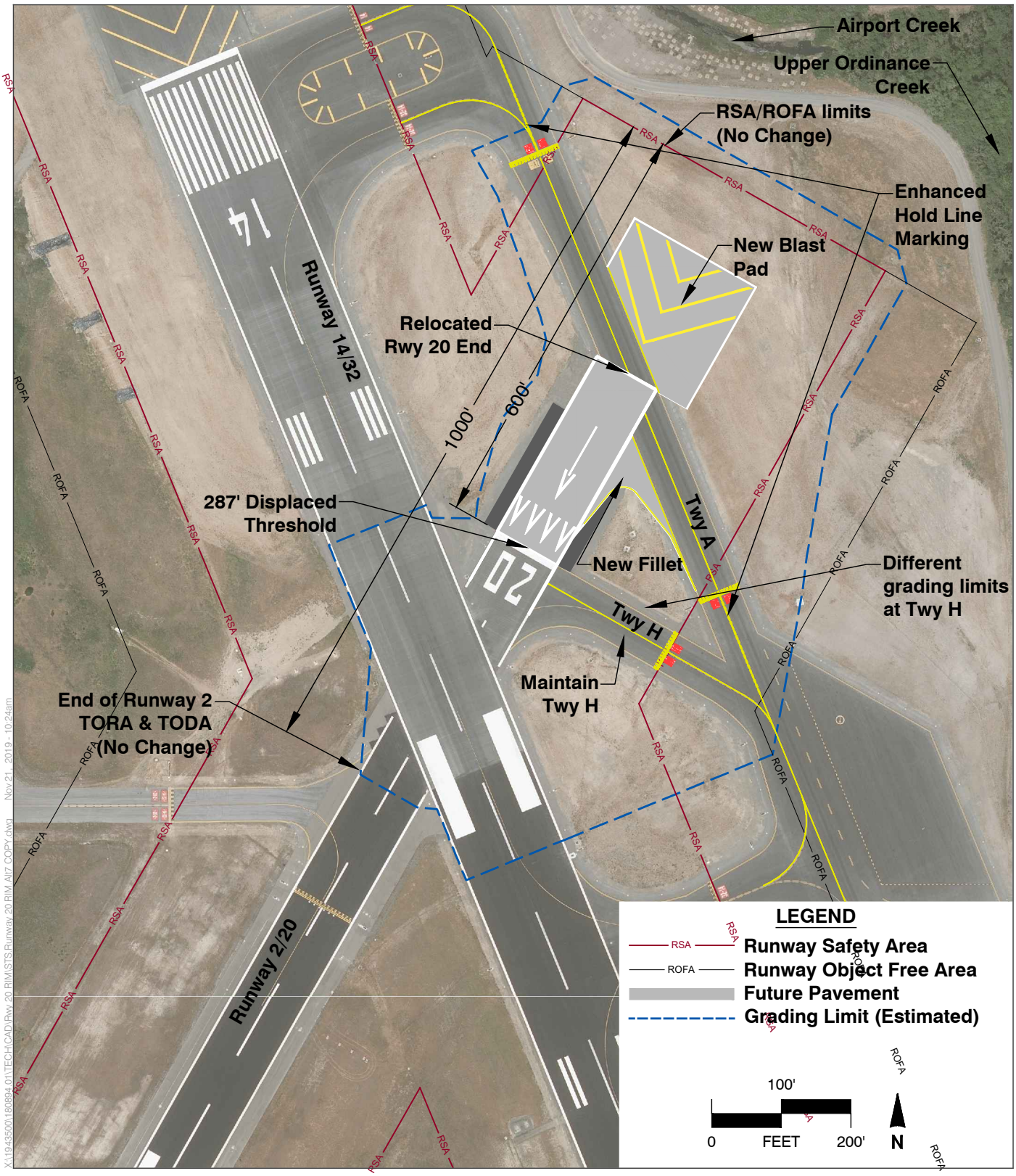
Alternative 1D: Extend Runway 2/20 to Taxiway A and Maintain Taxiway H

Alternative 1D was developed during conversations with ATCT staff after indications that it was important to maintain Taxiway H for operations flow and departures on Runway 20. This alternative is identical to Alternative 1A, except it retains Taxiway H to access Runway 2/20.

The cost to design and construct Alternative 1D would be slightly higher than Alternative 1A, because Taxiway H would have to be reconstructed to match the new elevation of Runway 2/20. A preliminary estimate of the cost to design and build this alternative is $5.9 million. Preparation of CEQA and NEPA environmental documents and follow-on permitting would cost an additional $500,000. Total mitigation costs for temporary impacts to California tiger salamander habitat, plus other mitigation measures to address water quality, erosion, emission and air quality would be an additional $115,000. The total estimated cost to implement this alternative is about $6.5 million. This alternative would be expected to take three to five years to implement. **Figure 3-10** details Alternative 1D and the likely impacts of runway extension and grading impacts with Taxiway H remaining.

- **Incursion Mitigation Value:** By diverting some operations to access Taxiway 20 via Taxiway A, this arrangement could reduce the number of runway incursions. However, it would retain the problematic Taxiway H – Runway 20 intersection. Available information indicates that transient pilots make the incursions. There are limits to the ability of ATCT staff to differentiate between transient and based pilots. Therefore, this alternative is judged to have only limited value in mitigating incursions.
- **Implementation Costs:** This alternative would be more expensive than Alternative 1A because it would add reconstruction of Taxiway H. Total implementation costs would be about $6.5 million.
- **Implementation Timetable:** Airspace review, approval of an ALP update, design, and construction would take an estimated three to five years.
- **Environmental Impacts:** Impacts to the California tiger salamander habitat would be slightly higher than Alternatives 1A and 1B, because of the slightly higher acreage being impacted.
- **Operations:** Retaining Taxiway H while adding a connection to Taxiway A would provide ATCT staff and pilots additional options for queueing for departures. This would provide a modest increase in capacity and flexibility.

Figure 3-10: Runway 20 RIM Alternative 1D



Alternative 2: Displace Runway 20 Landing Threshold 600 Feet

Alternative 2 proposes relocation of the landing threshold for Runway 20 southwest of the intersection with Runway 14/32 and maintaining Taxiway H. Total runway length would remain at 5,202 feet with a displaced threshold of approximately 600 feet. Displaced threshold chevrons would be added to the segment of Runway 20 prior to the landing threshold. This scenario would maintain the overall length of Runway 2/20 but would shorten the landing distance available on Runway 20 to 4,600 feet. This length would limit its utility as a runway designated for use by commercial airliners.

This alternative would require remarking the runway, changing the color of the lenses in the runway edge lights in the affected section, and the installation of runway threshold lights. The estimated order-of-magnitude cost to design and construct this alternative is $800,000. No costs for mitigation measures would be anticipated. This alternative would be expected to take one to two years to implement. Alternative 2 is shown in the preliminary alternatives graphic above, **Figure 3-6**.

- **Incursion Mitigation Value:** In this alternative, the existing 10-foot centerline stripe would be replaced with a 100-foot long displaced threshold arrow on the centerline. This would provide greater alignment information than the current centerline stripe. However, this alternative also would have the potential to increase incursions. Pilots taxiing from the hold bars at Taxiway H onto Runway 2/20 would have difficulty seeing the "20" marking 600 feet away due to the low viewing angle. The crown in Runway 14/32 will also limit a pilot's ability to observe the relocated designators. ATCT staff at the June 27, 2019, RSAT meeting indicated that they believed that pilots would have difficulty seeing the runway numbers.
- **Implementation Costs:** Due to the need to relocate the PAPI and threshold lights and change edge lights' lenses, this alternative would be more expensive than those that only involve marking changes. However, with an implementation cost of about $800,000, this alternative would be less expensive by orders of magnitude than those involving extension of Runway 2/20.
- **Implementation Timetable:** The one to two years required for implementation means that this alternative would land intermediately between the purely marking alternatives and the runway extension alternatives.
- **Environmental Impacts:** From a preliminary analysis it appears that the only disturbance of unpaved areas would be relocation of the PAPI and its associated electrical cables. The only biological impacts would be to tiger salamander habitat. Mitigation fees would need to be paid for the temporary and permanent impacts to this habitat.
- **Operations:** This alternative would reduce the length available for landing on Runway 20 to 4,600 feet. This would constrain some operations by large corporate jets and some airline aircraft, plus CalFire aircraft that utilize Runway 2/20 more than Runway 14/32. However, the full length would remain available for departures on Runway 20.

Alternative 3: Shorten Runway 2/20 to 3,200 feet

This alternative proposes shortening Runway 2/20 to 3,200 feet and the relocation of the end of Runway 20 to a point abeam Taxiway D. This option would decouple the runways and eliminate Taxiway H. Runway 2/20 would be accessed from Taxiway D. This alternative was considered previously during development of the most recent Airport Master Plan update.

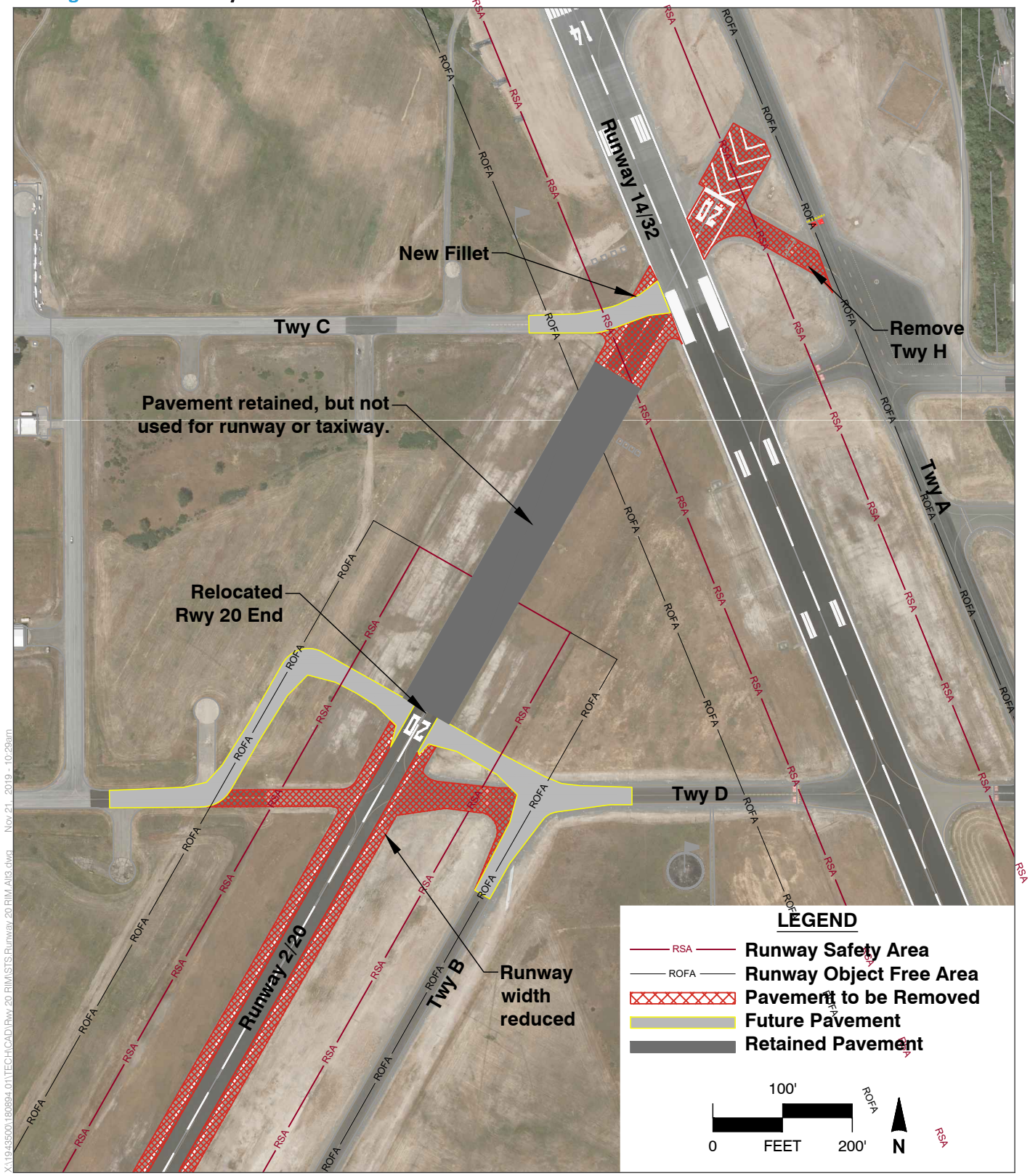
This alternative would require remarking the runway to a width of 75 feet and relocation of the runway edge and threshold lights. It is anticipated that a 100-foot section of runway pavement would be removed immediately south of Taxiway C. The balance of the abandoned section of runway would be retained but marked as unusable. The intersection of Taxiway C and Runway 2/20 would need to be modified to connect to Runway 14/32 at a right angle. Additionally, it is likely that Taxiway D would have to be modified to provide right-angle taxiway connections to the new runway end.

This alternative would change the critical aircraft for this runway, which would then change the Airport Reference Code to B-II, limiting the utility of the runway.

The estimated order-of-magnitude cost to design and construct this alternative is $3.6 million. Preparation of CEQA and NEPA environmental documents and follow-on permitting would cost an additional $500,000. Mitigation costs for temporary impacts to California tiger salamander habitat would be an additional $140,000. It appears possible that construction could avoid the delineated wetlands adjacent to Taxiways B and D. However, it is also possible that changes to drainage patterns could affect these wetlands, and if so, this would require mitigation. The total estimated cost to implement this alternative is about $4.2 million. It is expected that implementation would take three to five years. Alternative 3 is shown in **Figure 3-11**.

- **Incursion Mitigation Value:** Decoupling of Runway 2/20 and 14/32 would separate the runways and eliminate incursion potential from Taxiway H. However, in order to access the departure end of Runway 20 from the east side of the airfield, aircraft would have to cross Runway 14/32 at Taxiway A3. ATCT staff at the June 27, 2019 RSAT meeting felt strongly that this alternative would create a new source for runway incursions and would reduce the capacity of Runway 14/32.
- **Implementation Costs:** This would be one of the most expensive alternatives because of the need to modify Taxiways B, C, and D and reduce the runway's width. Costs would be an estimated $4.3 million.
- **Implementation Timetable:** The three- to five-year implementation period would be equal to the estimated duration of the runway extension alternatives.
- **Environmental Impacts:** There would be extensive impacts to California tiger salamander habitat and potential impacts to jurisdictional wetlands.
- **Operations:** This alternative would restrict the use of Runway 2/20 to aircraft no larger than medium turboprops and small jets.

Figure 3-11: Runway 20 RIM Alternative 3



RSAT Meeting

The six preliminary permanent RIM alternatives presented at the June 27, 2019, RSAT meeting. None of the runway extension alternatives were favorably received for these reasons, among others:

- Judgement that some extension alternatives would not significantly improvement pilot situational awareness.
- Concern by some ATCT staff that the connection to Taxiway A was similar to the configuration at Lexington Airport where a wrong-runway departure in 2006 killed 49 people.
- The length of time prior to implementation.

RSAT members and ATCT staff expressed concern over shortening Runway 2/20 because a shorter length limits its utility as a runway designated for use by commercial airliners and reduces the flexibility in managing landings by large aircraft. ATCT staff commented that shortening Runway 2/20 would make STS a one-runway airport for commercial and GA jet operations.

RIM – PERMANENT GEOMETRY DESIGN – ELIMINATED ALTERNATIVES

Five of the six preliminary alternatives were eliminated from further consideration based on disadvantages over other alternatives. This was the result of consultation with STS staff, STS ATCT staff, RSAT Team, and the ADO over 2020 and 2021. The alternatives were dismissed for one or more the following reasons.

- Does not provide a clear benefit over another alternative that is less expensive or has less extensive environmental impacts.
- Increases the potential for incursions on other parts of the airfield.
- Would eliminate the use of Runway 2/20 for commercial operations.
- Would likely not improve incursions (indicated by ATCT staff interviews).

Each dismissed alternative is presented below with a description of its incursion mitigation value, its impact on operations, and reasons for dismissal. Analysis of costs, environmental impacts, and impacts to operations are included as an order of magnitude comparison to the preferred alternatives.

Alternative 1B: Reasons for Elimination

- **Cost:** This one of the more costly alternatives.
- **Long implementation period:** There would be at least three years before any potential benefit would occur.
- **Environmental impacts:** This alternative has environmental impacts of a similar scale to Alternative 1A.
- **Operations:** Moving the Runway 20 landing threshold and extending the runway length 65 feet further than Alternative 1A increases the cost but does not provide any significant additional benefit for aircraft operations.

Alternative 1C: Reasons for Elimination

- **Costs:** Costs associated with Creek relocation, design, construction and environmental review would be significantly more than Alternative 1A, which provides similar incursion mitigation.
- **Long implementation period:** There would be at least four years before any potential benefit would occur.
- **Environmental Impacts:** Impacts would be significantly more than Alternative 1A and 1B, which provide similar incursion mitigation.

Alternative 1D: Reasons for Elimination

- **Costs:** Costs would be more than Alternatives 1A and 1B but would provide less mitigation value.
- **Long implementation period:** There would be at least three years before any potential benefit would occur.
- **Environmental Impacts:** Impacts would be greater than Alternative 1A and 1B.

Alternative 2: Reasons for Elimination

- **Incursions Mitigation:** Moving the Runway "20" designators south of Runway 14/32 would not be likely to improve a pilot's situational awareness and could actually decrease awareness and exacerbate the situation.
- **Operations:** This alternative would reduce landing distance available on Runway 20. This would impact some landings by large corporate jets and commercial operations on this runway by limiting load factors and routes serviced. At the June 27, 2019, RSAT meeting ATCT staff expressed concern over the reduction in flexibility for managing landings by large aircraft.

Alternative 3: Reasons for Elimination

- **Operations:** This alternative would reduce the utility of Runway 2/20. Commercial and large business jets would not be able to use Runway 2/20 due to its length. Most jet activity would also be excluded from Runway 2/20, and CalFire will likely not be able to utilize Runway 2/20 pushing more traffic onto Runway 14/32. Runway 2/20 is utilized by ATCT for departures during peak activity times. ATCT estimate that about 15 percent of GA jet departures are on Runway 20. This alternative would be expected to eliminate these operations. At the June 27, 2019, RSAT meeting, one ATCT staff member commented that this alternative would make this a one-runway airport for commercial and GA jet operations.
- **Incursions Mitigation:** This alternative would likely create a subsequent incursion issue. Aircraft taxiing to access Runway 2/20 would need to cross Runway 14/32 at Taxiway A3. ATCT staff stressed that this would increase the potential for incursions.

RIM – PERMANENT GEOMETRY DESIGN – ALTERNATIVES ADVANCED

After consultation with STS staff and the ADO, Alternative 1A was selected as the preferred permanent geometry alternative. This was advanced by the ADO through FAA regional and headquarters review. The FAA rejected Alternative 1A in August 2021.

Alternative 1A: Reasons for Elimination

The FAA review found the intersection of Taxiway A with the extended Runway 20 to be non-standard design. The segment of Taxiway A through Runway 20 would not be aligned at a 90-degree angle to the runway. This would create an intersection with a greater than 90-degree turn, an intersection that may be confusing to pilots. The FAA deemed this unconventional angled intersection of Taxiway A with Runway 20 to be potentially problematic and may continue to represent a Hot Spot with elevated risk for runway incursions (letter from FAA, Fernando Yanez, August 2, 2021).

The FAA recommended further evaluation of alternatives that include an entry taxiway/runway end design alternative that can best achieve a 90-degree geometry and allow for standard installation of REILs while still minimizing the RSA footprint to avoid critical, environmentally sensitive areas. The FAA recognized that further alternatives should leverage the limited available space beyond the current Runway 20 threshold, to the extent practicable. This acknowledgement essentially recognized that further alternatives should be limited to extension on the existing terrain beyond Runway 20. Alternatives should avoid extension into the creeks that are located father to the northeast to limit major environmental impacts.

Alternative 1E: Extend Runway 2/20 beyond Taxiway A and Retain Existing Landing Threshold

Alternative 1E proposes extending Runway 2/20 northeast, increasing the runway's length by 458 feet to a total of 5,660 feet. The landing threshold for Runway 20 would remain in the current location with a displaced landing threshold of 458 feet, and the additional runway pavement would be marked as a displaced threshold. This would permit the additional runway length to be used for takeoffs on Runway 20. Declared distances would be used to retain the current runway length for operations on Runway 2 for standard RSAs.

Taxiway A would be reconfigured to cross the Runway 20 end at a 90-degree angle. Aircraft departing on Runway 20 would enter Runway 2/20 from the realigned Taxiway A, or cross for departures on Runway 14. Taxiway H would be eliminated.

The combination of a displaced threshold for Runway 20 and declared distances on Runway 2 means that the RSA for this runway would not change with this alternative. This eliminates the need to extend the RSA to the northeast into Airport and Upper Ordinance Creeks.

The planning cost estimate for Alternative 1E is higher than Alternative 1A. Since the preliminary alternatives were created, unit costs have increased. Alternatives 1E also impacts drainage and California

tiger salamander habitat more than Alternative 1A. However, the need to reconstruct the intersection of the two runways is no longer needed with realignment of Taxiway A.

A preliminary estimate of the cost to design and build this alternative is $17 million. This includes preparation of CEQA and NEPA documents and follow-on permitting. Included in this are mitigation costs for temporary impacts to California tiger salamander habitat, plus other mitigation measures to address water quality, erosion, emission and air quality, which total about $2,500,000. This alternative would be expected to take three to five years to implement. A detailed plan of Alternative 1E is shown in **Figure 3-12** with the displaced threshold and reconfigured Runway 20 – Taxiway A intersection. **Figure 3-13** shows the location of the design aircraft at the new hold positions and clearances under the obstacle clearance surface (threshold siting surface). **Figure 3-14**: illustrates tower line of sight to the proposed runway end and hold positions. Trees north of Taxiway J will need to be trimmed at least 10 feet. The proposed remain overnight aircraft positions will need to be rotated so tails are parallel to the line of sight.

- **Incursion Mitigation Value:** (1) Elimination of Taxiway H with realignment of Taxiway A requires aircraft to enter Runway 2/20 from Taxiway A at 90-degree angles. (2) The displaced threshold centerline arrows would extend about 250 feet along the runway. This would provide greater orientation for pilots than the existing configuration. (3) Aircraft departing on Runway 20 will have 458 more feet of takeoff roll prior to crossing Runway 14/32, making it less likely that they would turn onto that runway.
- **Implementation Cost:** Total costs to implement were estimated to be $17 million.
- **Implementation Timetable:** Approval of ALP, project design, environmental mitigation, and project construction would take an estimated three to five years.
- **Environmental Impacts:** Extensive, temporary impacts would occur to California tiger salamander habitat.

Alternative 1E was submitted to the ADO for FAA review and approval.

Figure 3-12: Runway 20 RIM Alternative 1E

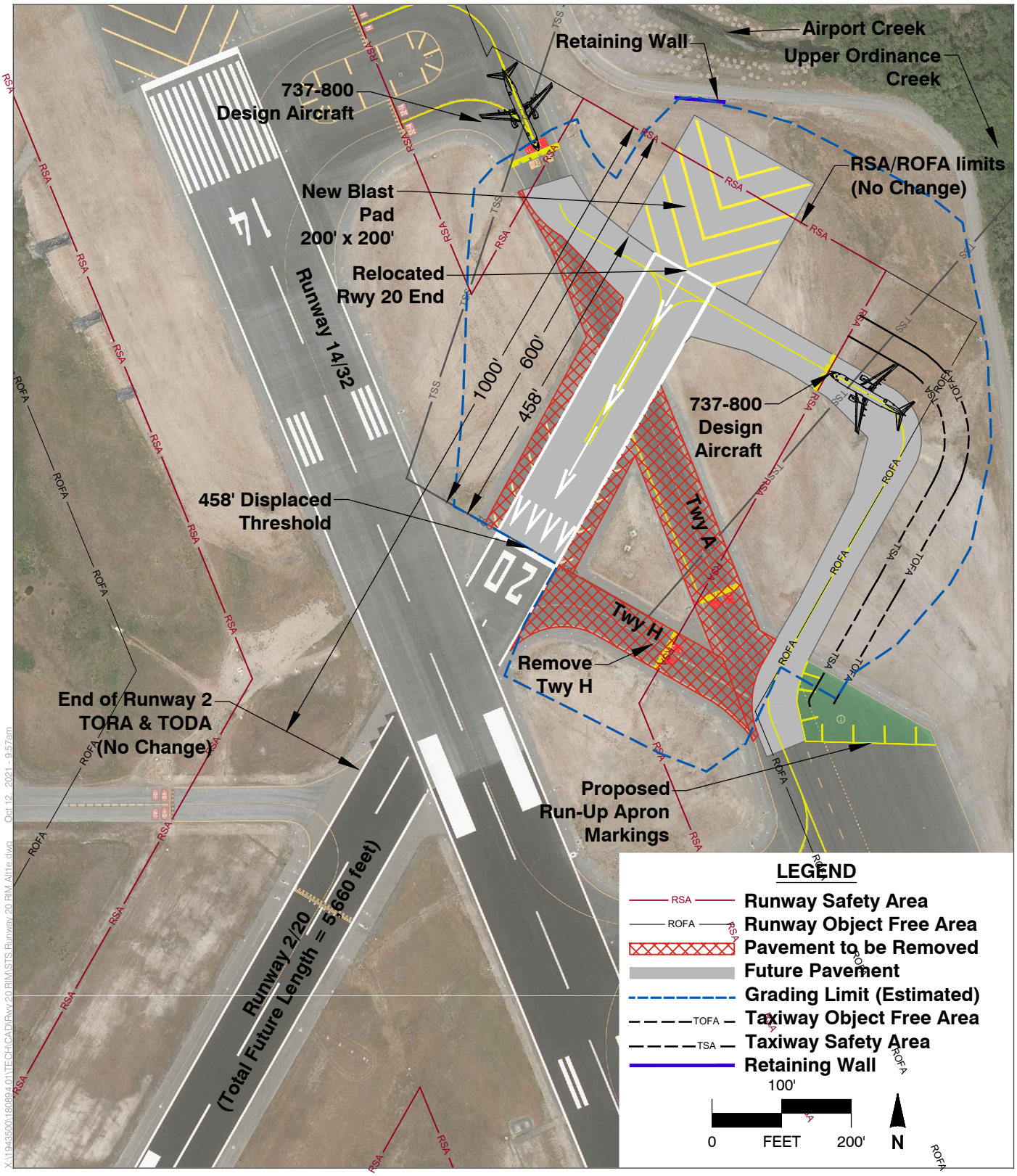


Figure 3-13: Runway 20 RIM Alternative 1E 737-800 Profiles

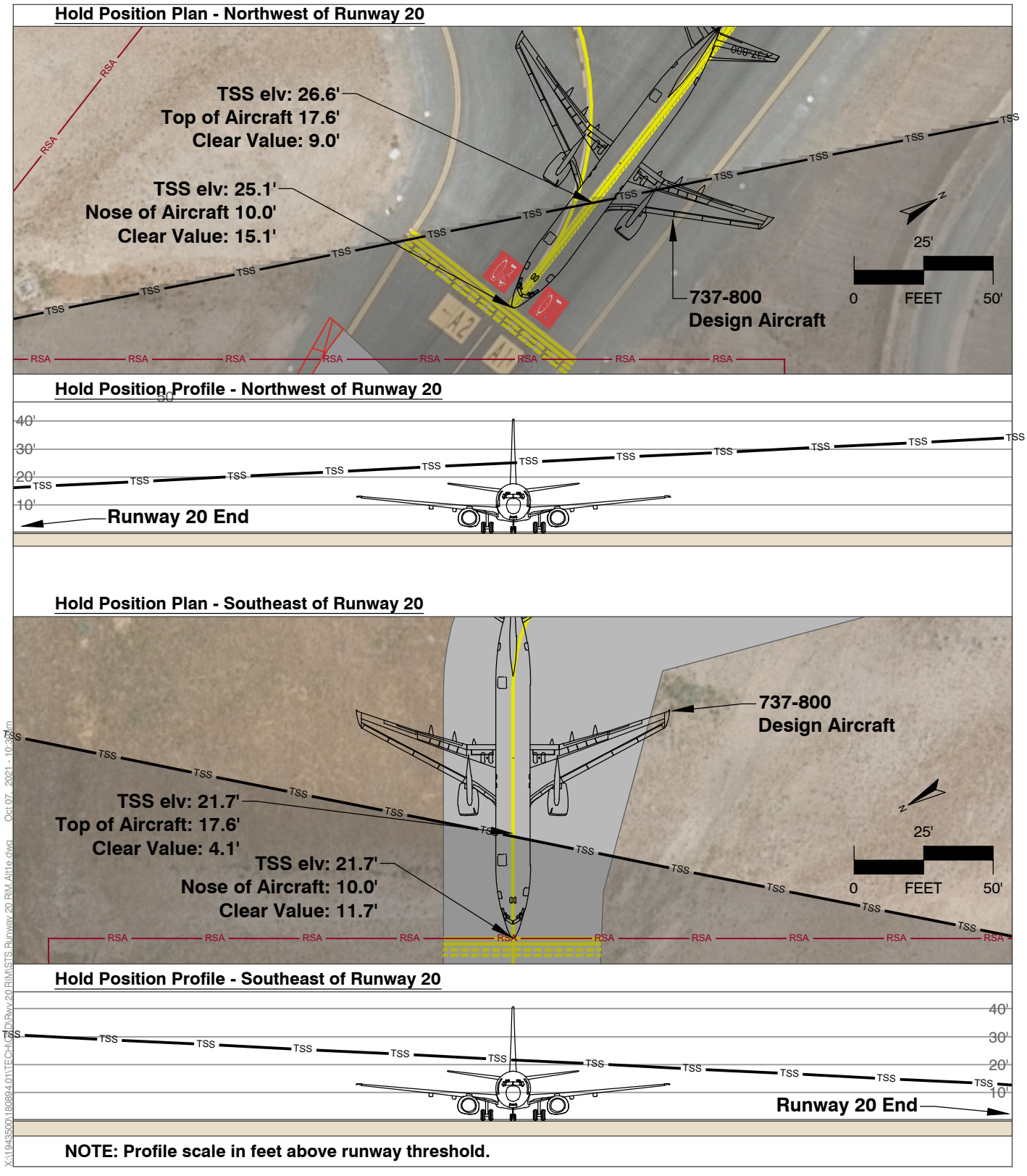
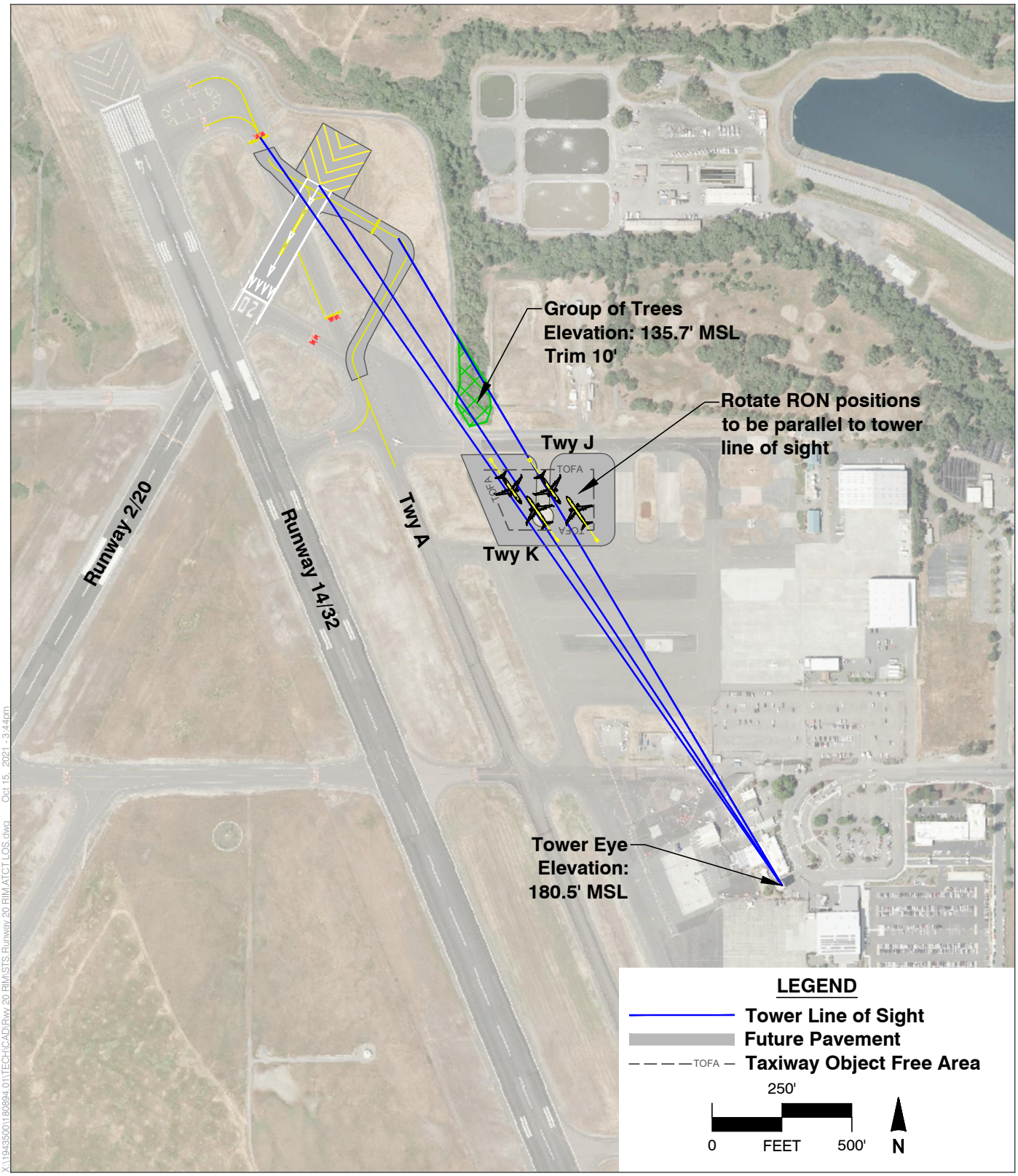


Figure 3-14: Runway 20 RIM ATCT Line of Sight



RIM ALTERNATIVES – INTERIM MODIFICATIONS

Discussions with STS, ATC, RSAT, and the ADO indicated that interim changes and modifications to signs and markings may help reduce or eliminate incursions. The interim modifications have the advantage of being relatively inexpensive, quick to implement, present no environmental impacts, and are easy to remove if they prove to not be effective. These alternatives will be submitted to the San Francisco ADO for formal review. ADO staff indicated that they wished to review each alternative separately. Ultimately, however, there may be value in combining these interim modifications.

A second advantage with interim modifications to signs and markings is these may offer immediate measures that reduce or eliminate incursions prior to implementation of the preferred Permanent Geometry Design, which may take several years.

Another advantage is these interim measures may eliminate incursions and eliminate the need to construct the preferred Permanent Geometry Design. It is recommended to continue coordination with ATC, ADO, and RSAT after these interim mitigation measures are completed to track incursions. During annual RSAT meetings, it is recommended that these interim measures be reevaluated with a report on incursion causes throughout the previous year.

The Interim Modifications propose potential sign and marking additions to the Runway 20-Taxiway A-H area that may help limit incursions prior to implementation of the preferred permanent geometry design.

- **Alternative 4 Group:** Add non-standard runway or taxiway markings or signs on TW H – RW 20.
- **Alternative 5 Group:** Add non-standard runway or taxiway markings or signs on TW A – RW 20.

Interim Modifications Alternatives: Taxiway H – Runway 20

Five preliminary alternatives were recommended for formal consideration for RIM Interim Modification:

- **Alternative 4A:** Extended Taxiway H Centerline Stripe
- **Alternative 4B:** Extend Runway 20 Centerline Across Runway 14/32
- **Alternative 4C:** Shift 20 Designator Marking Closer to Runway 14/32
- **Alternative 4D:** Reduce Taxiway H Width to 50 feet
- **Alternative 4E:** Extend Runway Centerline Northeast and Closer to Runway Designator

Alternative 4A: Extended Taxiway H Centerline Stripe

Alternative 4A, shown in **Figure 3-15**, proposes adding a yellow Taxiway H centerline stripe through the Runway 20 designator and continuing into Runway 14/32 and through the intersection. The intent would be to lead pilots across Runway 14/32 onto Runway 20. This scenario retains Taxiway H. This would be a nonstandard marking; a modification to standards (MOS) would be required before it could be implemented. There would be no changes to the length or threshold for Runway 2/20. The estimated order of magnitude cost to design and paint this stripe is $12,000. No environmental impacts would be anticipated for this alternative. This alternative could be implemented within one year.

RSAT Meeting

Alternative 4A was presented at the June 27, 2019, RSAT meeting. During the meeting ATCT staff proposed two additional marking alternatives, which are the two alternatives presented next. The consensus of the RSAT meeting was that all marking alternatives should be submitted to the ADO for formal consideration. Marking alternatives could be implemented within one year, which was viewed as a major advantage. All the marking alternatives will require modifications to standards. The modifications to standards process will provide a mechanism for additional review of the alternatives.

Alternative 4B: Extend Runway 20 Centerline Across Runway 14/32

This alternative was generated during the June 27, 2019, RSAT meeting. Like Alternative 4A, the intent is to provide a visual guide for pilots to follow across the open pavement at the runway intersection of Runway 2/20. This would be a nonstandard marking and would require approval of a MOS. This scenario retains Taxiway H. The estimated order of magnitude cost to design and paint this stripe is $12,000. No environmental impacts would be anticipated for this alternative. This alternative, illustrated in **Figure 3-16**, would be expected to take less than a year to implement.

Alternative 4C: Shift 20 Designator Marking Closer to Runway 14/32

Alternative 4C, detailed in **Figure 3-17**, was also generated during the June 27, 2019, RSAT meeting. The intent is to make the Runway 20 marking more visible to pilots turning onto the runway. This would increase the potential that pilots would maintain the correct orientation with the centerline of Runway 2/20. The 20 designator marking could be shifted a maximum of about 28 feet without entering Runway 14/32. This would be a nonstandard marking and would require approval of a MOS. This scenario retains Taxiway H. The estimated order of magnitude cost to move these markings is $20,000. No environmental impacts would be anticipated for this alternative. This alternative would take a year or less to implement.

Alternative 4D: Reduce Taxiway H Width to 50 Feet

Alternative 4D, illustrated in **Figure 3-18** proposes to reduce the width of Taxiway H to 50 feet, thereby shifting the taxiway centerline northeast slightly and providing pilots more area to turn and lineup on Runway 20 prior to departure. The perceived benefit is this geometry will allow pilots more pavement and time to recognize the Runway 20 designator. The non-standard condition of reducing Taxiway H is maintaining six existing taxiway lights at a distance greater than standard from the taxiway edge (10 feet). Alternative 4D was proposed by the ADO after review of Alternatives 4A-4C above.

Alternative 4E: Extend Runway Centerline Northeast and Closer to Runway Designator

Alternative 4E, is shown in **Figure 3-19** and proposes to extend the Runway 2/20 centerline northeast, 20 feet closer to the end designator. Alternative 4E was proposed by the ADO after review of Alternatives 4A-4C above. The existing centerline stripe is 11 feet long and it is proposed to extend this to 31 feet which is a non-standard condition due to the proximity of the centerline strip to the runway end designator. It is believed that by extending the centerline stripe, this will allow pilots to better recognize and align on Runway 20 prior to departures opposed to continuing to turn onto Runway 14/32.

Figure 3-15: Runway 20 RIM Alternative 4A

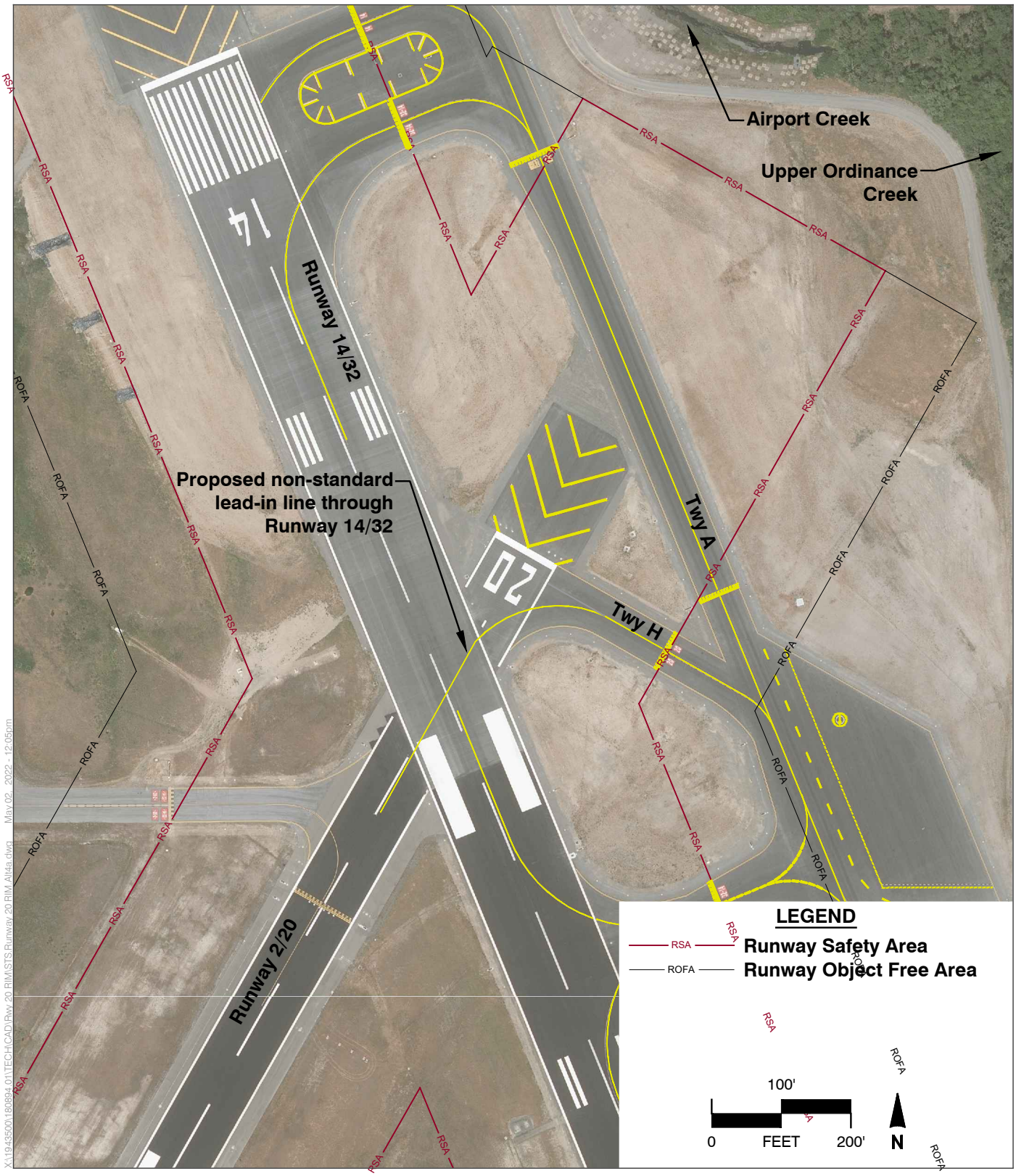


Figure 3-16: Runway 20 RIM Alternative 4B

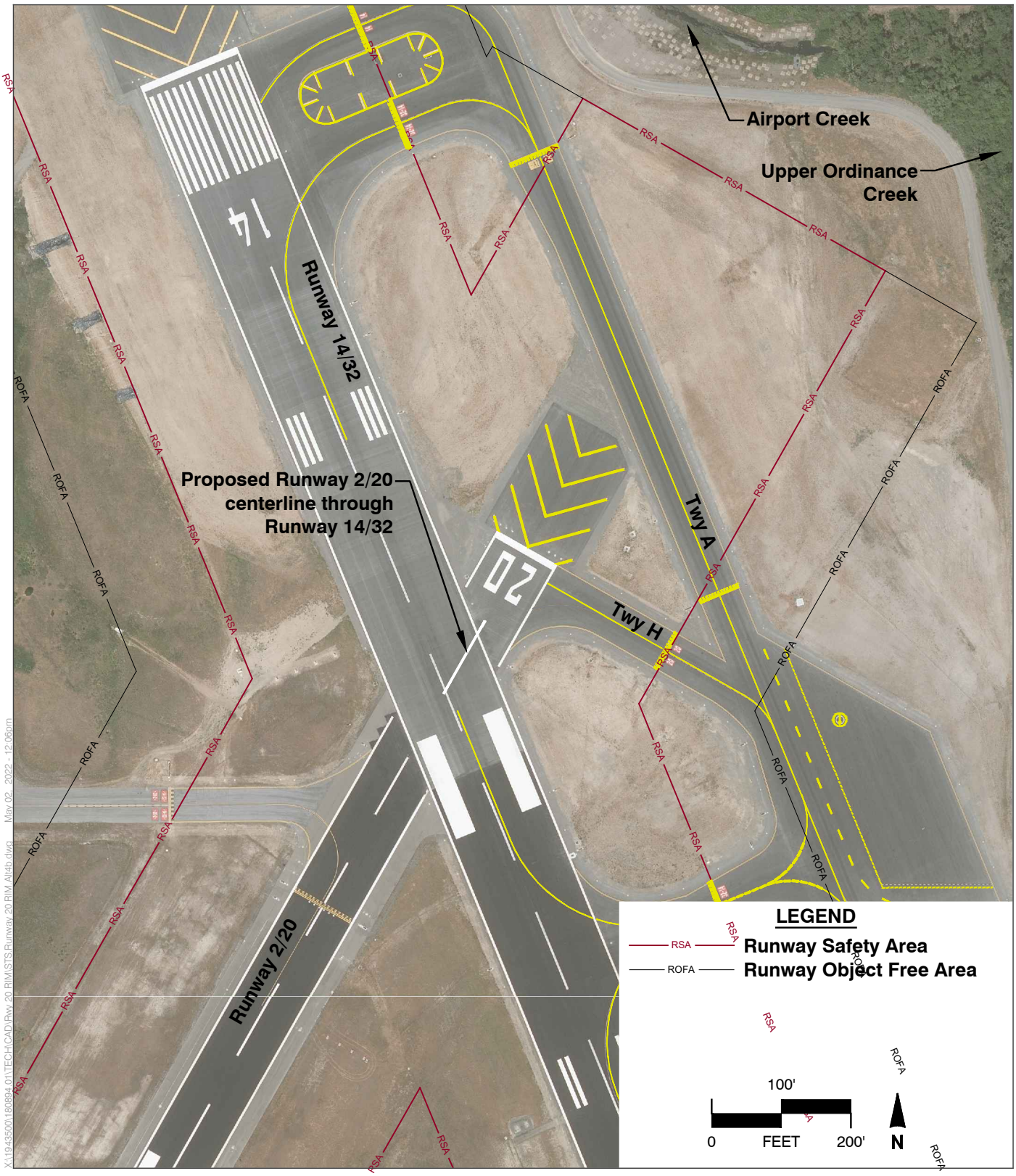


Figure 3-17: Runway 20 RIM Alternative 4C

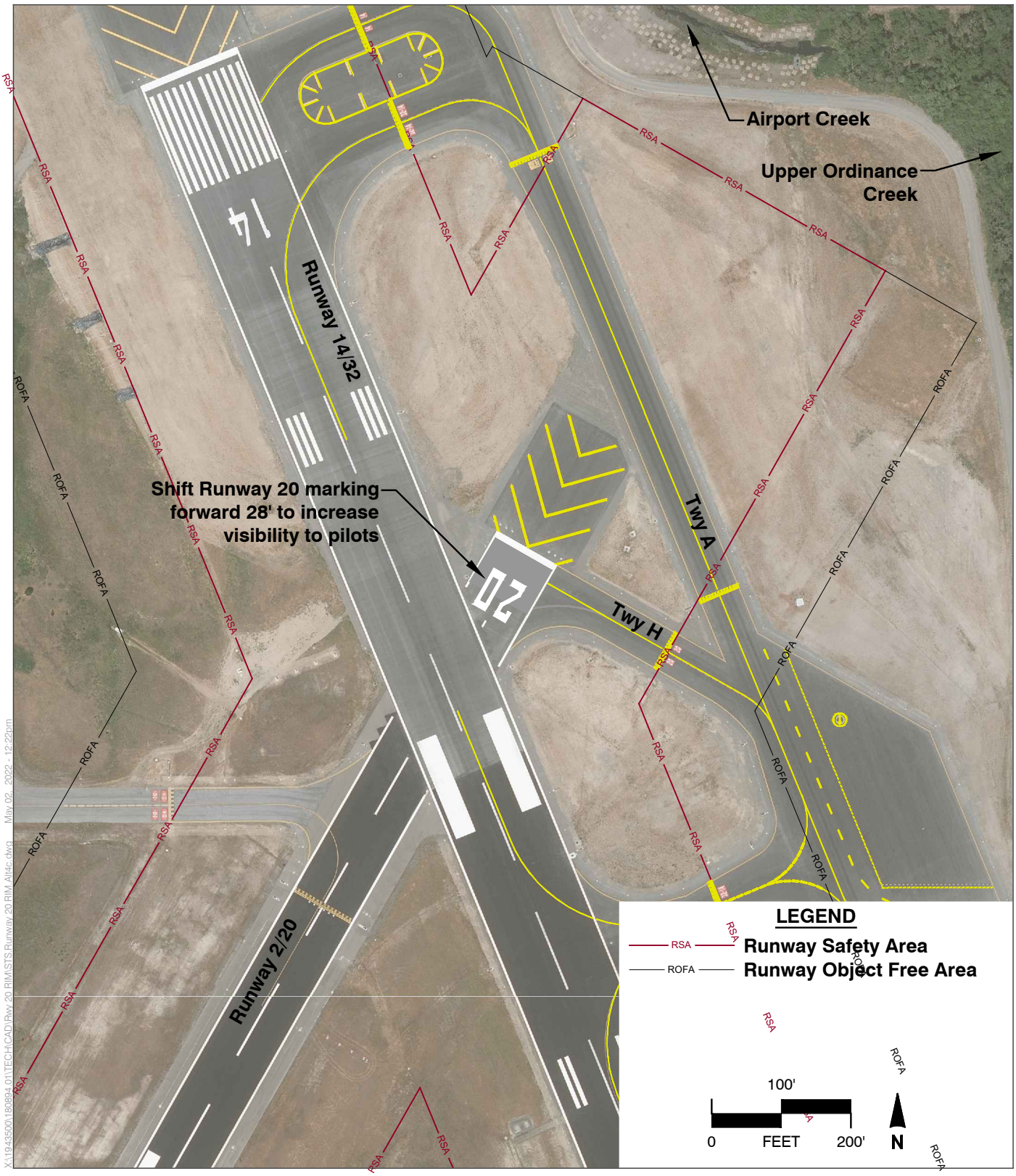


Figure 3-18: Runway 20 RIM Alternative 4D

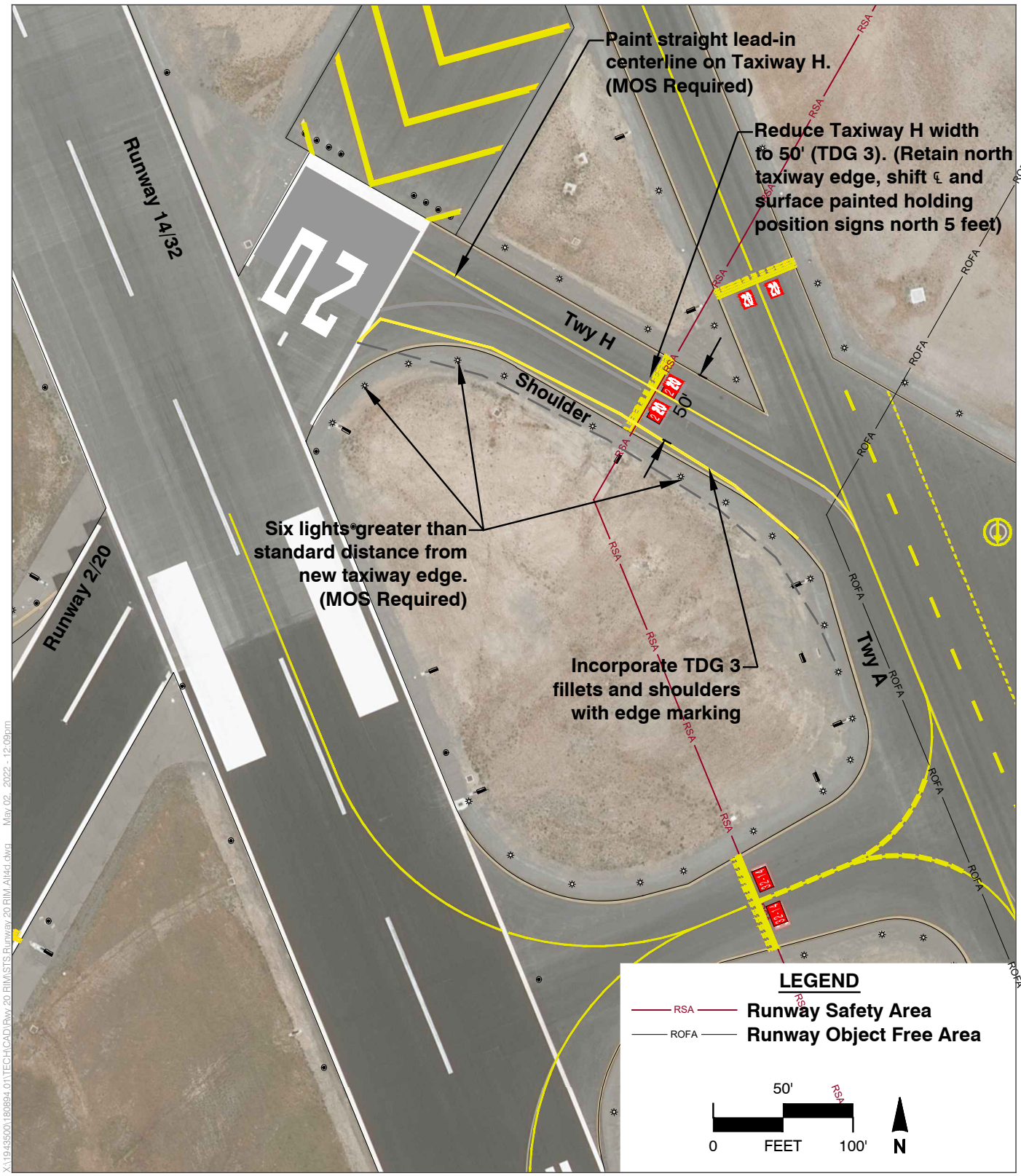


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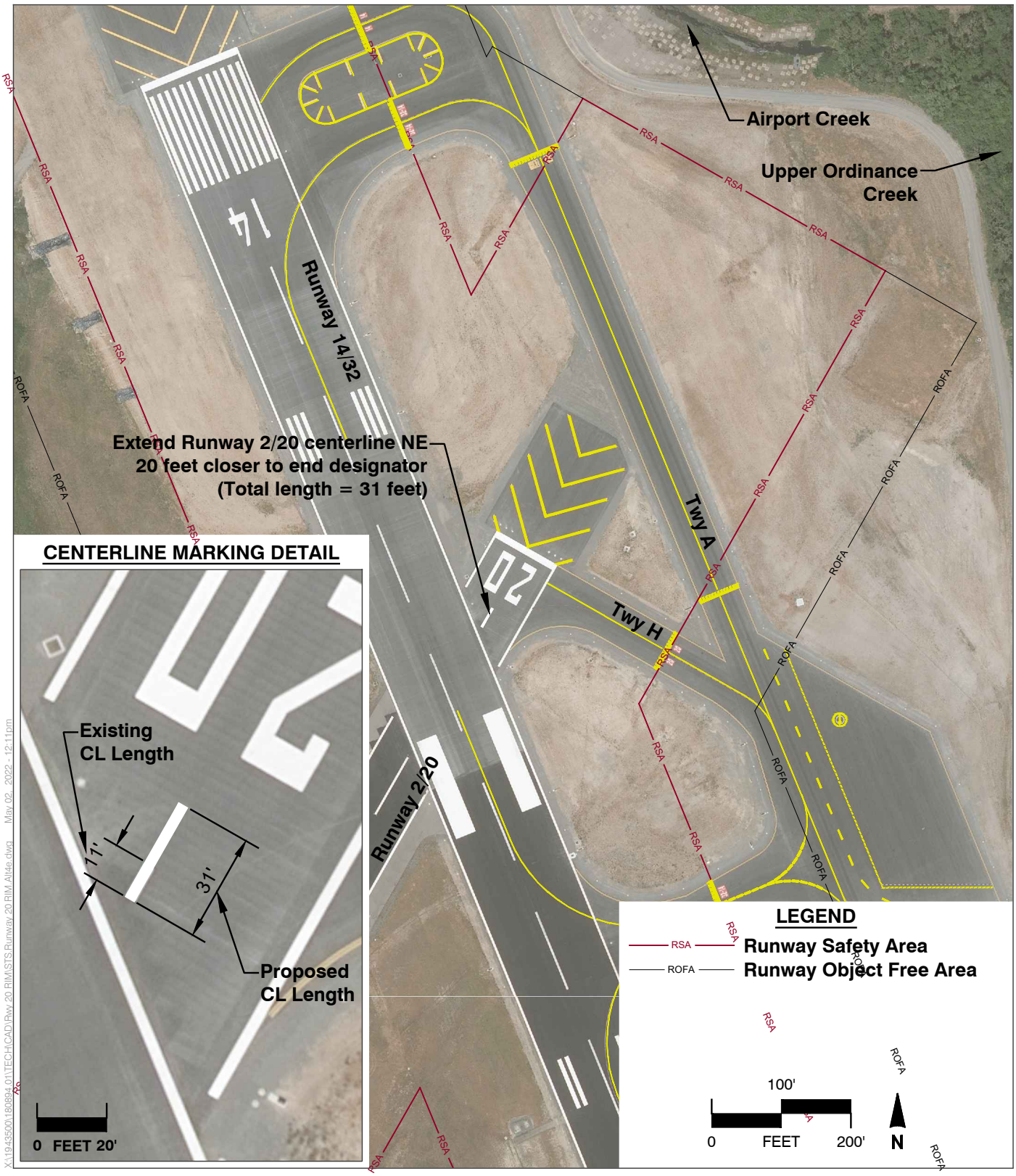
Figure 3-19: Runway 20 RIM Alternative 4E



Interim Modifications Alternatives: Taxiway A – Runway 20

The RSA of Runway 20 extends beyond the runway end, overlapping Taxiway A. An RSA serves the purpose of enhancing the safety of aircraft and is required to be free of objects except for objects that need to be located within the RSA for functionality, such as navigation aids.

Hold position pavement markings and signs are located on and adjacent to Taxiway A, at the outside edge of the Runway 20 RSA. These hold positions prevent the entrance of aircraft and vehicles into the Runway 20 RSA unless instructed otherwise by ATCT. Though these protective measures are in place, transient pilots have been reported to proceed beyond the pavement markings and signage resulting in incursions into Runway 20's approach area. This area is in proximity to the hold area that has been identified as Hot Spot 3, which causes pilot confusion. Additional visual cues on Taxiway A may help alleviate Hot Spot 3.

In this section, alternatives that propose to alter the existing pavement markings are presented with the intent to enhance situational awareness and reduce future runway incursions.

Hold markings on Taxiway A protecting the Runway 20 RSA can be enhanced to visually reinforce that there is a positively controlled RSA and approach area. Three preliminary alternatives are presented for initial consideration. A short description of the proposed changes and reasoning for each alternative is presented below with thumbnail sketches. These are summaries of the primary components for each alternative:

- **Alternative 5A:** Retain Approach Pattern "A" Hold Markings
- **Alternative 5B:** Paint Enhanced Centerline Markings
- **Alternative 5C:** Add Taxiway A Hold Position Signs

FAA Advisory Circular 150/5340-1M *Standards for Airport Markings* (AC 5340-1M) is referenced for signage and marking guidance on an airfield. Each alternative proposed is considered a nonstandard marking per AC 5340-1M. However, the unique circumstance of Taxiway A crossing through the RSA and approach to Runway 20 suggest a need for nonstandard marking to limit potential incursions. The ATCT staff at STS has endorsed the MOS on Taxiway A to enhance pilot awareness and help limit incursions at this location.

Alternative 5A: Retain Approach Pattern "A" Hold Markings

As shown in **Figure 3-20,** Alternative 5A proposes to retain surface painted approach hold position (SPAHP) Pattern "A" markings with associated runway designators to the existing hold lines. SPAHP markings are described in AC 5340-1M, in Section 4.5, "surface painted sign provides supplemental visual cues that alert pilots and vehicle drivers of an upcoming holding position location and the associated runway designator(s) as another method to minimize the potential for a runway incursion…" However, SPAHP markings added to a taxiway that does not lead directly onto the runway, such as a taxiway that crosses through an approach area, are nonstandard markings and would require approval of a MOS.

This combination will provide supplemental visual cues that alert pilots of an upcoming holding position as another method to minimize the potential for a runway incursion. The Pattern "A" approach hold markings and associated runway designators would have a similar presentation to standard runway holding positions and, when paired with the existing hold lines, reinforce pilots to hold when instructed by ATCT.

Alternative 5B: Paint Enhanced Centerline Markings

As detailed in **Figure 3-21**, Alternative 5B proposes to enhance the Taxiway A centerline to visually reinforce a positively controlled Runway 20 RSA and approach surface.

Enhanced centerline markings are described in AC 5340-1M, in Section 4.3.1, "The enhanced taxiway centerline marking provides supplemental visual cues to alert pilots of an upcoming runway holding position marking in order to minimize the potential for runway incursions." Standard holding position lines exist where the Runway 20 RSA and approach surfaces cross Taxiway A. Standard holding position signs are also co-located with the surface painted holding position lines indicating where pilots are to hold prior to crossing the Runway 20 RSA and approach. Nonetheless, the standard holding position lines and sign have not prevented incursions into the Runway 20 RSA and approach area.

However, enhanced centerline markings added to a taxiway that does not lead directly onto the runway, such as a taxiway that crosses through an RSA or approach area but not onto the runway itself, are nonstandard marking and would require approval of a MOS. The enhanced taxiway centerline markings will provide supplemental visual cues to alert pilots of an upcoming runway holding position marking to minimize the potential for runway incursions.

Alternative 5C: Add Taxiway A Hold Position Signs

As illustrated in **Figure 3-22**, Alternative 5C proposes to add two hold position signs on the right side (from a pilot's perspective) of Taxiway A. One sign will be north of the Runway 20 RSA and the other at the hold position south of the Runway 20 RSA. This is proposed to increase pilot situation awareness of the intersection to Runway 20 approach and RSA. Alternative 5C will require approval of a MOS. The signs may be designed and installed with the upcoming Taxiway A rehabilitation project.

Figure 3-20: Runway 20 RIM Alternative 5A

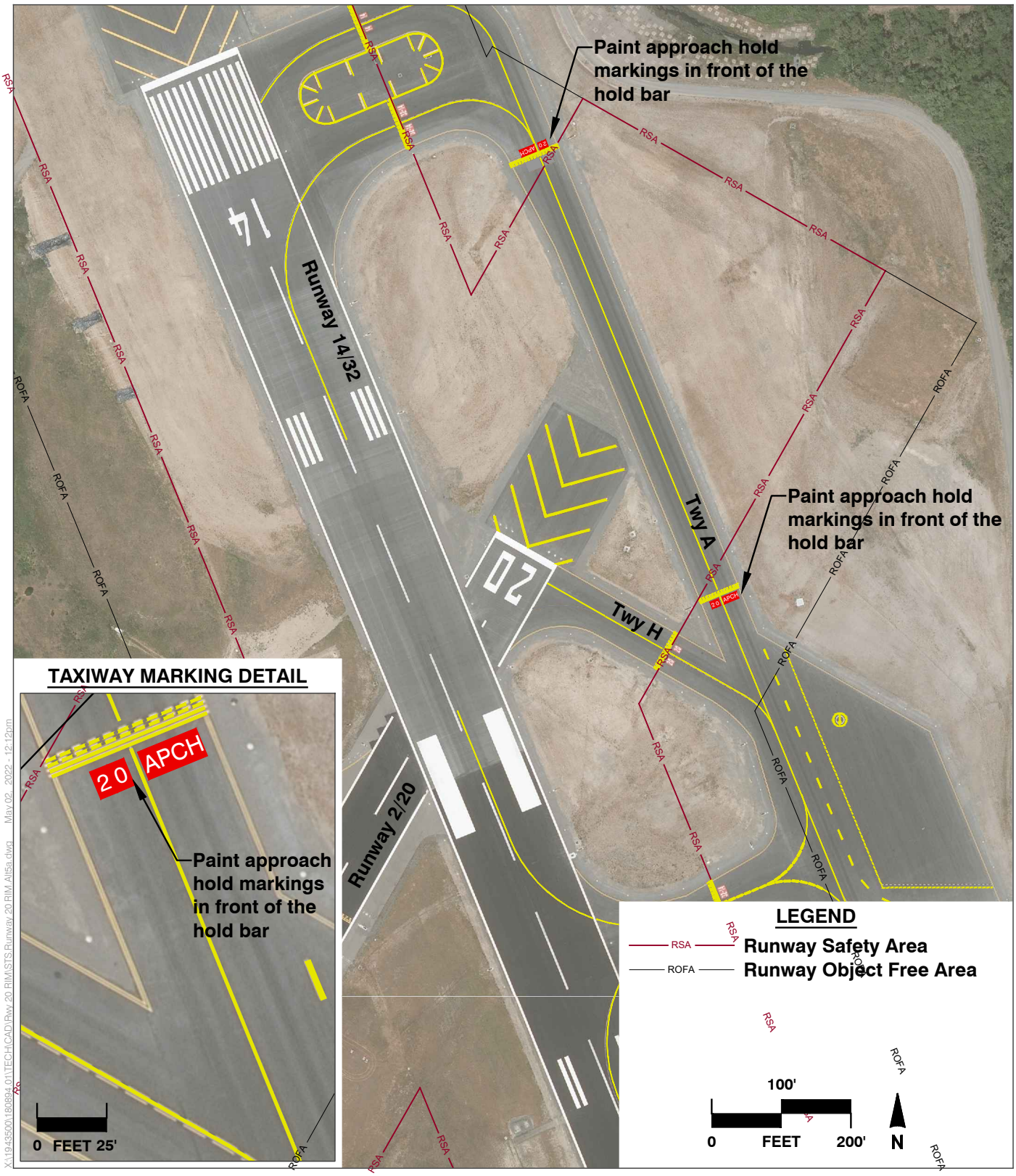


Figure 3-21: Runway 20 RIM Alternative 5B

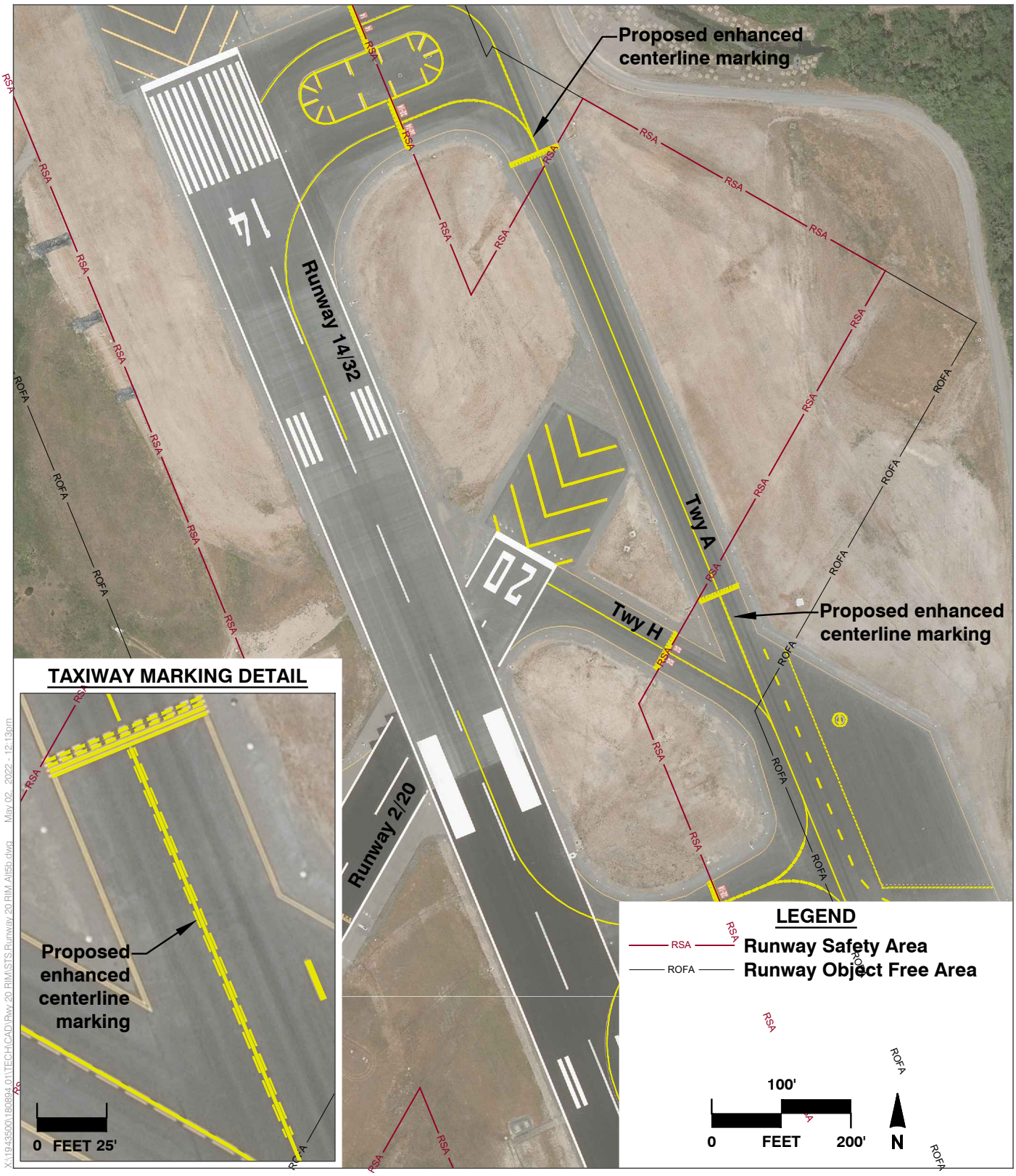


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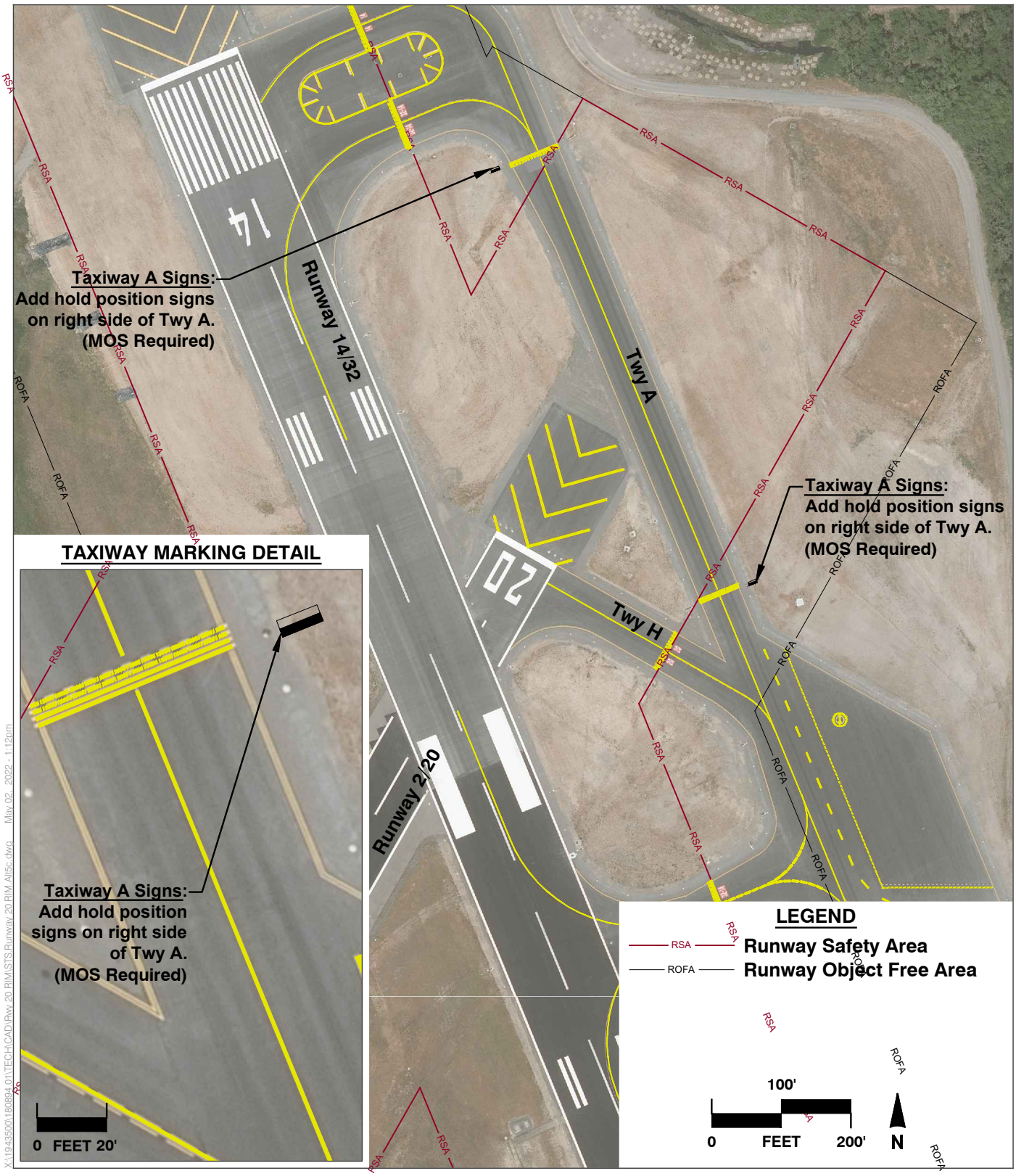
Figure 3-22: Runway 20 RIM Alternative 5C



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Interim Modifications Alternatives Selected for Formal Consideration

All interim modification alternatives offer potential value as mitigation measures to the existing Taxiway A–H–Runway 20–Runway 14 incursion issue. All have the important advantages of being relatively inexpensive, quick to implement, presenting no environmental impacts, and easy to remove if they prove to not be productive. It is recommended that these alternatives (4A-4E and 5A-5C) be submitted to the San Francisco ADO for formal review. ADO staff indicated that they wished to review each alternative separately. Ultimately, however, there may be value in combining these alternatives.

All of these proposals are nonstandard. A MOS will be needed before they could be implemented.

If these alternatives do not reduce incursions to less than one per calendar year, it would be appropriate to convene the RSAT team to reevaluate rejected alternatives and assess whether there might be other alternatives that could be more effective. Following acceptance of this Study by STS staff, next steps include:

- **ADO Submission:** After STS staff review of this Study, it will be revised as needed and submitted to the ADO with MOS for the preferred alternatives.
- **Internal FAA review of MOS:** FAA will provide comments to MOS prior to formal submittal.
- **Implementation:** After approval of MOS, marking or sign alternatives will be designed and applied.
- **Monitoring and one-year check-in:** Consultation with ATCT and RSAT team to determine if marking alternatives are successful at eliminating incursions.

PREFERRED RIM ALTERNATIVES

After multiple revisions and modification of standard submissions of alternatives presented above, consultation with the San Francisco ADO (Phone conference on August 31, 2020, and email follow up on February 24, 2020), the ADO recommended to move ahead with the following for inclusion with the ALP Update.

Interim Modifications

The ADO concurred with the following Interim Modifications:

- **Alternative 4E:** Extend Runway Centerline Northeast and Closer to Runway Designator
- **Alternative 5A:** Retain Approach Pattern “A” Hold Markings
- **Alternative 5B:** Paint Enhanced Centerline Markings
- **Alternative 5C:** Add Taxiway A Hold Position Signs

The ADO indicated that Alternatives 4E, 5A, and 5B may be implemented without submitting an MOS. The ADO stated a MOS is not required if adding the markings are locally funded.

In the case of Alternative 5A, the Pattern “A’ markings will be retained while the FAA evaluates policy and standards of updates to applicable Orders/SOP documentation. These updates are on hold pending additional headquarter evaluation. The ADO indicated, in the interim, Pattern “A” markings must be used for the approach/departure holding position.

The ADO concurred with the addition of hold position signs on Taxiway A (Alternative 5C). Since this will require FAA funding, a MOS is required for this condition. The ADO indicated they will support this MOS. The incorporation and design of these hold position signs will be completed with an upcoming Taxiway A project.

If the Interim Modifications do not reduce incursions to less than one per calendar year, it would be appropriate to convene the RSAT team to reevaluate rejected alternatives and assess whether there might be other alternatives that could be more effective.

Permanent Geometry Design

The ADO concurred with the selection of Alternative 1E (**Figure 3-23**) as the preferred alternative for Permanent Geometry Design. If after one year the Interim Modifications to signs and markings have not eliminated runway incursions, STS may pursue implementation of Alternative 1E. Implementation of Alternative 1E would involve the following steps:

- **Include in ALP:** To preserve this option, it is recommended that it be included in the current ALP Update. A note would be added to indicate that this alternative will not be implemented if the marking alternatives are successful in eliminating incursions.
- **Complete environmental process:** NEPA and CEQA documents will need to be prepared to assess impacts, refine the design to minimize impacts, and define mitigation measures. Resource agency permits and approvals will then need to be obtained.
- **Implementation:** After all environmental approvals are received, the engineering design can be prepared. Construction would then proceed.
- **Monitoring and one-year check-in:** Consultation with ATCT and RSAT team will take place to determine if this build alternative was successful at eliminating incursions.

Figure 3-23: Runway 20 RIM: Preferred Interim Geometry and Marking Modifications